Review Assessment: q01

Name: q01

Status : Completed

Score: 41 out of 100 points

Instructions:

Question 1 — **0 of 10 points**

The e is a unit of charge. It is not an SI unit of charge but it is a valid unit of charge. In terms of this unit of charge, what is the charge of each of the particles listed below?

Question	Correct Match	Selected Match
proton	✓ D. +1 e	✗ A. -2 e
electron	✓ B. -1 e	[None Given]
helium nucleus	✓ E. +2 e	[None Given]
hydrogen atom	✓ C. 0 e	[None Given]

Feedback: The "e" is indeed a unit of charge. Sometimes people get mixed up on the sign because the long name for the "e" is the "electron." It is the name of a unit of charge equivalent to $+1.6 \times 10^{-16}$ C. Because that unit of charge has the same name as a particle which has a negative charge, folks often make the mistake of thinking that the unit of charge is a negative amount of charge. It isn't. The "e" is a positive amount of charge. The particle in question, namely the electron has an amount of charge equal to -1e. The proton has +1e. It was the charge on these particles that led to the definition of the unit. To avoid the confusion it is best to avoid the use of the long name for the unit of charge. Just call it the "e". The hydrogen nucleus is a single proton. Hence the charge of the hydrogen nucleus is the charge of one proton, namely, +1e. A helium nucleus consists of two protons and two neutrons. Neutrons have no charge, and, each proton has a charge of +1e. So, the charge of a helium nucleus is +2e.

Question 2 — **0 of 8 points**

A neutral Ping Pong ball hangs from the ceiling by a thread. A person rubs a rubber rod with animal fur and then touches the Ping Pong ball with the rubber rod. After that, what is the charge of the Ping Pong ball?

Selected Answer: ✗ Positive.

Correct Answer: ✓ Negative

Feedback: Rubbing the rubber rod with animal fur gives the rubber rod a negative charge. The statement that the rod becomes charged is based on the fact that the experiment has been done millions of times with that result. The fact that the charge is negative is simply a definition, Ben Franklin's definition. A neutral object that comes in contact with a charged object acquires the same kind of charge as the charged object. This is called charging by contact. The Ping Pong ball acquires a negative charge because it comes in contact with the negatively charged rubber rod.

Question 3 — **7 of 7 points**

A neutral, hollow, metal ball is on the end of a glass rod so that one can move it around easily without touching the ball. A rubber rod is rubbed with rabbit fur. The rubber rod is brought very near the metal ball but not allowed to touch the metal ball. In this arrangement the pair is brought near a metal faucet and the ball is touched momentarily to the faucet. (The faucet is attached to a copper pipe which extends deep into the earth.) The rod and ball are moved away from the faucet and then they are moved farther away from each other. At this point, what kind of charge, if any, does the ball have?

Selected Answer: ✓ Positive.

Correct Answer: ✓ Positive.

Feedback: Way to go!

The rubber rod, after being rubbed by the rabbit fur, has a negative charge. When it is brought near the metal ball, the rubber rod repels the negatively charged particles in the ball. The charged particles in the metal ball are free to move around. We know this because metal is a conductor. Until the ball is brought into contact with the faucet, however, the negative charges repelled by the rod cannot escape the metal ball, but, once the metal ball is brought into contact with the faucet, the negative charges have an escape route. They are repelled right into the earth by the negatively charged rubber rod. Once contact with the faucet is lost, the negative charge cannot get back into the ball. The ball, having lost some of its negative charge, is positive.

Question 4 **0 of 7 points**

Consider two identical plastic foam balls each having a thin sheath of aluminum foil. One of the balls has some positive charge and the other has the same amount of negative charge. All of the charge resides on the aluminum foil. Each ball is on the end of its own thin glass rod which serves as a handle. A person brings one of the balls in contact with the other and then separates them. What is the sign of the charge on the ball that was originally charged positively.

Selected Answer: ✗ Positive.

Correct Answer: ✓ It has no charge.

Feedback: Charge moves around freely in metal. As soon as the two balls come into contact, all the charge on one of the balls flows onto the other ball rendering both of the balls neutral.

Question 5 **0 of 7 points**

Consider two small metal balls, one having a charge of +1 microcoulombs and the other having a charge of +3 microcoulombs. The balls are brought into momentary contact with each other (assume each ball is on the end of its own non-conducting rod for handling purposes) and then separated. What is the charge on each ball then?

Selected Answer: ✗ They are both neutral.

Correct Answer: ✓ Each ball has +2 microcoulombs of charge.

Feedback: Because both charged objects are conductors, once they touch, the charge is free to go anywhere on the two objects. Because it is all the same kind of charge, the charge will distribute itself so that it is, on the average, as spread out as possible. Based on symmetry, because the two objects are identical, half the charge will wind up on one ball and half on the other. Since there was originally four microcoulombs of charge, there must, by conservation of charge, be four microcoulombs of charge in the final arrangement. Dividing this by two, there must be 2 microcoulombs of charge on each metal ball.

Question 6 **8 of 8 points**

Consider two Styrofoam cups. Each is on the end of its own neutral slender glass rod which serves as a handle. One of the cups has a fixed amount of positive charge uniformly distributed over the entire surface of the cup. The other cup has the same amount of negative charge uniformly distributed over its entire surface. A person taps one of the cups with the other cup. After the tap, what is the sign of the charge of the cup that was originally positively charged?

Selected Answer: ✓ Positive.

Correct Answer: ✓ Positive.

Feedback: Good answer!

Styrofoam is an electrical insulator. Charge does not move around in or on Styrofoam. The spot on each cup, where the two touch, becomes neutral but the rest of each cup retains its original charges. The net result is that the cup that was originally positive is still positive and the cup that was originally negative is still negative. Neither cup has as much total charge as it originally had, but both cups are still charged.

Question 7 **0 of 7 points**

If you rub a rubber rod with rabbit fur (thus giving the rod a negative charge) and bring the rod near some bits of neutral paper, the rod will attract the bits of paper. Though they remain neutral, the bits of paper do become polarized--the end of a bit of paper closer to the rod becomes positive while the end farther from the rod becomes negative. Given that the amount of negative charge on one end of the bit of paper is equal to the amount of positive on the other end, it might seem that the negatively charged rubber rod would repel the negative end of the bit of paper with just as much force as that with which it attracts the positive end. Why then, is there a net attractive force on the bit of paper?

Selected Answer: ✗ The far end of the bit of paper is shielded from the rod by the rest of the paper so the rubber rod does not repel it.

Correct Answer: ✓ The end of the bit of paper that has positive charge is closer to the rubber rod then the end with the negative charge. The Coulomb force depends on the separation of the rubber rod and the other charge. The smaller the separation, the greater the force. Hence the rubber rod exerts a greater attractive force on the positive end of the bit of paper than it does a repulsive force on the negatively charged end. The result is a net attractive force.

Feedback: According to Coulomb's Law, distance matters. It's that square of the separation of the DENOMINATOR that communicates this fact to us in the mathematical expression of Coulomb's Law. The greater the separation, the weaker the force. As a result, the closer positive end of the bit of paper is attracted more strongly than the more distant negative end, even though each end has the same amount of charge as the other.

Question 8 **2 of 6 points**

Consider an electron and a proton, at an instant in time, to be at a separation of 5 cm from each other. Assume the pair to be totally isolated from its surroundings in the vacuum of outer space.

Question	**Correct Match**	**Selected Match**
Upon which particle, if either, is the greater force being exerted?	✓ C. Neither.	✗ A. The electron.
Which particle, if either, is experiencing the greater acceleration?	✓ A. The electron.	✓ A. The electron.
Which particle, if either, has the greater velocity?	✓ D. Not enough information is given to answer this question.	✗ A. The electron.

Feedback: By Newton's third law, the Coulomb force of attraction exerted by each particle on the other is of one and the same magnitude. The electron has much less mass than the proton however, so the electron experiences a much greater acceleration. The force directly determines the acceleration so it governs how fast the velocity will change, but, it does not directly determine what the velocity *is*. From the information given, each particle could have any velocity greater than or equal to 0 but less than the speed of light. We have no way of knowing what the velocity of either particle is.

Question 9 **8 of 8 points**

Consider two charged particles at a separation of 4 cm. Particle #1 has a charge of +2 microcoulombs. Particle #2 has a charge of +16 microcoulombs. How does the magnitude of the force exerted on particle #1 by particle #2 compare with the magnitude of the force exerted on particle #2 by particle #1?

Selected Answer: ✓ The two forces are identical in magnitude.

Correct Answer: ✓ The two forces are identical in magnitude.

Feedback: Nice work!

By Newton's 3rd Law, the force that one particle exerts on another particle is equal in magnitude and opposite in direction to the force that the second particle exerts on the first particle. There is no way around Newton's 3rd law. A particle can't be pushing on another particle without that second particle pushing back just as hard. There are no exceptions!

Question 10 **0 of 8 points**

Consider two charged particles. At a given separation each particle exerts a force of .12 N on the other. What force does each exert on the other after someone moves the particles closer together so that their distance is half the original distance?

Selected Answer: ✗ .03 N

Correct Answer: ✓ .48 N

Feedback: The force exerted on one charged particle by another is proportional to the reciprocal of the square of the separation of the two charged particles. So, if the separation is changed to ½ of the original separation then the force becomes the reciprocal of the square of ½, times the original force. The reciprocal of the square of ½ is 4. So the new force is 4 times the old force. The old force was .12 N so the new force must be .48 N.

This can be worked out in equation form as shown below where F is the original force and F' is the new force. Also r is the original separation and r' is the new separation. Given is the fact that r' = ½ r.

$$F = \frac{kq_1q_2}{r^2}$$

$$F' = \frac{kq_1q_2}{r'^2}$$

SUBSTITUTE $r' = \frac{1}{2}r$

$$F' = \frac{kq_1q_2}{(\frac{1}{2}r)^2}$$

$$F' = \frac{kq_1q_2}{\frac{1}{4}r^2}$$

$$F' = 4\underbrace{\frac{kq_1q_2}{r^2}}$$

THIS IS F
(SEE FIRST LINE)

$$F' = 4F$$

$$F' = 4(.12N)$$

$$\boxed{F' = .48N}$$

Here's another way:

① $F = \frac{kq_1q_2}{r^2}$

② $F' = \frac{kq_1q_2}{r'^2}$

Form the ratio $\frac{F'}{F}$:

$$\frac{F'}{F} = \frac{\left(\frac{kq_1q_2}{r'^2}\right)}{\left(\frac{kq_1q_2}{r^2}\right)}$$

Dividing by a fraction is the same as multiplying by the reciprocal:

$$\frac{F'}{F} = \frac{\cancel{kq_1q_2}}{r'^2}\,\frac{r^2}{\cancel{kq_1q_2}}$$

Question 11 **8 of 8 points**

Consider two charged particles. At a given separation each particle exerts a force of .12 N on the other. What force does each exert on the other after someone moves the particles farther apart so that their separation is twice the original distance?

Selected Answer: ✓ .03 N

Correct Answer: ✓ .03 N

Feedback: Nice work!

The force exerted on one charged particle by another is proportional to the reciprocal of the square of the separation of the two charged particles. So, if the separation is changed to 2 times the original separation then the force becomes the reciprocal of the square of 2, times the original force. The reciprocal of the square of 2 is 1/4. So the new force is 1/4 of the old force. The old force was .12 N so the new force must be .03 N.

This can be worked out in equation form as shown below where F is the original force and F' is the new force. Also r is the original separation and r' is the new separation. Given is the fact that r' = 2r.

$$F = \frac{k q_1 q_2}{r^2}$$

$$F' = \frac{k q_1 q_2}{r'^2}$$

substitute $r' = 2r$

$$F' = \frac{k q_1 q_2}{(2r)^2}$$

$$F' = \frac{k q_1 q_2}{4 r^2}$$

$$F' = \frac{1}{4} \underbrace{\frac{k q_1 q_2}{r^2}}$$

This is F
(see 1st line)

$$F' = \frac{1}{4} F$$

$$F' = \frac{1}{4} (.12\ N)$$

$$\boxed{F' = .03\ N}$$

Here's another way:

① $F = \dfrac{k q_1 q_2}{r^2}$

② $F' = \dfrac{k q_1 q_2}{r'^2}$

Form the ratio $\frac{F'}{F}$:

$$\frac{F'}{F} = \frac{\left(\frac{k q_1 q_2}{r'^2}\right)}{\left(\frac{k q_1 q_2}{r^2}\right)}$$

Dividing by a fraction
is the same as
multiplying by the reciprocal:

Question 12 **8 of 8 points**

Consider two positively charged particles at a separation of 2.0 cm. One of the charged particles is moving toward the other charged particle with a speed of 15 m/s. No forces except for the Coulomb force of repulsion (also known as the electrostatic force of repulsion) act on either particle. Is this situation, the one just described, actually possible?

Selected Answer: ✓ Yes.

Correct Answer: ✓ Yes.

Feedback: Way to go!

Of course it is possible for a positively charged particle, at some instant in time, to have a velocity directed at another positively charged particle. There is a repulsive force but force directly determines acceleration, not velocity. The force just makes it so that the velocity in this case is decreasing. To say that a positively charged particle can never be approaching another positively charged particle would be like saying that a free ball can never be going upward near the surface of the earth.

In both cases, history matters, but the details of that history are not relevant. Something in the past must have caused that particle to have some velocity toward the other positively charged particle. What keep's it going? The best answer is "nothing." The natural tendency of a particle in motion is to keep on going in the same direction at the same speed (Newton's 1st Law). It doesn't need anything to keep it going forward. The fact that there is a force in the direction opposite to the particle's velocity will indeed cause the particle to deviate from its constant speed behavior. It makes it so that as time goes by the particle slows down. An okay alternate answer to the question as to what keeps the particle moving is "its inertia."

Question 13 **0 of 8 points**

Consider two identical small metal balls, one having a charge of +1 microcoulombs and the other having a charge of +3 microcoulombs. The balls are separated from each other by 15 cm. Each exerts a force F on the other. The balls are brought into momentary contact with each other (assume each ball is on the end of its own non-conducting rod for handling purposes) and then separated such that the distance between them is once again 15 cm. At this point, each exerts a force F' on the other. How does F' compare with F?

Selected Answer: ✗ F' = F

Correct Answer: ✓ F' > F

Feedback: Given that the separation is the same in the two cases, the only variable that the force depends on is the product of the charges. In the case of F this is 1μC × 3μC which is 3 $(\mu C)^2$. When the two balls are touched together the charge redistributes itself such that each ball has a charge of 2μC. For F' the product of the charges is thus 2μC × 2μC which is 4 $(\mu C)^2$. Since this product is greater, F' > F.

OK

Review Assessment: q02

Name: q02

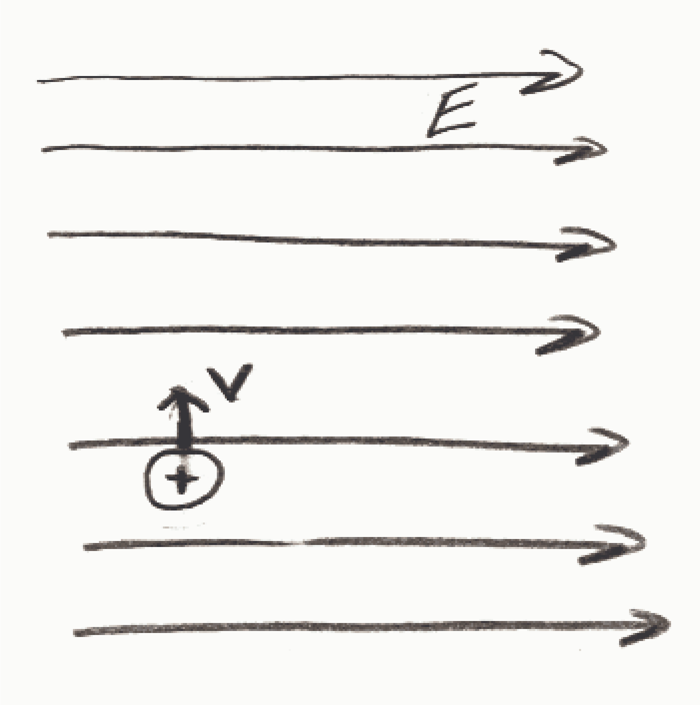
Status : Completed

Score: 0 out of 100 points

Instructions:

Question 1 **0 of 20 points**

Depicted below is a positively charged particle in a rightward-directed electric field. The particle has a velocity directed toward the top of the screen. What is the direction of the force, if any, exerted on the charged particle by the electric field?



Selected Answer: ✗ Toward the top of the screen.

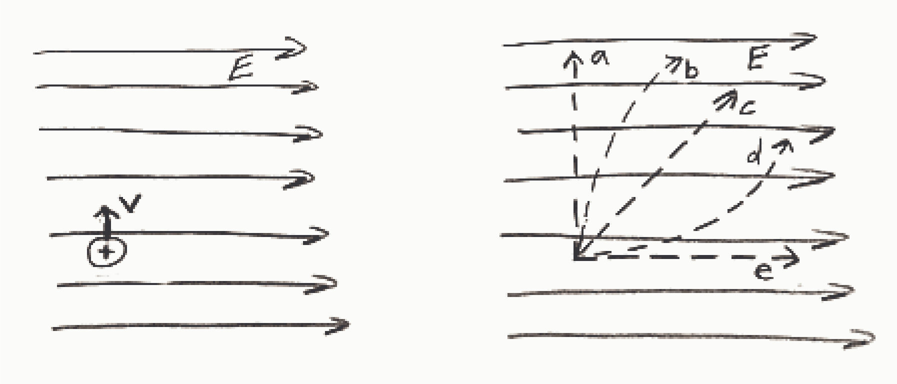
Correct Answer: ✓ Rightward.

Feedback: An electric field exerts a force on a positively-charged particle that is in the electric field, in the same direction that the electric field is in at the location of the charged particle. In this case, at the location of its positive "victim", the electric field is rightward. Thus the force exerted on the "victim" by the electric field is rightward.

The velocity of the particle has no effect on the direction of the force.

Question 2 **0 of 20 points**

Depicted below is a positively charged particle in a uniform rightward-directed electric field. The particle has a velocity directed toward the top of the screen. Which of the paths depicted below right is the particle most likely to follow given that the force, if any, exerted on the particle by the electric field is the only force exerted on the particle.



Selected Answer: ✗ Path a

Correct Answer: ✓ Path b

Feedback: The electric field exerts a rightward force on the positively charge particle. The result is a rightward acceleration. The initial velocity is toward the top of the page, at right angles to the acceleration. Because it is at right angles to the acceleration, this component of the velocity never changes. The rightward-directed velocity is initially zero. Because of the rightward acceleration, the rightward component of the velocity grows with time. Moving toward the top of the page at a constant speed while moving rightward at an ever-increasing speed, results in a parabolic trajectory such as that depicted by curve b.

Question 3 **0 of 20 points**

Is it possible for an electron to be moving northward in a northward-directed electric field?

Selected Answer: ✗ Only if there is a northward force exerted on the particle by some agent other than the electric field.

Correct Answer: ✓ Yes, even if the force exerted on the electron by the electric field is the only force acting on the particle.

Feedback: The force exerted on a negatively charged particle by an electric field is in the direction opposite to the direction of the electric field at the location of its negatively-charged "victim". So in this case, there is a southward force on the electron. This results in a southward acceleration. If the particle is going northward, and the electric force is the only force acting on it, then the particle must be slowing down. But there is no reason that it can't be moving forward under these circumstances. It doesn't need a force in the northward direction to be moving northward. It's analogous to a rock thrown upward. After it leaves the thrower's hand, the rock is going upward, even though the only force (assuming air resistance to be negligible) acting on it is the gravitational force which is in the downward direction. There may have been a northward force acting on the particle in the past, but that is part of its history. The question is about the electron's "here and now".

Question 4 **0 of 20 points**

Which of the following is not true of an electric field?

Selected Answer: ✗ It has direction.

Correct Answer: ✓ It cannot exist in vacuum.

Feedback: An electric field can and does exist in vacuum. Except for the one about vacuum, all the answers are part of the definition of the electric field.

It is an electric field in the vacuum inside a television picture tube which accelerates electrons to the front of the picture tube where they crash into a phosphorescent coating causing the latter to emit the light which we see as television images.

Question 5 **0 of 20 points**

Why is it nonsense to say that an electric field attracts a charged particle?

Selected Answer: ✗ Electric fields only repel charged particles. If the particle is positive the electric field repels it one way and if it is negative the electric field repels it the other way, but, the electric field always repels a charged particle.

Correct Answer: ✓ The electric field exerts a force on a charged particle that is in the electric field. But the word "attract" cannot be used to characterize that force. For an electric field to attract a charged particle the electric field would have to pull the charged particle toward itself. But the particle is "in" the electric field so there is no such direction as "toward the electric field." It would be like saying that air attracts a helium-filled balloon that is in the air or that seawater attracts a fish that is in the ocean.

OK

Review Assessment: Lec 03 Quiz

Name: Lec 03 Quiz

Status : Completed

Score: 24 out of 100 points

Instructions:

Question 1 — **0 of 20 points**

In the expression ½kx^2 for the potential energy stored in the spring, what does the x represent?

Selected Answer: ✗ The length of the spring.

Correct Answer: ✓ The amount by which the spring is stretched or compressed.

Feedback: Quite often, we consider there to be an object at one end of the spring while the other end of the spring is fixed in position (e.g. by being attached to a wall). x is the position of the object measured with respect to its equilibrium position. The value of x represents a position on an x-axis which is collinear with the spring and whose origin is at the equilibrium position. The equilibrium position is the position of the object for which the spring is neither stretched nor compressed.

The positive direction for the x-axis is typically chosen to be the direction in which one has to move the object from its equilibrium position in order to stretch the spring. In that case, x is the amount by which the spring is stretched (where a negative amount of stretch means the spring is actually compressed).

It is acceptable to define the x-axis such that the positive direction is the direction in which one has to move the object from its equilibrium position in order to compress the spring. In that case, x is the amount by which the spring is compressed (where a negative amount of compression means the spring is actually stretched).

Question 2 — **4 of 20 points**

Match the units to the physical quantity that is measured in those units.

Question	Correct Match	Selected Match
kg	✓ D. mass	✗ A. time
J	✓ C. energy	✗ A. time
m	✓ E. distance	✗ A. time
m/s	✓ B. velocity	✗ A. time
s	✓ A. time	✓ A. time

Feedback: The main purpose of this question is to familiarize you with the jargon "physical quantity". It is important to recognize that there is a distinction between a physical quantity and the units in which that physical quantity is measured.

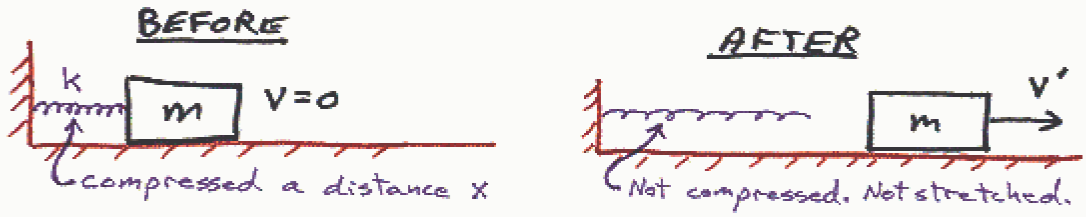
Question 3 — **0 of 20 points**

A block of mass m, on a flat horizontal frictionless surface, is pushed up against the end of a horizontal spring, the other end of which is connected to a wall, so that it compresses the spring by an amount x. The force constant of the spring is k. Consider the mass of the spring to be negligible. The block is released, and the spring pushes the block away from the wall. What is the kinetic energy of the block after it loses contact with the spring? (Hint: From the wording of the question you are supposed to know that m, k, and x are to be considered known quantities, and, that your answer should have only known quantities in it.)

Selected Answer: ✗ 0 mgh

Correct Answer: ✓ ½kx^2

Feedback: We start with a spring sticking out of a wall. The spring extends horizontally over a flat, horizontal frictionless surface. Now someone pushes a block up against the end of the spring. The person pushes the block directly toward the wall compressing the spring. Energy is stored in the spring as it is compressed. Then the person releases the block. It is at this instant, the instant that the person is out of the picture, that we can begin applying conservation of energy. At that instant, before the spring has had time to start expanding, the spring is compressed the known amount x and the block is at rest. That is the instant to be characterized by the *Before Picture*.



In the after picture, the block is free of the spring. We can solve for the kinetic energy K' in the after picture by setting the total mechanical energy in the before picture equal to the total mechanical energy in the after picture:

$$E = E'$$

$$K + U = K' + U'$$

$$0 + \tfrac{1}{2}kx^2 = K' + 0$$

$$K' = \tfrac{1}{2}kx^2$$

Note how important it is to write a lower case k (spring constant) that is distinguishable from an upper case K (kinetic energy).

Question 4 **20 of 20 points**

Which has more rotational kinetic energy, an object with a rotational inertia of 4 kg·m^2 and an angular velocity of 8 rad/s, or, an object with a rotational inertia of 8 kg·m^2 and an angular velocity of 4 rad/s?

Selected Answer: ✓ An object with a rotational inertia of 4 kg·m^2 and an angular velocity of 8 rad/s.

Correct Answer: ✓ An object with a rotational inertia of 4 kg·m^2 and an angular velocity of 8 rad/s.

Feedback: Nice work!

$I_1 = 4\,\mathrm{kg\cdot m^2}$

$\omega_1 = 8\,\frac{\mathrm{rad}}{\mathrm{s}}$

$K_1 = \frac{1}{2} I_1 \omega_1^2$

$K_1 = \frac{1}{2}(4\,\mathrm{kg\cdot m^2})(8\,\frac{\mathrm{rad}}{\mathrm{s}})^2$

$K_1 = 128\,\mathrm{J}$

$I_2 = 8\,\mathrm{kg\cdot m^2}$

$\omega_2 = 4\,\frac{\mathrm{rad}}{\mathrm{s}}$

$K_2 = \frac{1}{2} I_2 \omega_2^2$

$K_2 = \frac{1}{2}(8\,\mathrm{kg\cdot m^2})(4\,\frac{\mathrm{rad}}{\mathrm{s}})^2$

$K_2 = 64\,\mathrm{J}$

$$\boxed{K_1 > K_2}$$

Question 5 **0 of 20 points**

A disk lies horizontally on a massless, frictionless, rotational motion support such that the disk is spinning freely about a vertical axis through the center of the disk and perpendicular to the face of the disk. A second disk, identical to the first disk is held in place a negligible height (immeasurably close but not touching) above the first disk. The second disk is aligned so perfectly with the first disk that the axis of rotation of the first disk also passes through the center of the second disk. The person holding the second disk drops it onto the first disk and the two disks spin as one. Is mechanical energy conserved in this process?

Selected Answer: ✗ Yes

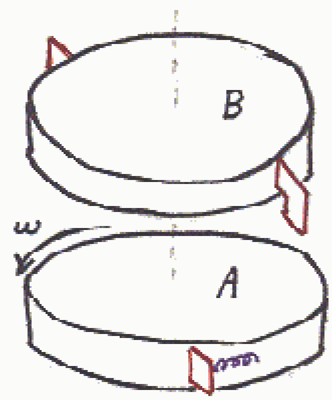
Correct Answer: ✓ No

Feedback: Make sure that you don't justify the correct answer (no) on the basis of gravitational energy mgh. We are told that the initial height of the dropped disk is negligible, so, we must neglect it in our considerations. That means nothing undergoes a non-negligible elevation change in the process, so, gravitational potential energy is not relevant here.

The new spin rate is clearly less than the original spin rate of the one disk in that two disks spinning together at the original spin rate would have twice as much kinetic energy as the one disk spinning at that rate and the kinetic energy of the system is certainly not going to increase. So the first disk, let's call it disk A, slows down and the second disk, let's call it disk B, speeds up (from 0 rad/s) upon being dropped onto disk A.

The correct answer (no) is easy to arrive at in a case where the two disks are made, for instance, out of concrete and one can observe that when B is dropped on A, the top surface of A slides against the bottom surface of B while B speeds up and A slows down until they are both spinning at the same rate. Sliding friction is what causes the two disks to eventually spin with the same angular velocity and we know that energy is converted from mechanical energy to thermal energy when sliding friction takes place so mechanical energy is not conserved.

But suppose disk A is spinning slowly enough that sliding is not apparent. Suppose we do the experiment and it looks like B locks immediately onto A in such a manner that there is no obvious conversion of mechanical energy into thermal energy. By observation of the interaction, there may or may not be some such energy conversion. To determine whether mechanical energy is conserved in such a case, we turn to an idealized version of the experiment in which it is easier to keep track of the energy. Suppose the top surface of A was completely frictionless but we had an ideal, massless, springs-and-tabs arrangement on the disks as shown in the diagram below (in which our view of the spring on the back side of A is blocked).



B is dropped (from a negligible height) onto the frictionless surface of A. A continues to rotate a fraction of a turn, as if nothing had happened, until the springs on A run into the tabs on B. The "collision", gets B spinning ever faster in the same direction of A and slows A down, while compressing the springs, until at one instant, A and B are spinning at the same rate. At that instant, the disks are spinning as one with a single velocity just as in the case of two plain disks with friction. (As time goes by after that, the spring will decompress speeding up B even more and slowing A even more but we focus our attention on that instant when the spring is maximally compressed and the disks have one and the same angular velocity). The pair-of-disks with the springs and tabs, at that instant, will have the same kinetic energy as the pair-of-disks with friction. In the case of the disks with the springs and tabs, however, there is also potential energy stored in the springs. There is no such additional mechanical energy in the case of the plain disks with friction. As such, that amount of mechanical energy that would be stored in the springs in the idealized case, must have been lost (converted to other forms such as thermal energy and permanent deformation) in the actual case involving two plain disks with friction. Mechanical energy is not conserved whether sliding is apparent or not.

OK

Review Assessment: Lec 04 Quiz

Name: Lec 04 Quiz

Status : Completed

Score: 0 out of 100 points

Instructions:

Question 1 **0 of 20 points**

Consider a bowling ball and a Ping Pong ball, each moving along a straight line path at constant velocity. Which has the greater magnitude of momentum?

Selected Answer: ✗ Neither, they both have the same momentum.

Correct Answer: ✓ Insufficient information is given to determine a definite answer.

Feedback: One needs to know the speed of each. Given the objects, the bowling ball clearly has much more mass. But momentum depends on both mass and velocity. Suppose the bowling ball's mass is 1000 times that of the Ping Pong ball. If the speed of the Ping Pong ball is less than 1000 times the speed of the bowling ball, then the magnitude of the bowling ball's momentum is greater. But if the speed of the Ping Pong ball is greater than 1000 times the speed of the bowling ball, then the magnitude of the Ping Pong ball's momentum is greater.

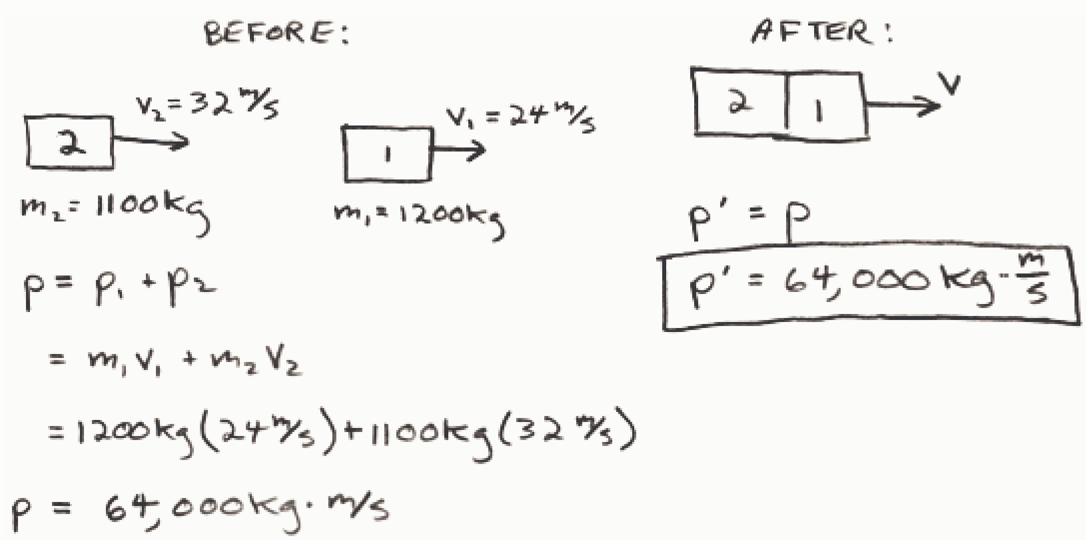
Question 2 **0 of 20 points**

Consider two cars, both moving eastward along a straight road. Car 1 is in front of car 2. Car 1 has a mass of 1200 kg and a speed of 24 m/s. Car 2 has a mass of 1100 kg and a speed of 32 m/s. Consider eastward to be the positive direction. Car 2 collides with car 1. The two cars stick together and move off as one object. No external eastward/westward forces act on either car. What is the total momentum of the combination object, consisting of the two cars stuck together, after the collision?

Selected Answer: ✗ Zero

Correct Answer: ✓ 64,000 kg·m/s

Feedback:



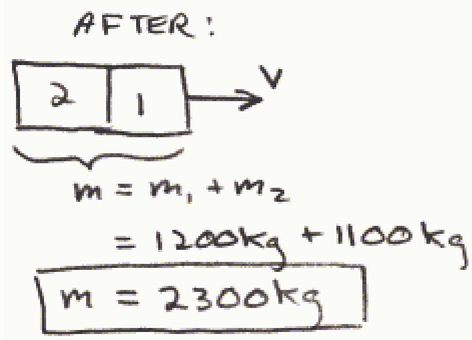
Question 3 **0 of 20 points**

Consider two cars, both moving eastward along a straight road. Car 1 is in front of car 2. Car 1 has a mass of 1200 kg and a speed of 24 m/s. Car 2 has a mass of 1100 kg and a speed of 32 m/s. Consider eastward to be the positive direction. Car 2 collides with car 1. The two cars stick together and move off as one object. No external eastward/westward forces act on either car. What is the mass of the combination object consisting of the two cars stuck together?

Selected Answer: ✗ 100 kg

Correct Answer: ✓ No other answer provided is correct.

Feedback:



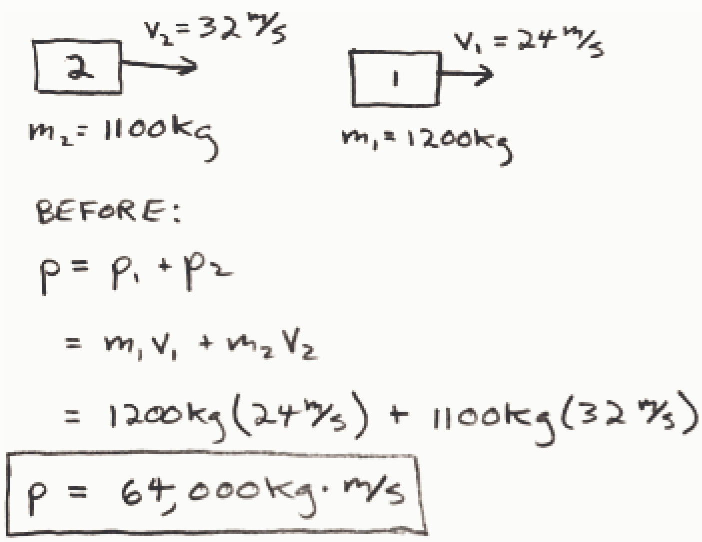
Question 4 **0 of 20 points**

Consider two cars, both moving eastward along a straight road. Car 1 is in front of car 2. Car 1 has a mass of 1200 kg and a speed of 24 m/s. Car 2 has a mass of 1100 kg and a speed of 32 m/s. Consider eastward to be the positive direction. Car 2 collides with car 1. The two cars stick together and move off as one object. No external eastward/westward forces act on either car. What is the total momentum of the system of cars prior to the collision?

Selected Answer: ✗ Zero

Correct Answer: ✓ 64,000 kg·m/s

Feedback: The total momentum is the sum of the momentum of car 1 and the momentum of car 2. Calculate each momentum individually and then add them together.



Question 5 **0 of 20 points**

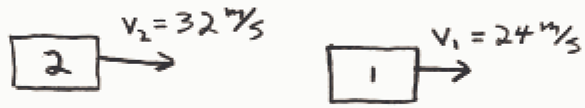
Consider two cars, both moving eastward along a straight road. Car 1 is in front of car 2. Car 1 has a mass of 1200 kg and a speed of 24 m/s. Car 2 has a mass of 1100 kg and a speed of 32 m/s. Consider eastward to be the positive direction. Car 2 collides with car 1. The two cars stick together and move off as one object. No external eastward/westward forces act on either car. What is the velocity of the combination object, consisting of the two cars stuck together, after the collision?

Selected Answer: ✗ Zero

Correct Answer: ✓ 28 m/s

Feedback:

BEFORE:



$m_2 = 1100\,kg$ $\quad$ $m_1 = 1200\,kg$

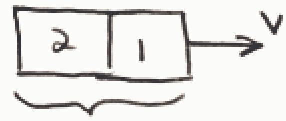
$$p = p_1 + p_2$$

$$= m_1 v_1 + m_2 v_2$$

$$= 1200\,kg(24\ m/s) + 1100\,kg(32\ m/s)$$

$$p = 64{,}000\,kg \cdot m/s$$

AFTER:



$$m = m_1 + m_2$$

$$= 1200\,kg + 1100\,kg$$

$$\boxed{m = 2300\,kg}$$

$$p' = p$$

$$\boxed{p' = 64{,}000\,kg \cdot \frac{m}{s}}$$

$$p' = mV$$

$$V = \frac{p'}{m}$$

$$V = \frac{64{,}000\,kg\,\frac{m}{s}}{2300\,kg} = 27.8\,\frac{m}{s}$$

$$\boxed{V = 28\,\frac{m}{s}}$$

OK

Review Assessment: q05

Name: q05

Status : Completed

Score: 0 out of 100 points

Instructions:

Question 1 **0 of 30 points**

Which of the following is true of the electric potential? (Indicate all that apply.)

Selected Answers: ✗ It gives the force-per-charge that a charged particle would experience if it were located at a point in space where the electric potential exists.

Correct Answers:
✓ It gives the electric-potential-energy-per-charge-of-the-particle that a charged particle would have if it were located at a point in space where the electric potential exists.
✓ It is a scalar.
✓ It characterizes empty points in space in the region of a charged particle or distribution of charged particles.

Feedback: Except for the "force-per-charge" option, every response is part of the definition of electric potential. The force-per-charge is the electric *field*, not the electric potential.

Recall that a scalar is something that has magnitude only, no direction. It is to be contrasted with a vector which has both magnitude and direction. The electric potential is a scalar whereas the electric field is a vector. The mass of a particle is a scalar whereas the velocity of a particle is a vector.

Question 2 **0 of 15 points**

"A proton (a positively charged elementary particle) is released from rest at a point in space where the electric potential is 15 volts. Subsequent to its release the particle is subject to no force other that that due to the electric field characterized by the electric potential. Later when the particle is at a point in space where the electric potential is 25 volts..."

Are the circumstances discussed in the above quote possible?

Selected Answer: ✗ Yes.

Correct Answer: ✓ No.

Feedback: For a positively charged particle, the electric potential *energy* has the same algebraic sign as the electric potential of the point in space the particle occupies. So, in going from a point in space where the electric potential is 15 volts to a point where it is 25 volts the proton is going from a point where it has one positive value of potential energy to a point where it has a greater positive value of potential energy.

Now once we get to talking about potential energy rather than potential, I like to think about the gravitational potential energy of an object near the surface of the earth. It is not exactly relevant here but it makes for a useful analogy. Consider a rock near the surface of the earth. I know that when it goes upward its potential energy is increased. Now it is possible for a free rock to go upward, but to do so, it must have some initial upward velocity. A free rock *at rest* near the surface of the earth will never go upward. It will never go to a region where its gravitational potential energy is greater than that at its current location. The same goes for any kind of potential energy. A proton, starting *at rest* (in the absence of all forces but the electric force characterized by the electric potential) will never go to a location with a greater potential energy than that at its initial location. To do so would be like releasing a rock near the surface of the earth and seeing it fly upward. It would be a violation of the conservation of energy.

The phrase *at rest* is absolutely key here. Given enough initial velocity, the proton could definitely make it from a point where the potential is 15 volts to a point where it is 25 volts. In doing so it would be going against the force of the electric field, just like a rock thrown upward, on the way up, is going against the force of gravity. But the proton would be slowing down the whole way, just as the rock would be slowing down the whole way up. The potential energy of the proton would be increasing while its kinetic energy would be decreasing, such that, the total energy would remain the same.

Question 3 **0 of 20 points**

Which one of the following is true of electric potential but is **not** true of an electric field?

Selected Answer: ✗ It exists in the region of space around a charged particle or distribution of charged particles.

Correct Answer: ✓ It is the association of a scalar with empty points in space.

Feedback: The electric field associates a **vector** with empty points in space.

Question 4 **0 of 20 points**

What is the difference between electric potential and electric potential energy? (Indicate all that apply.)

Selected Answers: ✗ As its name implies, electric potential energy is a form of energy. Electric potential, on the other hand, is a kind of force.

Correct Answers:
✓ Electric potential energy is the energy of position that a particle with a particular amount of charge has or would have (because of the fact that it is in an electric field) if it were at a particular point in space, whereas, electric potential characterizes a point in space which may be empty.
✓ Electric potential energy is just that whereas electric potential is electric-potential-energy-per-charge.

Feedback: Suppose you want to know the electric potential energy that a particular particle, say a particle with charge q, would have if it were at a particular point in space at which the electric potential is V.

The electric potential energy U of the particle depends on a characteristic of the particle, namely q, and a characteristic of the point in space, namely V.

$U=qV$

Question 5 **0 of 15 points**

A source charge creates an electric field to exist in the region of space around that source charge. The electric field exerts a force on any test charge that finds itself in the region of space where the electric field exits. The source charge or distribution of source charge is the cause of the electric field. The test charge is the "victim" of the electric field.

In the case of the electric potential, when we write

$$U = qV$$

is the q the source charge or is it the test charge?

Selected Answer: ✗ The source charge.

Correct Answer: ✓ The test charge.

Feedback: We have used some jargon here. By a "source charge" we mean a particle that has an amount of charge equal to what we call the source charge. By a "test charge" we mean a particle that has an amount of charge equal to what we call the test charge.

Source charge causes an electric field that with which we can associate an electric potential V. Thus source charge causes V. A test charge q, that is a particle with charge q that finds itself in the electric field, will have a potential energy U. That potential energy U depends on the electric potential V caused by the source charge, and, on the charge q of the test charge as:

$$U = qV$$

OK

Review Assessment: q06

Name: q06

Status : Completed

Score: 15 out of 100 points

Instructions:

Question 1 **0 of 24 points**

Which of the following represent the two kinds of basic (single-concept) electric potential problems? (TWO ANSWERS)

Selected Answers: ✗ Given information on the electric field in a region of space, find the velocity of the charged particle that is producing that electric potential.

Correct Answers:
✓ Given a charged particle or distribution of charged particles, find the electric potential at a point or points in space in the vicinity of that charged particle or distribution of charged particles.
✓ Given the electric potential, find the electric potential energy of a charged particle that finds itself at a location in space where the electric potential is known.

Question 2 **0 of 16 points**

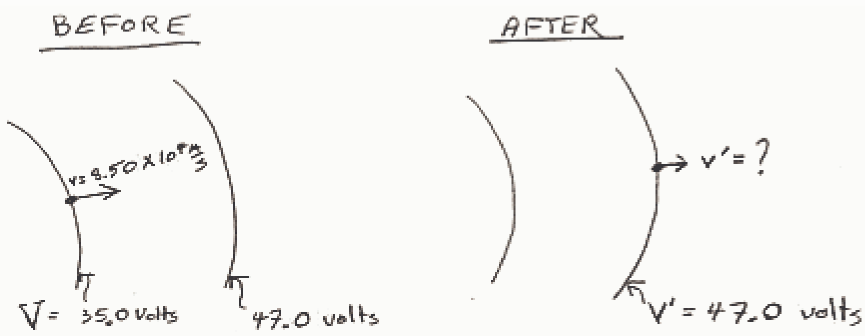
A proton (mass = 1.67×10^{-26} kg, charge = 1.60×10^{-19} C) is moving at a speed of 8.50×10^{4} m/s at a point in an evacuated region of space where the electric potential is 35.0 volts. No force but the force of the electric field characterized by the electric potential acts on the proton. The particle travels to a point in the evacuated region of space where the electric potential is 47.0 Volts. What is the speed of the particle at that point in space?

Selected Answer: ✗ 0 m/s

Correct Answer: ✓ 8.36×10^{4} m/s

Feedback: This is a conservation of energy problem. It is important to use SI units. The kinetic energy of the particle expressed as $K = \frac{1}{2} mv^2$ comes out in Joules if mass is in kg and velocity in m/s. One cannot combine a kinetic energy in Joules with a potential energy in eV without converting units first.

Note that it is most convenient, in a diagram, to depict the value of the potential at a point in space by means of an equipotential line labeled with the value of electric potential. (An equipotential line is just a line or curve on which all points are at one and the same value of electric potential.)



ENERGY BEFORE = ENERGY AFTER

$$E = E'$$

$$K + U = K' + U'$$

$$\frac{1}{2}mv^2 + qV = \frac{1}{2}mv'^2 + qV'$$

$$\frac{1}{2}mv'^2 = \frac{1}{2}mv^2 + q(V - V')$$

$$v' = \sqrt{v^2 + \frac{2q}{m}(V - V')}$$

$$v' = \sqrt{\left(8.50 \times 10^4 \frac{m}{s}\right)^2 + \frac{2(1.60 \times 10^{-19} C)}{1.67 \times 10^{-26} kg}(35.0 \text{ volts} - 47.0 \text{ volts})}$$

$$\boxed{v' = 8.36 \times 10^4 \text{ m/s}}$$

UNITS: $\sqrt{\left(\frac{m}{s}\right)^2 + \frac{C}{kg} \text{ volt}} = \sqrt{\left(\frac{m}{s}\right)^2 + \frac{\cancel{C}}{kg} \frac{J}{\cancel{C}}}$

$$= \sqrt{\left(\frac{m}{s}\right)^2 + \frac{1}{\cancel{kg}} \frac{\cancel{kg} \cdot m^2}{s^2}}$$

$$= \sqrt{\left(\frac{m}{s}\right)^2}$$

$$= \frac{m}{s}$$

Question 3 **0 of 15 points**

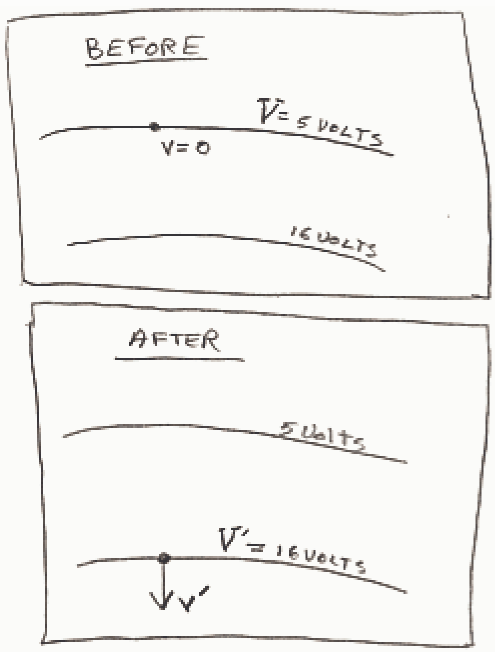
An electron is released from rest at a point in an evacuated region of space at which the electric potential is 5.0 volts. No force other than the force of the electric field characterized by the electric potential under discussion acts on the electron. What is the kinetic energy of the electron when it is at a location where the electric potential is 16 volts?

Selected Answer: ✗ 21 m/s

Correct Answer: ✓ 11 eV

Feedback: The charge of an electron is −1e and the potential energy of a charged particle in an electric field is the product of the charge of the particle and the value of the electric potential at the location of the particle. The electron starts out at a location where the electric potential is 5V so its initial potential energy is −1e times 5V. That's −5eV. The eV is a non-SI unit of energy. It's easy enough to convert a value in eV to Joules. Just replace the e with 1.6×10^{-19} C and the V with 1 J/C (that's what a volt is, a Joule per Coulomb), and simplify. But why bother. The eV might not be an SI unit of energy but it's still a unit of energy. And "−5" is easier to write than "-8×10^{-19}".

At the point where the electric potential is 16V, the potential energy of the electron is −1e × 16V or −16eV. So the electric potential energy of the electron goes from −5eV to −16eV representing a decrease in the potential energy of the electron of 11eV. By conservation of energy this decrease must be accompanied by a corresponding increase in the kinetic energy of the electron. That is, the electron's kinetic energy increases by 11eV. Since it started out with zero kinetic energy (we were told it started at rest) the final kinetic energy of the electron must be 11eV. This is worked out for you in mathematical notation below.



ENERGY BEFORE = ENERGY AFTER

$$E = E'$$

$$\cancel{K}^{0} + U = K' + U'$$

$$qV = K' + qV'$$

$$K' = qV - qV'$$

$$K' = q(V - V')$$

$$K' = -1e\,(5\text{ volts} - 16\text{ volts})$$

$$\boxed{K' = 11\,\text{eV}}$$

Question 4 **0 of 15 points**

Given a set of equipotential surfaces how does one determine the corresponding set of electric field lines?

Selected Answer: The electric field lines are those lines which are everywhere perpendicular to the equipotential surfaces and are directed (as indicated in a diagram by means of arrowheads) from low potential toward high potential.

Correct Answer: The electric field lines are those lines which are everywhere perpendicular to the equipotential surfaces and are directed (as indicated in a diagram by means of arrowheads) from high potential toward low potential.

Feedback: An equipotential surface represents a set of points all having the same value of electric potential, that is the same value of electric potential energy per charge. That means that if you were to move a test charge from one point on an equipotential surface to another, it would experience no change in electric potential energy. This means that the electric field the test charge is in would do no work on the test charge (since work = the negative of the change in potential energy). Now work is force-along-the path times the length of the path and the electric field is force per charge. The only way you can move a charged particle in an electric field from one point to another with no work being done on the particle by the electric field along any part of the path is for the force-along-the-path to be zero. In this case this means that the component of the electric field along the path must be zero. This means that the electric field must be perpendicular to the path. Since the path can be any path in the equipotential surface, the electric field must, everywhere, be perpendicular to the equipotential surface. This argument holds true for any equipotential surface so the electric field is perpendicular to all equipotential surfaces.

Question 5 **0 of 15 points**

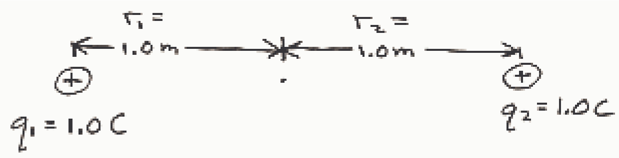
Two identical particles, each having a charge of 1.0 coulombs, are separated by 2.0 meters. What is the electric potential, due to the pair of charged particles, at the point midway between the two particles.

Selected Answer: 0 volts

Correct Answer: 18×10^9 volts

Feedback: In calculating the electric potential at an empty point in space due to a charged particle, it is important to remember that the relevant separation is the separation between the empty point in space and the charged particle. In this case there are two charged particles contributing to the electric potential at one empty point in space. For each charged particle, we use the separation of the empty point in space and that charged particle to get the contribution of that charged particle to the electric potential at the empty point in space. The separation of the two charged particles from each other is NOT directly relevant.

Note that had the question been about the electric field the answer would have been zero because each charged particle makes an equal-in-magnitude but opposite-in-direction contribution to the electric field at the midpoint. But the electric potential is a scalar. It has no direction. Both particles are positive so they both make a positive contribution to the electric potential.



$$V = V_1 + V_2$$

$$= k\frac{q_1}{r_1} + \frac{kq_2}{r_2}$$

$$= 8.99 \times 10^9 \frac{N \cdot m^2}{C^2} \frac{1.0C}{1.0m} + 8.99 \times 10^9 \frac{N \cdot m^2}{C^2} \frac{1.0C}{1.0m}$$

$$= 18 \times 10^9 \frac{N \cdot m}{C}$$

$$= 18 \times 10^9 \frac{J}{C}$$

$$\boxed{V = 18 \times 10^9 \text{ volts}}$$

Question 6 **15 of 15 points**

Where is the electric potential due to a single negatively charged particle a maximum?

Selected Answer: ✓ At any location that is an infinite distance from the charged particle.

Correct Answer: ✓ At any location that is an infinite distance from the charged particle.

Feedback: Give yourself a pat on the back!

One could get at this one by looking at the formula for the electric potential due to a point charge $V = -kq/r$. r is the separation between the charged particle and the empty point in space where one wants to know the electric potential. By inspection of the equation, as r gets smaller V gets more and more negative. V approaches negative infinity as r approaches zero. On the other hand, the bigger r gets, the closer V gets to zero. It is odd to think of zero as a maximum value but when all the other values are negative that is just what it is.

I think it is better to get at this from a more conceptual viewpoint. One does indeed have to remember that the choice of the zero of electric potential is made for you in the case of the electric potential due to a point charge, namely the electric potential is zero at infinity. You also have to remember that electric potential is electric potential energy per charge, so the electric potential energy at any point in space has the same algebraic sign as that of the electric potential energy of a positively charged particle. Now imagine a positive point charge in the electric field caused by the given negatively charged particle. If you grab the positive charge and move it to a point farther away from the charged particle, you do work on the positive charge. You are moving the positive point charge against the force of attraction that it feels for the negatively charged particle. This is like lifting a rock near the surface of the earth. You move the rock in the opposite direction to the gravitational force of the earth. When you do that you store potential energy, that is you increase the potential energy of the rock when you lift it. By analogy, in moving the positively charged particle away from the negatively charged particle that is attracting it, you increase the potential energy of the positively charged particle. By the definition of the electric potential, that means that the farther an empty point in space is from the negatively charged particle, the greater the electric potential at that empty point in space.

OK

Review Assessment: q07

Name: q07

Status : Completed

Score: 0 out of 100 points

Instructions:

Question 1 **0 of 20 points**

The electric potential at a point in a uniform electric field in an evacuated region of space is 4.0 volts. The electric potential at a point 25 cm to the east of the first point is 8.0 volts. The separation of the points is the shortest distance between the equipotential surfaces on which each point lies. What is the magnitude and direction of the electric field in the evacuated region of space?

Selected Answer: ✗ .16 N/C eastward

Correct Answer: ✓ 16 N/C westward

Feedback: The method used here will, for more general cases give you an average value for the electric field between the two points. But, in this case, it is stated that the electric field is a uniform electric field, meaning that it has one and the same value throughout the region under consideration. So the average value of the electric field between two points is the actual value of the electric field anywhere in the region under consideration.

To relate the electric field to the potential we use the fact that the work done on a positive test charge moved from the point where the electric potential is 4 volts to the point where it is 8 volts is the same whether you calculate it as force along the path times the length of the path or the negative of the change in the electric potential energy. The electric field is westward since the electric potential increases eastward. Hence, the electric force is in the direction opposite to the direction in which the test charge is moved so we use -qE for the force along the path.

$$W = -\Delta U$$

$$F_{\parallel} d = -(U_2 - U_1)$$

$$(-qE)d = -(qV_2 - qV_1)$$

$$-\cancel{q}Ed = -\cancel{q}(V_2 - V_1)$$

$$E = \frac{V_2 - V_1}{d}$$

$$E = \frac{8\text{ volts} - 4\text{ volts}}{.25\text{ m}}$$

$$E = 16\ \frac{\text{volts}}{\text{m}}$$

$$\boxed{E = 16\ \frac{\text{N}}{\text{C}}}$$

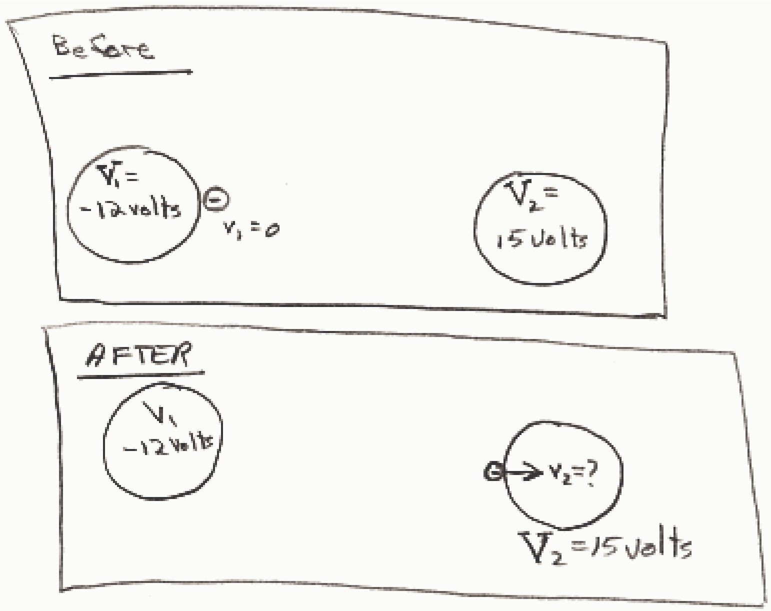
Question 2 **0 of 20 points**

Two perfectly conducting spheres are in an evacuated region of space. One is at a potential of −12 volts and the other is at a potential of 15 volts. A free electron is released from rest at the surface of the sphere at −12 volts. With what speed does it crash into the other sphere? (The mass of an electron is 9.11×10^{-31} kg.)

Selected Answer: ✗ 0 m/s

Correct Answer: ✓ 3.1×10^{6} m/s

Feedback: This is a conservation of energy problem. Sought is the speed of the electron at the instant before it hits the 15 volt sphere.



$$E_1 = E_2$$

$$\cancel{K_1}^{0} + U_1 = K_2 + U_2$$

$$qV_1 = \tfrac{1}{2} m v_2^2 + qV_2$$

$$\tfrac{1}{2} m v_2^2 = q(V_1 - V_2)$$

$$v_2 = \sqrt{\frac{2q}{m}(V_1 - V_2)}$$

$$= \sqrt{\frac{2(-1.6 \times 10^{-19} C)}{9.11 \times 10^{-31} kg}(-12 \text{ volts} - 15 \text{ volts})}$$

$$\boxed{v_2 = 3.1 \times 10^{6} \frac{m}{s}}$$

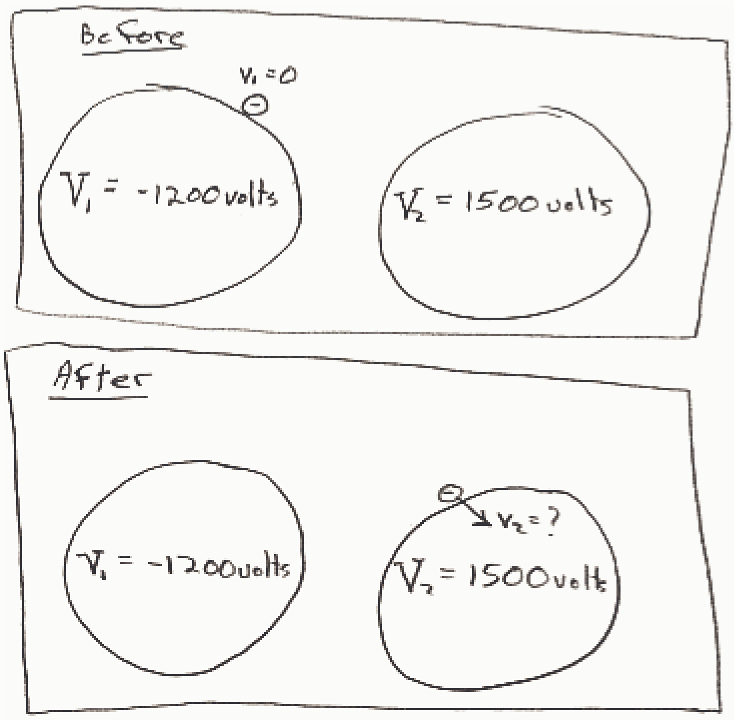
Question 3 **0 of 20 points**

Two perfectly conducting spheres are in an evacuated region of space. One is at a potential of -1200 volts and the other is at a potential of 1500 volts. A free electron is released from rest at the surface of the sphere at -1200 volts. With what kinetic energy does it crash into the other sphere?

Selected Answer: ✗ There is no way it would ever crash into the other sphere. It is already at the lowest potential in the region.

Correct Answer: ✓ 2700 eV

Feedback: This is a conservation of energy problem. Sought is the kinetic energy of the electron at the last instant prior to the collision. Since we are not asked about velocity we should NOT use K = ½ mv^2, and, because of that and the fact that the answers are all given in eV, there is no need to work in SI units.



$$E_1 = E_2$$

$$\cancel{K_1}^{0} + U_1 = K_2 + U_2$$

$$qV_1 = K_2 + qV_2$$

$$K_2 = qV_1 - qV_2$$

$$K_2 = (-1e)(-1200\text{ volts} - 1500\text{ volts})$$

$$\boxed{K_2 = 2700\text{ eV}}$$

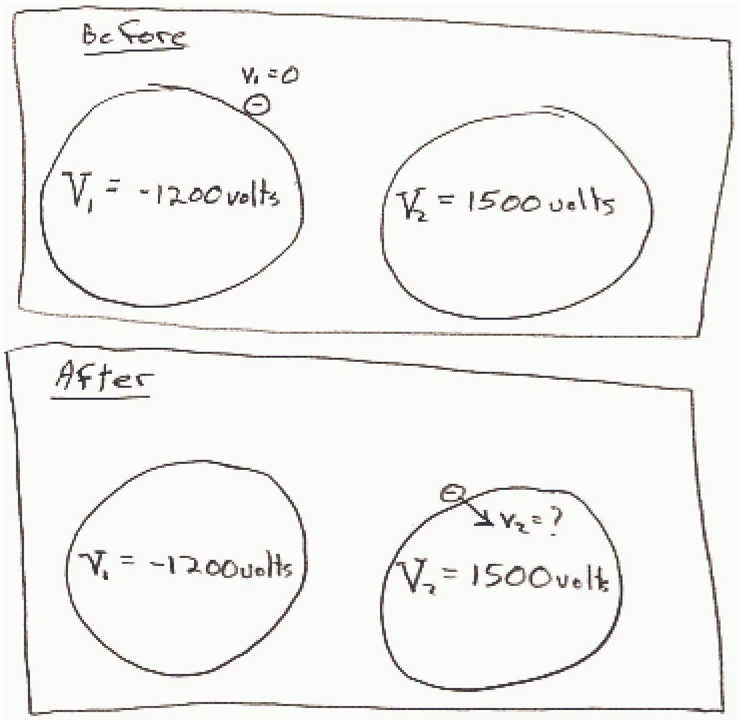
Question 4 **0 of 20 points**

Two perfectly conducting spheres are in an evacuated region of space. One is at a potential of -1200 volts and the other is at a potential of 1500 volts. A free electron is released from rest at the surface of the sphere at -1200 volts. With what kinetic energy does it crash into the other sphere?

Selected Answer: ✗ There is no way that the electron would ever crash into the other sphere.

Correct Answer: ✓ 4.3×10^{-16} J

Feedback: This is a conservation of energy problem. Sought is the kinetic energy of the electron at the last instant prior to the collision. Since we are not asked about velocity we should NOT use $K = \frac{1}{2} mv^2$. Under these circumstances, it is convenient to use the eV as the unit of energy, but, since the answers are given in Joules we will have to convert the result to joules.



$$E_1 = E_2$$

$$\cancel{K_1}^{0} + U_1 = K_2 + U_2$$

$$qV_1 = K_2 + qV_2$$

$$K_2 = qV_1 - qV_2$$

$$K_2 = (-1e)(-1200 \text{ volts} - 1500 \text{ volts})$$

$$K_2 = 2700 eV$$

$$K_2 = 2700\,(1.6 \times 10^{-19} C)\left(1 \frac{J}{C}\right)$$

$$\boxed{K_2 = 4.3 \times 10^{-16} J}$$

Question 5 **0 of 20 points**

Which statement about the electric potential of a solid object made out of a perfectly conducting medium is most correct?

Selected Answer: ✗ The electric potential everywhere in and on the conductor must be zero.

Correct Answer: ✓ The electric potential can have any value but all points in and on the conductor always have one and the same value of electric potential.

Feedback: It's the electric field which is zero anywhere within a perfect conductor. The electric potential doesn't have to be zero but it does have to be single-valued. The two facts are consistent with each other. If the electric potential, which is the electric potential energy per charge has the same value everywhere in and on the conductor, then the change in potential energy of a test charge, moved from one point in/on the conductor to another point in/on the conductor, has to be zero. Since the work done on the particle by the electric field is equal to the negative of the change in potential energy of the test charge, the work done is zero. By definition, the work done on the test charge is also the force along the path times the length of the path. For this to be zero for any path within the conductor, the electric force on the particle must always be zero. But the force is the charge of the particle times the electric field and we stipulated that the particle had some charge so the electric field has to be zero everywhere in the conductor. (This shows that if the electric potential has one and the same value everywhere in/on a perfect conductor then the electric field is zero everywhere in the conductor. The converse is true as well.)

OK

Review Assessment: q08

Name:	q08
Status :	Completed
Score:	20 out of 100 points
Instructions:	

Question 1 **0 of 20 points**

A capacitor can serve as which of the following? (Indicate all that apply.)

Selected Answers: ✗ A current measuring device.

Correct Answers: ✓ A charge storage device.
✓ An energy storage device.

Feedback: By definition a capacitor is a charge storage device. In storing charge a capacitor also stores energy. If you connect a charged capacitor across a resistor the capacitor will discharge through the resistor and the energy that was stored in the capacitor will manifest itself as a temperature increase of the resistor.

The amount of energy stored in a capacitor can be expressed in terms of the charge on the capacitor as ½ 1/C Q^2 or in terms of the voltage across the capacitor as ½ C V^2.

Question 2 **0 of 20 points**

Consider a capacitor consisting of two flat metal plates of one and the same size. The plates are facing each other and, they are well-aligned with each other. The plates are separated by air. Which of the following statements is true?

Selected Answers: ✗ The greater the separation of the plates, the greater the capacitance of the capacitor.

Correct Answers: ✓ The smaller the separation of the plates, the greater the capacitance of the capacitor.

✓ The greater the area of the plates, the greater the capacitance of the capacitor.

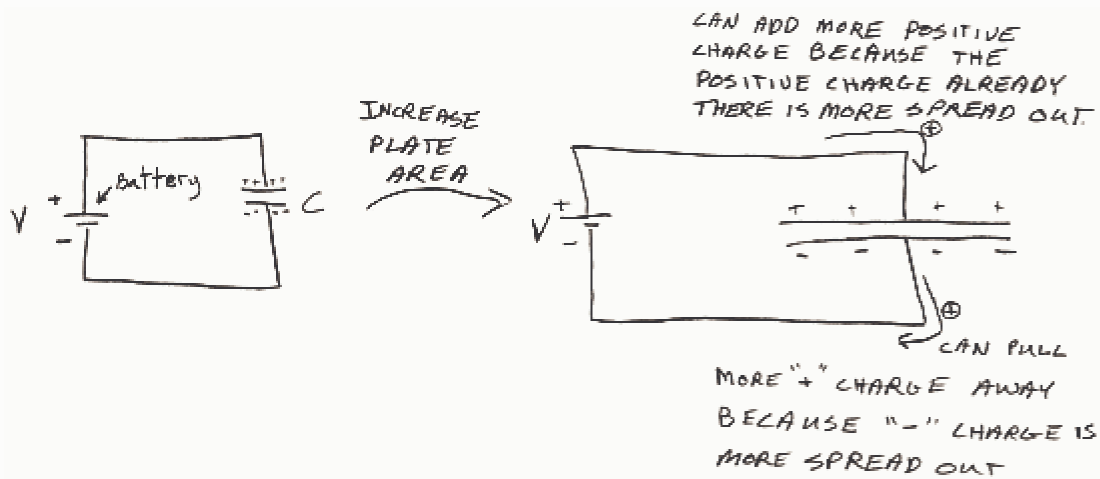
Feedback: [This argument is carried out in the model used in the definition of current, the model in which the charge carriers are positive.]

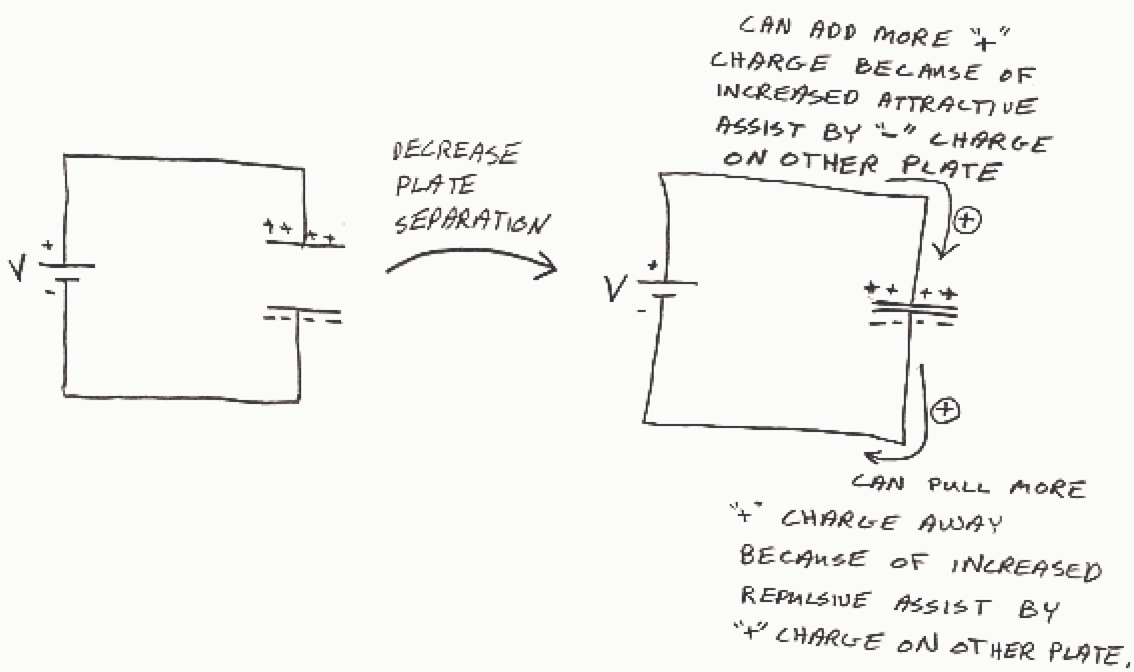
The capacitance of a capacitor is a measure of how much charge the capacitor will hold for a given voltage across the capacitor. Imagine connecting a battery across a capacitor. The battery pulls positive charge from one plate of the capacitor and pushes it onto the other. The more charge that has already been move, the harder it is for the battery to do this. It is hard to pull positive charge from the negative plate because the negative charge on the plate attracts the positive charge. And it is hard to push the positive charge onto the positive plate because the positive charge already there repels the positive charge being added. When it gets too hard for the battery to move any more charge, the process ceases and the capacitor is fully charged.

Now imagine that one increases the area of each of the plates of the capacitor. It would be easier to pull some positive charge from the negative plate because the negative charge on the negative plate would be more spread out, thus, on the average, more distant from the positive charge being removed. (Greater distance means weaker force of attraction). It would be easier to push that positive charge onto the positive plate because the positive charge already there would be more spread out, hence, on the average, more distant from the positive charge being pushed onto the plate. (Greater distance means weaker force of repulsion.) So, if the plate area is increased, the same battery can move more charge from one plate to the other, meaning the capacitor stores more charge for the same voltage, meaning the capacitance is increased.

Now suppose the plates are moved closer together. The negative charge on the negative plate still makes it hard to pull positive charge off, but, the positive charge on the plate on the other side of the gap actually helps the battery pull positive charge from the negative plate by repelling that positive charge away from the capacitor. The closer the plates are to each other the greater this assist and hence, the more positive charge the battery can pull from the negative plate. As the battery pushes that charge onto the positive plate the battery gets an assist from the negative charge on the negative plate on the other side of the gap. (The negative charge exerts a force which tends to pull the positive charge onto the capacitor. So, moving the plates closer together makes it so that the same battery can move more charge from one plate to the other. Thus for the same voltage, the capacitor has more charge. This means that the closer the plates are to each other, the greater the capacitance of the capacitor.

The two situations are depicted schematically below.





Question 3 **0 of 20 points**

Suppose that you were given a capacitor having capacitance C and that for various voltage settings of a power supply, you measured the voltage across the capacitor and the charge on the capacitor. Assume that your results are ideal. If you made a graph of the charge on the capacitor vs. the voltage across the capacitor, on what kind of curve or line would your data points fall.

Selected Answer: ✗ An increasing exponential curve.

Correct Answer: ✓ A straight line of slope C passing through the origin.

Feedback: The charge on a capacitor is directly proportional to the voltage across the capacitor. The proportionality constant is the capacitance of the capacitor, C. A graph of charge vs. voltage thus yields a straight line passing through the origin with slope C.

Question 4 **20 of 20 points**

What do we mean when we say that a capacitor has an amount of charge Q on it?

Selected Answer: ✓ One of the plates of the capacitor holds a charge Q and the other holds a charge −Q.

Correct Answer: ✓ One of the plates of the capacitor holds a charge Q and the other holds a charge −Q.

Feedback: Good!
If we take the expression "the charge on the capacitor" too literally, the value is always zero because the charge on one plate of a capacitor is always equal to the negative of the charge on the other plate. The expression is physics jargon and we just have to remember that it means the absolute value of the charge on either plate. So, if one plate has 15 mC of charge on it, the other plate has –15 mC of charge on it, and the capacitor is said to have a charge of 15 mC on it.

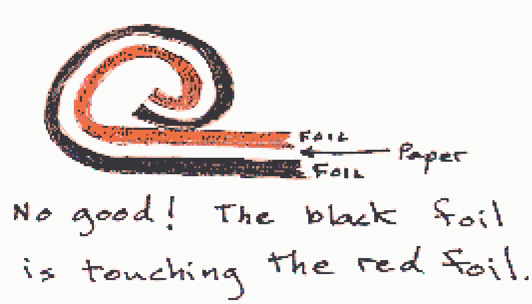
Question 5 **0 of 20 points**

You are provided with two strips of metallic foil, two strips of waxed paper, and two metal paper clips. Each strip is in the shape of a rectangle, 2 inches wide and 5 feet long. Which of the following would result in the best capacitor?

Selected Answer: ✗ Layer the strips, alternating metal with paper. Roll up the stack into the shape of a 2-inch-long cylinder. Attach one paper clip to one of the pieces of waxed paper and the other to the other piece of waxed paper. The paper clips serve as the terminals of the capacitor.

Correct Answer: ✓ Layer the strips, alternating metal with paper. Roll up the stack into the shape of a 2-inch-long cylinder. Attach one paper clip to one of the pieces of foil and the other to the other piece of foil. The paper clips serve as the terminals of the capacitor.

Feedback: If you just sandwich one strip of waxed paper in between the two strips of metal foil without using the second strip of waxed paper, the two pieces of foil will come in contact with each other when you roll up the "sandwich" shorting out your would-be capacitor.



OK

Review Assessment: q09

Name: q09

Status : Completed

Score: 20 out of 100 points

Instructions:

Question 1 **4 of 24 points**

Match each item to its description.

Question	Correct Match	Selected Match
Seat of EMF	✓ F. A two-terminal circuit element designed to maintain a constant potential difference between its terminals.	✗ A. Charge flow rate.
Resistor	✓ D. A two-terminal circuit element intentionally designed to be a poor conductor.	✗ A. Charge flow rate.
Circuit	✓ G. A closed conducting path.	✗ A. Charge flow rate.
Current	✓ A. Charge flow rate.	✓ A. Charge flow rate.
Voltage	✓ C. Electric potential difference—something that exists but does not go anywhere.	✗ A. Charge flow rate.
Terminal	✓ B. One of the two metal ends of a circuit element (such as resistor or seat of EMF) to which one connects wires when one connects that circuit element in a circuit.	✗ A. Charge flow rate.

Feedback: Note that an ammeter measures the current (charge flow rate) at a point in a circuit whereas a voltmeter measures the potential difference between two points in a circuit.

Question 2 **16 of 16 points**

Consider a high school built to handle 1500 students but attended by 2500 students. Between classes, the halls are jam-packed with students moving to their next class. About an hour after school however, the halls are practically empty and the students from the track team zip through those halls at a fast pace. Which situation is a better analogy for the movement of charge through a circuit?

Selected Answer: ✓ The students moving through the crowded halls.

Correct Answer: ✓ The students moving through the crowded halls.

Feedback: Wonderful performance!

A circuit is so jam-packed with charged particles participating in the flow that, for a typical current, even though the average velocity of a charged particle is very small, a huge number of charged particles pass a given point in the circuit every second.

Question 3 **0 of 20 points**

Consider a positively charged particle in a circuit. As it moves through a resistor in the circuit, the positively charged particle moves from a point (one end of the resistor) in the circuit where the electric potential is high to a point (the other end of the resistor) where the electric potential is low. That means it moves from a point where it has high potential energy to a point where it has low potential energy. Conservation of energy would suggest that the decrease in the potential energy of the particle should be accompanied by an increase in kinetic energy. Why doesn't the particle speed up as it goes through the resistor?

Selected Answer: The particle does speed up. In fact, the charged particles in a circuit are continually speeding up the whole time the circuit is connected.

Correct Answer: There is indeed a tendency of the positively charged particle to speed up but it keeps bumping into lattice imperfections and impurities in the resistor, thus giving up some of its energy to the resistor. Such energy manifests itself as thermal energy of the resistor which is given off by the resistor as heat.

Feedback: Inside a resistor, electric potential energy is converted to thermal energy.

Question 4 **0 of 20 points**

In that part of a circuit, outside of any batteries or power supplies, what is it that actually pushes charged particles through the circuit?

Selected Answer: The resistance of the resistors.

Correct Answer: An electric field.

Feedback: By definition, a seat of EMF, that is, an ideal battery or power supply, maintains a constant electric potential difference between its terminals. Now electric potential is something we use to characterize an electric field. So if there is an electric potential there must be an electric field. Indeed, a seat of EMF creates an electric field in the circuit in the same direction as the current. Indeed the current is a result of this electric field as it is the electric field which exerts the force on the charged particles which makes them move around the circuit. One rarely hears of the electric field in a circuit because it is not useful in circuit calculations, and, it is difficult to measure.

Question 5 **0 of 20 points**

What is electric current? (Choose the one BEST answer.)

Selected Answer: Electric potential difference.

Correct Answer: Charge flow rate.

Feedback: From Ohm's Law, V = IR with R being a constant, one finds that I = V/R. So current is equal to voltage divided by resistance. But this doesn't say what current is. It is just a statement of an expression that allows one to calculate the current through a resistor. It is not the one best answer.

OK

Review Assessment: q10

Name: q10

Status : Completed

Score: 20 out of 100 points

Instructions:

Question 1 **0 of 15 points**

What all can the power P possibly represent in the expression $P = IV$ where I is current and V is voltage?

Selected Answers:

✓ The rate at which energy is delivered to a resistor by the rest of a circuit of which that resistor is a part.

Correct Answers:

✓ The rate at which energy is delivered to a resistor by the rest of a circuit of which that resistor is a part.
✓ The rate at which energy is delivered to a circuit by a seat of EMF.
✓ The rate at which electrical energy is converted to thermal energy in a circuit.
✓ The rate at which heat is given off by a resistor when the voltage across the resistor is, and has for a long time been, V and the current through the resistor is, and has for a long time been, I.
✓ The rate at which chemical energy is converted to electrical energy in a battery that is in a circuit.

Feedback: The short definition for power is "the rate at which work is done." This definition encompasses all the responses for this question.

Question 2 **0 of 10 points**

What are some of the differences between resistance and resistivity?

Selected Answers:

✓ Resistance can be used to characterize a given piece of wire whereas resistivity characterizes the material of which the wire is made.

Correct Answers:

✓ Resistance can be used to characterize a given piece of wire whereas resistivity characterizes the material of which the wire is made.
✓ Resistance is measured in ohms whereas resistivity is measured in ohm's per meter.

Feedback:

The resistance R of a wire depends on both the size and shape of the wire and on the resistivity ρ, a physical quantity whose value characterizes the material of which the wire is made.

$$R = \rho \frac{\ell}{A}$$

where ℓ is the length of the wire and A is the cross-sectional area of the wire.

Question 3 **0 of 15 points**

What is power? (Indicate all that apply.)

Selected Answers: ✓ The rate at which work is done.

Correct Answers:
- ✓ The rate at which work is done.
- ✓ The rate at which energy is converted from one form to another form.
- ✓ The rate at which energy is delivered from one system to another system.

Feedback: That "seat of EMF" response is SO wrong. Not only is the rate of charge delivery not power, but, a seat of EMF does not deliver charge. A seat of EMF (a battery or a power supply) maintains a potential difference in a circuit which makes it so that charge that is already in the circuit undergoes some motion but a seat of EMF should not be thought of as a charge delivery device.

Question 4 **10 of 20 points**

Wire A and wire B are both made out of copper. Both wires have the same length. The diameter of wire B is twice that of wire A.

Question	Correct Match	Selected Match
Which wire has the greater resistance?	✓ A. Wire A.	✓ A. Wire A.
Which wire has the greater resistivity?	✓ C. Neither.	✗ A. Wire A.

Feedback: Resistivity is a property of the material. It does not depend on the size and shape of the object. (The object is a piece of wire in each case.) Since both wires are made of copper, the resistivity is the same for both wires.

The skinnier wire offers the smaller passageway for charged particles to flow through. As such it offers more resistance to the flow of charge. In other words, the resistance of the skinnier wire is greater than that of the fatter wire.

Question 5 **10 of 20 points**

Wire A and wire B are both made out of copper. Wire B is twice as long as wire A. The diameter of wire B is twice that of wire A.

Question	Correct Match	Selected Match

Which wire has the greater resistance?	✓ A. Wire A.	✓ A. Wire A.
Which wire has the greater resistivity?	✓ C. Neither.	✗ A. Wire A.

Feedback: Resistivity is a property of the material of which something is made—it does not depend on the size and shape of that something. Both wires are made of copper so they both have the same resistivity.

The bigger wire has characteristics that tend to offset each other. The greater length, by itself, would give the wire a greater resistance as the charged particles have farther to go to make it through the wire. The greater diameter, by itself, would result in a smaller resistance as it means the passageway through which the charged particles flow is both wider and taller.

The resistance is the resistivity times the ratio L/A of the length to the cross-sectional area of the wire. Doubling the length introduces a factor of 2 into the numerator of that ratio. But the area is proportional to the square of the diameter so doubling the diameter introduces a factor of 4 into the denominator of the ration. So, doing both is equivalent to multiplying the expression for the resistance by 2/4. Hence the resistance of the bigger wire is 1/2 that of the smaller wire.

Question 6 **0 of 10 points**

The power delivered to a 15 watt light bulb in normal operation is 15 watts. In normal operation, how much energy is delivered to such a bulb in an hour?

Selected Answer: ✗ 15 eV

Correct Answer: ✓ 54 kJ

Feedback: From the definition of power one should be able to reason that E = Pt where E is energy, P is power, and t is time. If P is how fast energy is being delivered to the resistor, that is if P is how many Joules-per-second of energy are being delivered to the resistor, then of course, all one has to do is multiply by the number of seconds, the time, to get the total energy delivered in that time. Now an hour is 3600 seconds (not 60 seconds!) so E = (15 watts)×(3600 seconds) which means E = 54,000 joules which is the same as 54 kJ.

Question 7 **0 of 10 points**

The resistance-per-length of a wire is the wire's resistivity.

Selected Answer: ✗ True

Correct Answer: ✓ False

Feedback: Resistivity has units of ohms per meter so, as regards wire, it is indeed natural to assume that resistivity is a measure of the resistance per length of the wire. Such reasoning is called dimensional analysis and quite often can be used to recall a formula. For instance, speed has units of meters per second. The meter is a measure of distance and the second a measure of time so one can (correctly in this case) conclude that speed is distance-per-time.

In the case of resistivity, dimensional analysis leads to an incorrect conclusion. Resistivity is resistance times length-per-area which has the same units as resistance-per-length but is not the same thing.

One who knows that resistivity is a characteristic of a substance, not of an object, could judge the statement to be false in that resistance-per-length would depend on how fat the wire is (a dimension of the object), not just on what material the wire is made of.

OK

Review Assessment: q11

Name: q11

Status : Completed

Score: 10 out of 100 points

Instructions:

Question 1 **0 of 20 points**

Consider three resistors having three unique values of resistance. Suppose the resistors are connected in parallel with each other. Further suppose that the parallel combination of the three resistors is connected in a circuit such that at least some charge is flowing through each of the resistors. Which of the following statements is true? (Indicate all the correct answers.)

Selected Answers: ✗ The current through each resistor is one and the same value.

Correct Answers:
✓ The voltage across each resistor is one and the same value.
✓ The effective resistance of the combination of resistors is less than the resistance of any one of the individual resistors.

Feedback: [For communication purposes we arbitrarily identify one end of each resistor to be the right end and the other to be the left end.]

Given that the resistors are connected in parallel, the left ends of all the resistors are connected together, and, separately, the right ends of all the resistors are connected together. To say that all the left ends are connected together is to say that all the left ends are part of one and the same conductor. Since all points in and on a conductor are at one and the same electric potential, the left end of every resistor is at one and the same potential, call it V_L. A similar argument can be made for the right end of each resistor. Hence, the right end of every resistor is at one and the same value of electric potential, call it V_R, different from the one value of potential of the left ends. The voltage across any of the resistors is just the difference between V_L and V_R. Since all the resistors share the same V_L and the same V_R, the voltage across the resistors has one and the same value for every resistor.

Each time you put a resistor in parallel with another resistor, you create an additional path though which charge can flow. Because of this, a combination of resistors in parallel provides less resistance to the flow of charge than does any of one the resistors by itself.

Question 2 **0 of 20 points**

Consider three resistors having three unique values of resistance. Suppose the resistors are connected in series with each other. Further suppose that the series combination of the three resistors is connected in a circuit such that at least some charge is flowing through each of the resistors. Which of the following statements is true? (Indicate all the correct answers.)

Selected Answers: ✓ The current through each resistor is one and the same value.

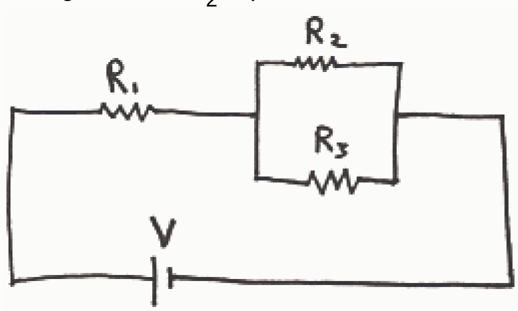
Correct Answers:
✓ The current through each resistor is one and the same value.
✓ The effective resistance of the combination of resistors is greater than the resistance of any one of the individual resistors.

Feedback: If the resistors are in series, a charged particle that works its way through one of the resistors has no choice but to go through the next resistor and from there it has no choice but to go through the third resistor. As the electric field pushes charge through the first resistor in line, the exact same amount of charge has to be pushed through the second resistor. Otherwise, charge would pile up in between the two resistors in contradiction to all observations. And, as the electric field pushes that charge through the second resistor, the exact same amount of charge must be pushed through the third. So for any amount of charge going through the first resistor, the exact same amount of charge goes through the second and third resistors. Hence, for any amount of charge-per-second going through the first resistor, there is the same amount of charge-per-second going through the second resistor and the third resistor. That is to say that the current is the same in all three resistors.

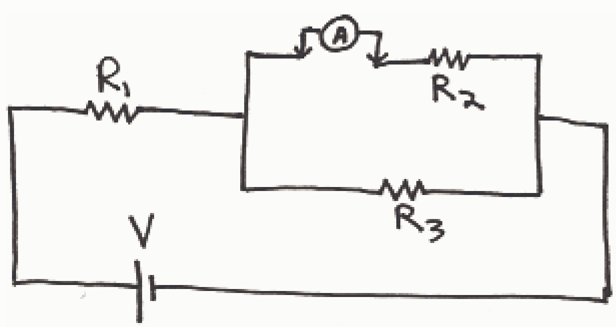
Putting resistors in series has an additive effect on the overall resistance to the flow of charge. The charge flow in a circuit is restricted if, in traveling through the circuit, charge is forced to work its way through a resistor. If, having made its way through one resistor, the charge has no choice but to work its way through a second resistor, as is the case for two resistors in series, then that second resistor further restricts the flow of charge. And if, having made its way through two resistors, one after another, the charge has no choice but to work its way through a third resistor, as is the case for three resistors in series, then that third resistor further restricts the flow of charge. The more the flow of charge is restricted, the greater the overall resistance, so, the resistance of three resistors in series is greater than the resistance of any one of the resistors by itself. The total resistance is, in fact, the sum of the three individual resistances.

Question 3 **0 of 20 points**

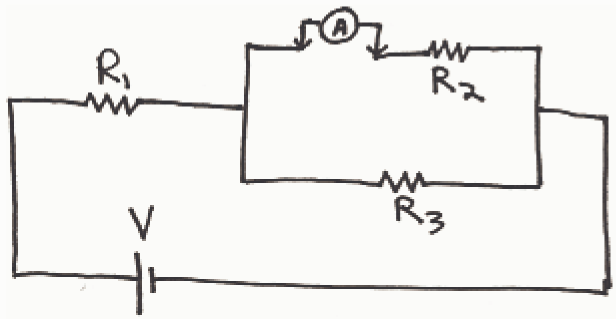
For this circuit, which of the following represents a correct way of connecting an ammeter to measure the current through resistor R_2? (Indicate all the correct answers.)



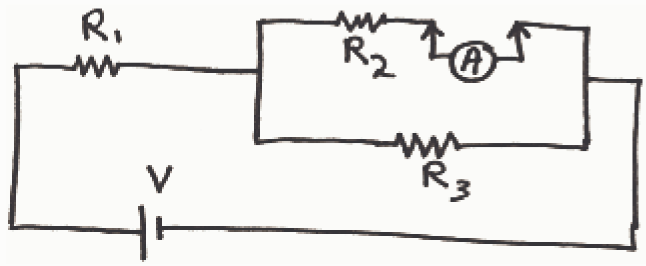
Selected Answers: ✓



Correct Answers: ✓



✓



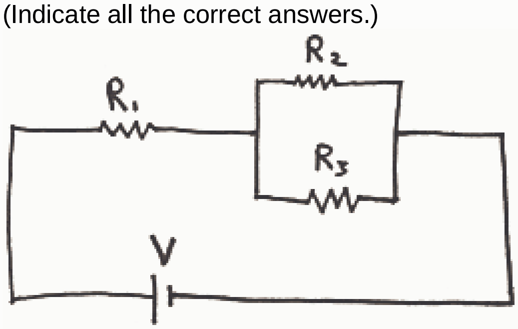
Feedback: An ammeter acts like a piece of wire that measures the charge flow rate through itself. To use it, in principle, one simply removes a piece of wire in that branch of the circuit through which one wishes to measure the current, and replaces that piece of wire with the ammeter.

A branch of a circuit is also known as a leg of a circuit. It is a single conducting path with no "forks in the road." If the circuit consists of only one single conducting path, there is but one branch to the circuit--the whole circuit is the one and only branch of the circuit. If the circuit has junctions where three or more wires meet, then the circuit has more than one branch. Each single conducting path extending from one junction to another, with no junctions in between, is a branch of the circuit. The current everywhere in a branch of a circuit has one and the same value.

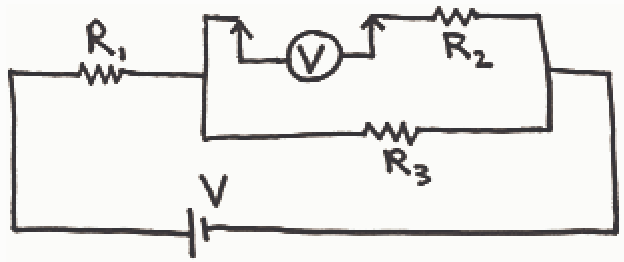
To measure the current through R_2, in principle, one has to remove a section of wire from the branch containing R_2 and replace that section of wire with an ammeter. In practice, this is the same as disconnecting the wire from R_2, connecting one end of the ammeter to the end of the wire just disconnected from R_2 and the other end of the ammeter to the terminal of R_2 from which the wire was removed.

Question 4 **0 of 10 points**

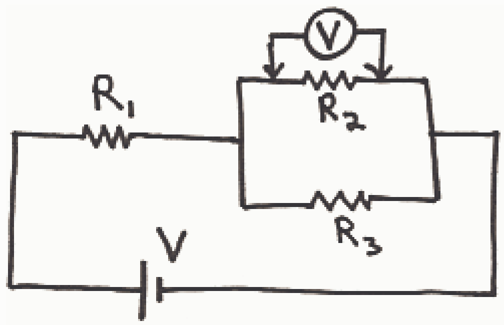
For this circuit, which of the following shows a correct way to connect a voltmeter to measure the voltage across R_2? (Indicate all the correct answers.)



Selected Answers: ✗



Correct Answers: ✓



Feedback: An ideal voltmeter has infinite resistance. As regards the effect it has on the circuit, a voltmeter acts like dry air (unlike an ammeter which acts like a piece of wire). A voltmeter has two probes, one marked positive and the other negative. If you connect the positive probe to point A in the circuit and the other to point B in the circuit, the voltmeter shows how much higher the electric potential at A is than that at point B.

(Some, but not all voltmeters allow for negative readings. Point A being at a potential that is –5 Volts higher than the potential at point B is the same as point B being at a potential that is 5 Volts higher than the potential at point A.)

Taking a voltage reading is a passive activity. There is no need to modify the circuit prior to connecting the voltmeter. One simple touches or connects each probe to a point in the circuit.

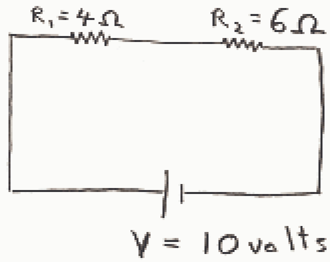
Question 5 **0 of 10 points**

A circuit consists of a 10 volt battery connected in series with a 4 ohm resistor and a 6 ohm resistor. A person calculates the current through the 4 ohm resistor using Ohm's Law by dividing 10 volts by 4 ohms. What is wrong with this?

Selected Answer: ✗ There is nothing wrong with it. That is exactly what one must do to get the current through the 4 ohm resistor.

Correct Answer: ✓ In using Ohm's Law to determine the current through a resistor, one must use the resistance of the resistor and the voltage across the resistor. One cannot just use any voltage that happens to appear in the circuit. 10 volts is not the voltage across the resistor.

Feedback: The simplest method for correctly determining the current through the 4 ohm resistor in the circuit

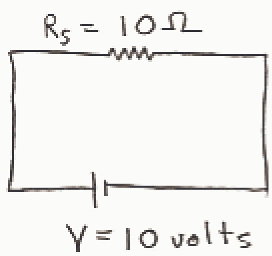


is to use the method of effective resistance. The two resistors are in series so they can be combined to form the single effective resistance R_S.

$R_S = R_1 + R_2$

R_S = 4 ohms + 6 ohms

R_S = 10 ohms



In the simpler circuit the seat of EMF is connected directly across the effective resistance R_S. So the voltage across the 10 ohm resistor R_S is the same as the EMF voltage, namely 10 volts. Now we can use Ohm's law:

$V = I\, R_S$

$I = V / R_S$

I = (10 volts) / (10 ohms)

I = 1 ampere

We have found the current through the single effective resistance R_S. The last step in the problem is to take what we have found in the simplified circuit and apply it to the original circuit. Because R_S represents a series combination of resistors, the current through R_S is the current through each of the resistors making up R_S. So, the current through the 4 ohm resistor labeled R_1 in my diagram of the original circuit is 1 ampere.

Question 6 **0 of 10 points**

A circuit consists of a 10 volt battery connected in series with a 4 ohm resistor and a 6 ohm resistor. Why is it utter nonsense to say that 4 volts goes through the 4 ohm resistor? (Choose the one best answer.)

Selected Answer: ✗ Because the resistors are in series, the whole ten volts goes through each resistor.

Correct Answer: ✓ Voltage is potential difference. It doesn't ever go through anything. It doesn't "go" anywhere. It exists.

Feedback: What does "go" in a circuit, is charge. Charge flows through a circuit. The flow rate of charge is called current.

Voltage exists. Current flows.

(The statement that "current flows" is jargon. Technically it is charge that flows and current is the charge flow rate. But the expression "current flows" has pervaded the field so it will not be avoided.)

Question 7 **10 of 10 points**

A seat of EMF is in series with a resistor R_1 and with a parallel combination of two other resistors R_2 and R_3. R_2 is a variable resistor whose resistance can be changed just by turning a knob. As the knob is turned to increase the resistance of R_2 what happens to the voltage across R_3?

Selected Answer: ✓ It increases.

Correct Answer: ✓ It increases.

Feedback: Outstanding performance!

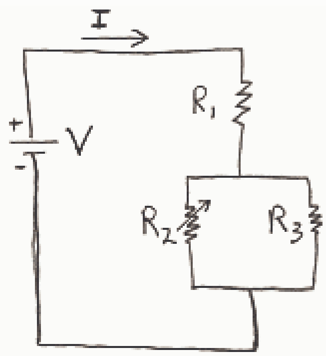


FIGURE 1

The arrow through R_2 in Figure 1 means that R_2 is a variable resistor.

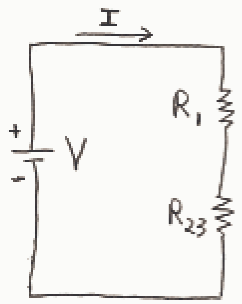


FIGURE 2

R_{23} in Figure 2 is the effective resistance of the parallel combination of R_2 and R_3.

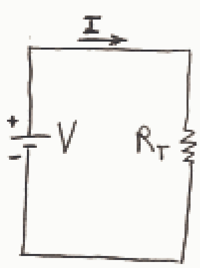


FIGURE 3

Resistor R_T in Figure 3 is the effective resistance of the series combination of R_1 and R_{23}. The increase in R_2 that causes R_{23} also increases R_T. Figure 3 shows, based on Ohm's Law, that an increase in R_T results in a decrease in current I. The I in Figure 3 is also the I in Figure 2. The given circuit is depicted in Figure 1. Looking at Figure 2 and recognizing that I is the current through R_1, according to Ohm's Law, the decrease in I results in a decrease in voltage across R_1. Now the voltage across the series combination R_1 and R_{23} (the voltage across R_1 plus the voltage across R_{23}) is the voltage across the seat of EMF, which does not change. So if the voltage across R_1 decreases then the voltage across R_{23} must increase, in order for the sum to stay the same. But the voltage across R_{23} is the voltage across R_3 so the voltage across R_3 must increase.

OK

Review Assessment: q12

Name: q12

Status : Completed

Score: 45 out of 100 points

Instructions:

Question 1 **5 of 20 points**

Match.

Question	Correct Match	Selected Match
The voltage across a resistor is directly proportional to the current through it.	✓ A. Ohm's Law	✓ A. Ohm's Law
The sum of the voltage changes about any closed loop is zero.	✓ D. Kirchoff's Voltage Law	✗ A. Ohm's Law
The sum of the currents into a junction is equal to the sum of the currents out of that junction.	✓ E. Kirchoff's Current Law	✗ A. Ohm's Law
The force exerted on one charged particle by another is inversely proportional to the square of the separation of the two charged particles.	✓ F. Coulomb's Law	✗ A. Ohm's Law

Question 2 **20 of 20 points**

An idealistic model for a battery is just an ideal seat of EMF. A more realistic model, commonly used to model actual batteries is:

Selected Answer: ✓ A resistor, known as the internal resistance of the battery, in series with an ideal seat of EMF.

Correct Answer: ✓ A resistor, known as the internal resistance of the battery, in series with an ideal seat of EMF.

Feedback: Super!
Note that the internal resistance in series with the ideal seat of EMF is still a model. The battery both maintains a potential difference and provides resistance to any charge that may flow through it. But the two effects, in practice, cannot be separated from each other. The entire material of the battery contributes to the resistance. The battery just *acts* like a resistor in series with an ideal seat of EMF. A battery can never physically be separated into a resistor and an ideal seat of EMF.

Question 3 **20 of 20 points**

In applying Kirchoff's voltage law, one draws a schematic diagram of the circuit and then indicates the current in each leg (a.k.a. branch) of the circuit. For each leg of the circuit, how does one know which way to draw the current.

Selected Answer: ✓ It doesn't matter which way one draws the current. One should just make a quick guess.

Correct Answer: ✓ It doesn't matter which way one draws the current. One should just make a quick guess.

Feedback: Nice job.

If you guess wrong on the current direction, when you solve for the current in that branch of the circuit, you get a negative value for the value of the current. A negative value for a current in a specified direction is simply a current in the opposite direction.

Question 4 **0 of 20 points**

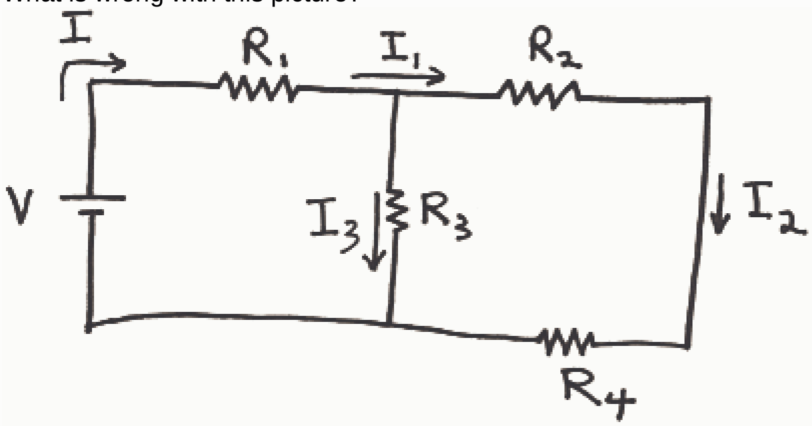
In using Kirchoff's Laws to analyze a circuit, a student correctly calculates a negative value for one of the currents in the circuit. What does the negative sign mean?

Selected Answer: ✗ One of the premises of the question is wrong. A negative sign for a current indicates that there is a mistake in the calculation.

Correct Answer: ✓ The positive sense for the current in question is established by means of an arrow pointing in that direction defined to be the positive direction for current. The negative sign in the result indicates that the current is actually in the direction opposite to that direction specified by the arrow.

Question 5 **0 of 20 points**

What is wrong with this picture?



Selected Answer: ✗ I, I_1, and I_2 are all one and the same current.

Correct Answer: ✓ I_1 is depicted as going right through a junction. In actuality, where a current meets a junction (of three wires) part of the current goes one way and part of it goes another--it never just goes straight through the junction.

Feedback: Current is the flow rate of charge. When the charge gets to the junction of three wires (including the wire the charge is in) the charge has two options on which way to go. Some goes one way, and some goes the other.

OK

Review Assessment: q13

Name: q13

Status : Completed

Score: 0 out of 100 points

Instructions:

Question 1 **0 of 20 points**

For the case of a capacitor which is initially charged and then connected across a resistor; the charge on the capacitor, the voltage across the capacitor, and the current through the resistor all decrease exponentially with time. What does it mean to say that any one of these quantities "decreases exponentially with time?"

Selected Answers: ✗ It means that the amount by which that quantity decreases in a second, increases with time. For instance, if the voltage across the capacitor decreases from 9.0 volts to 8.8 volts in one second starting at time 5.0 seconds, it might decrease from 5.0 volts to 4.0 volts in one second starting at time 25 seconds (where time 0 is the instant at which the charged capacitor is connected across the resistor).

Correct Answers: ✓ It means that the amount by which that quantity decreases in a second, decreases with time. For instance, if the voltage across the capacitor decreases from 9.0 volts to 7.4 volts in one second starting at time 5.0 seconds, it might decrease from 0.14 volts to 0.11 volts in one second starting at time 25 seconds (where time 0 is the instant at which the charged capacitor is first connected across the resistor).

✓ It means that one can define a half-life for the quantity where, the amount of charge the capacitor has on it for instance, at time t plus one half-life is one half the charge that it has on it at time t, no matter what time t you start with. Suppose for instance the capacitor has 12 microcoulombs of charge on it at time 2 seconds (with time 0 being the instant at which the charged capacitor is first connected across the resistor) and that the half-life is 4 seconds. Then at time t = 6 seconds, the charge on the capacitor will be 6 microcoulombs. Further if the charge on the capacitor is 1.5 microcoulombs at t = 13 seconds then once again it will be half that 4 seconds later, that is, the charge will be .75 microcoulombs at t = 17 seconds.

Feedback: An additive change in clock reading has a multiplicative effect on the current. In the case of exponential *decay*, the factor* is less than one.

---

*A factor is a number that is multiplying something else. The expression "...a multiplicative effect on the current" means that the current is multiplied by a factor.

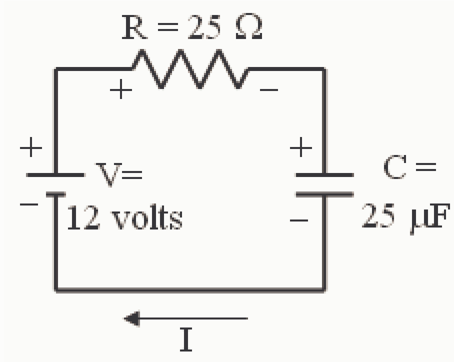
Question 2 **0 of 20 points**

A 12 volt battery is connected in series with an initially-uncharged 120 microfarad capacitor and a 25 ohm resistor. What is the current through the resistor at the instant the connection is made?

Selected Answer: ✗ 0 amperes

Correct Answer: ✓ .48 amperes

Feedback: Just for an instant, after the connection is made but before any charge has built up on the capacitor, the capacitor "acts like" a piece of wire. Thus, for that instant only, it is as if the battery in the given circuit is connected across the resistor. Hence, for that instant, the resistor voltage is the battery voltage. Using the battery voltage in V=IR and solving for I we find that I = 0.48 A.



Question 3 **0 of 20 points**

Consider a capacitor which is charged to 12 volts and then connected across a resistor. Let $t_{1/2}$ be the time it takes for the voltage to drop down to 6 volts. Suppose the experiment is repeated, but with a pair of capacitors connected in parallel with each other in place of the original capacitor, where each element of the pair has the same capacitance as the original capacitor. How does the new $t_{1/2}$ compare with the original $t_{1/2}$?

Selected Answer: ✗ The new $t_{1/2}$ is the same as the original $t_{1/2}$.

Correct Answer: ✓ The new $t_{1/2}$ is twice the original $t_{1/2}$.

Feedback:

$$V = V_o e^{-\frac{t}{\tau}}$$

$t_{1/2}$ is the time it takes for V to decrease to $\frac{1}{2}V_o$. Thus:

$$\begin{aligned}
\tfrac{1}{2}V_o &= V_o e^{-\frac{t_{1/2}}{\tau}} \\
\tfrac{1}{2} &= e^{-\frac{t_{1/2}}{\tau}} \\
\ln\tfrac{1}{2} &= -\frac{t_{1/2}}{\tau} \\
\ln 2 &= \frac{t_{1/2}}{\tau} \\
\tau \ln 2 &= t_{1/2} \\
t_{1/2} &= \tau \ln 2 \\
t_{1/2} &= RC \ln 2
\end{aligned}$$

From the development at left we see that the half-life, $t_{1/2}$ is proportional to the capacitance C. Now, capacitors in parallel add, so, when we hook two identical capacitors in parallel, the effective capacitance is twice the capacitance of either one alone. Essentially, by hooking an identical capacitor in parallel with one in a circuit, we are doubling the capacitance. Since, as we have shown, the half-life, $t_{1/2}$ is proportional to the capacitance C, when we double C we double the half-life. That is to say that the new half-life is twice the original half-life.

Question 4 **0 of 20 points**

Consider a capacitor which is charged to 12 volts and then connected across a resistor. Let $t_{1/2}$ be the time it takes for the voltage to drop down to 6 volts. Suppose the experiment is repeated, but with a pair of capacitors connected in series in place of the original capacitor, where each element of the pair has the same capacitance as the original capacitor. How does the new $t_{1/2}$ compare with the original $t_{1/2}$?

Selected Answer: The new $t_{1/2}$ is the same as the original $t_{1/2}$.

Correct Answer: The new $t_{1/2}$ is half the original $t_{1/2}$.

Feedback:

$$V = V_0 e^{-t/\tau}$$

At $t = t_{1/2}$ $V = \frac{1}{2}V_0$

so:

$$\frac{1}{2}V_0 = V_0 e^{-t_{1/2}/\tau}$$

$$\frac{1}{2} = e^{-t_{1/2}/\tau}$$

$$\ln\frac{1}{2} = -\frac{t_{1/2}}{\tau}$$

$$\frac{t_{1/2}}{\tau} = -\ln\frac{1}{2}$$

$$\frac{t_{1/2}}{\tau} = \ln 2$$

$$t_{\frac{1}{2}} = (\ln 2)\tau$$

but $\tau = RC$

$$t_{1/2} = (\ln 2)\, RC$$

Replacing C with 2 identical capacitors C in series is the same as replacing C with $C_s = \dfrac{1}{\frac{1}{C}+\frac{1}{C}} = \frac{1}{2}C$.

$$t'_{1/2} = (\ln 2)\, RC_s$$

$$= (\ln 2) R \left(\tfrac{1}{2}C\right)$$

$$= \tfrac{1}{2}(\ln 2) RC$$

$$\boxed{t'_{1/2} = \tfrac{1}{2} t_{1/2}}$$

Question 5 **0 of 20 points**

Consider a capacitor which is charged to 12 volts and then connected across a resistor. Let $t_{1/2}$ be the time it takes for the voltage to drop down to 6 volts. Suppose the experiment is repeated, but with a resistor whose resistance is twice that of the original resistor. How does the new $t_{1/2}$ compare with the original $t_{1/2}$?

Selected Answer: ✗ The new $t_{1/2}$ is the same as the original $t_{1/2}$.

Correct Answer: ✓ The new $t_{1/2}$ is twice the original $t_{1/2}$.

Feedback:

$$V = V_0 e^{-t/\tau}$$

At $t = t_{1/2}$ $V = \frac{1}{2} V_0$

so:

$$\frac{1}{2} V_0 = V_0 e^{-t_{1/2}/\tau}$$

$$\frac{1}{2} = e^{-t_{1/2}/\tau}$$

$$\ln \frac{1}{2} = -\frac{t_{1/2}}{\tau}$$

$$\frac{t_{1/2}}{\tau} = -\ln \frac{1}{2}$$

$$\frac{t_{1/2}}{\tau} = \ln 2$$

$$t_{1/2} = (\ln 2)\tau$$

but $\tau = RC$

$$t_{1/2} = (\ln 2) RC$$

Doubling R in this expression results in a doubling of $t_{1/2}$.

OK

Review Assessment: q14

Name: q14

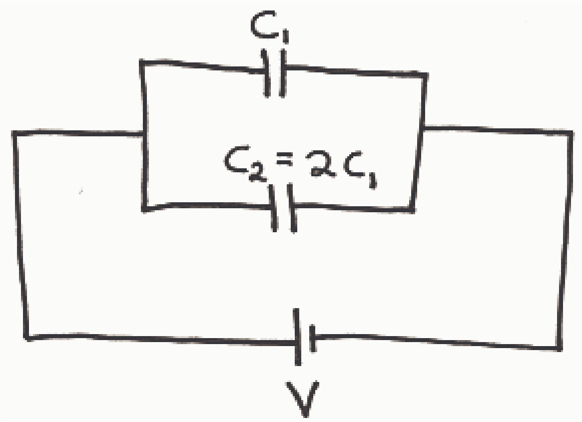
Status : Completed

Score: 15 out of 100 points

Instructions:

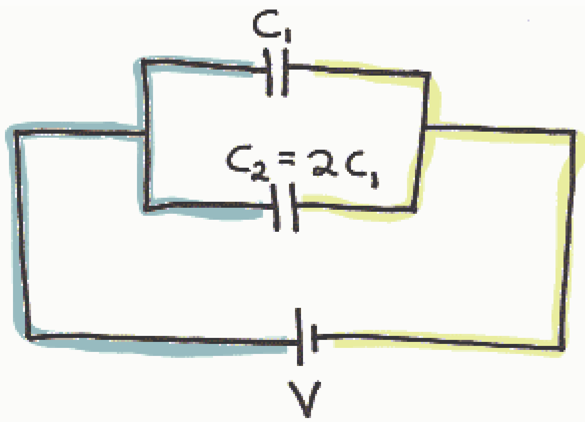
Question 1 **0 of 20 points**

A 12 Volt battery is connected across a parallel combination of two capacitors, C_1 and C_2. The capacitance of C_2 is twice that of C_2.



Question	Correct Match	Selected Match
Which capacitor has the greater charge?	✓ B. C_2	✗ A. C_1
Across which capacitor is the voltage greater?	✓ C. Neither. It is the same for both capacitors.	✗ A. C_1

Feedback: Here we indicate the two unique conductors in the circuit by coloring one blue, and one yellow:

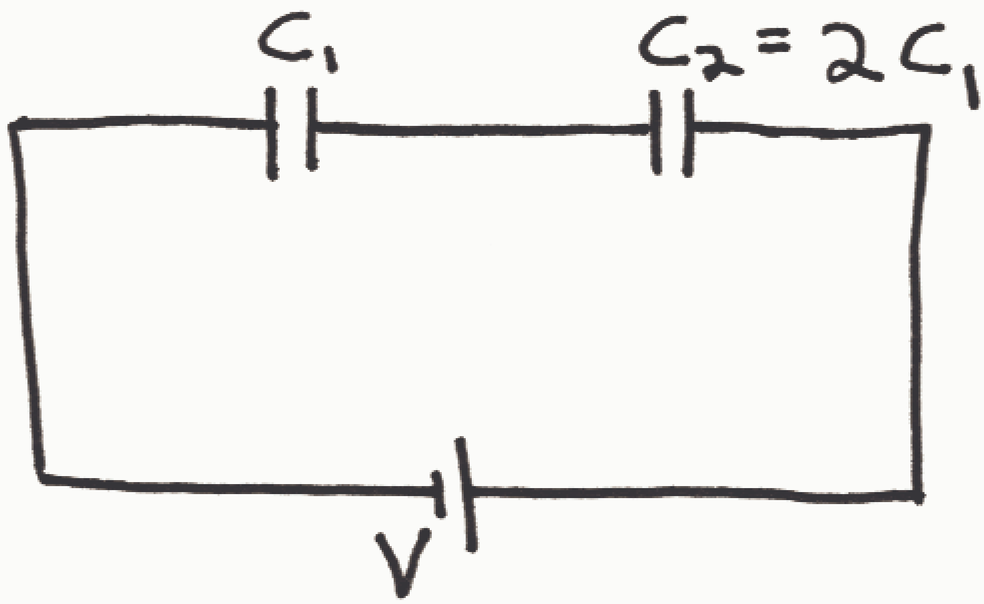


The voltage across C_1 is the potential difference between the terminals of C_1. One terminal of capacitor C_1 is on the blue conductor and the other is on the yellow conductor. Hence the potential difference between the terminals of C_1 is the potential difference between the blue conductor and the yellow conductor. Thus the voltage across C_1 is the potential difference between the blue conductor and the yellow conductor. But the same can be said of capacitor C_2. The voltage across C_2 is also the potential difference between the blue conductor and the yellow conductor. Hence, the voltage across C_2 is the same as the voltage across C_1.

Now the charge on a capacitor is given by Q=CV. So, for two capacitors having one and the same voltage, the capacitor with the larger capacitance is going to have the greater charge.

Question 2 **10 of 20 points**

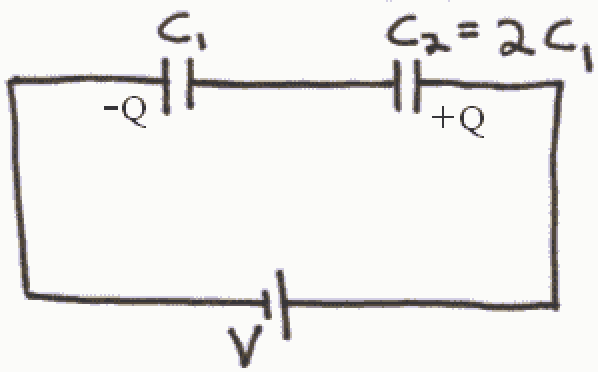
A 12 volt battery is connected across a series combination of two capacitors, C_1 and C_2. The capacitance of C_2 is twice that of C_1.



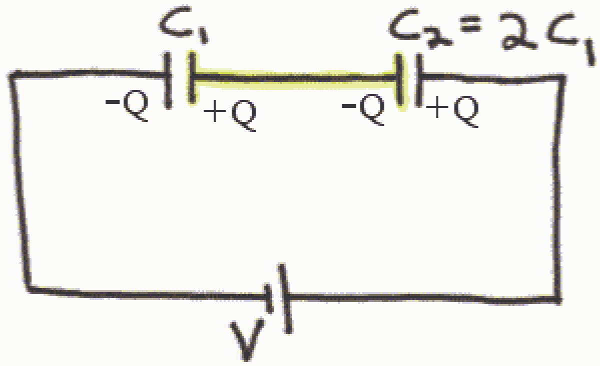
Question	**Correct Match**	**Selected Match**

Which capacitor has the greater charge?	✓ C. Neither. They both have the same amount.	✗ A. C_1
Which capacitor has the greater voltage?	✓ A. C_1	✓ A. C_1

Feedback:



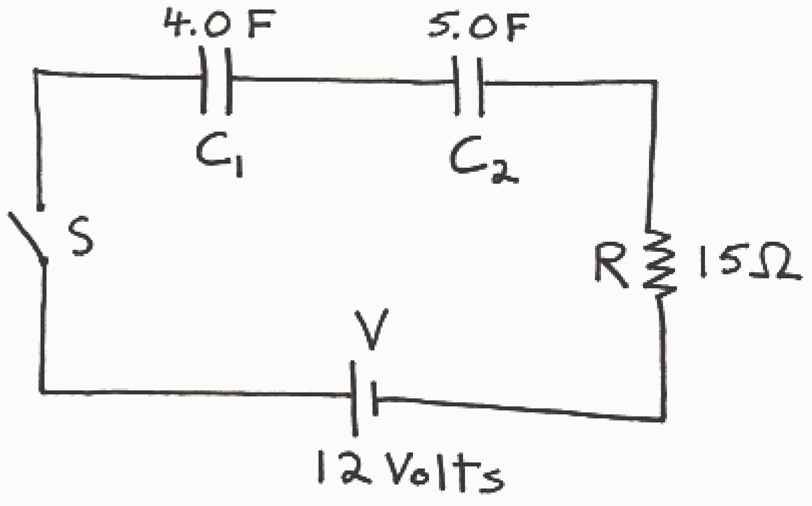
Suppose the seat of EMF moves an amount of charge Q from the left side of C_1 to the right side of C_2. This leaves −Q on the left plate of C_1 and puts +Q on the right plate of C_2. Now check out the conductor in the middle, highlighted in yellow here:



That conductor is isolated from the surroundings. It starts out neutral and because it is isolated from the surroundings it remains neutral, but, charge can move around within it. Positive charge on the right side of this conductor (the left plate of C_2) is repelled by the positive charge on the right plate of C_2. It is also attracted by the negative charge on the left plate of C_1. So, positive charge moves from the left plate of C_2 to the right plate of C_1. This causes a buildup of positive charge on the right plate of C_1 and leaves negative charge on the left plate of C_2. The charge keeps moving until there is no more negative charge on the left plate of C_1 then there is positive charge on the right plate. That is, a total amount of charge Q moves from the left plate of C_2 to the right plate of C_1. Thus, each capacitor has charge Q on one of its plates and -Q on the other. So each capacitor has one and the same value of charge, Q. (Recall that when a capacitor is said to have charge Q, it really has −Q on one plate and +Q on the other.) Admittedly, one can simply memorize the fact that for capacitors in series, every capacitor in the series combination has one and the same value of charge, but, one will be better able to solve problems if one can picture the redistribution of charge that results in the fact that every capacitor in a series combination of capacitors must have one and the same value of charge. Once the charge issue is settled, the voltage question is easy. Solving the defining equation for capacitance, Q=CV, for V we get V=Q/C. Since both capacitors have the same charge, and, because the "C" in this equation is in the denominator, the capacitor with the greater capacitance will have the smaller voltage.

Question 3 **5 of 35 points**

C_1 and C_2 are initially uncharged.



Question	Correct Match	Selected Match
At the instant the switch is closed, what is the voltage across resistor R?	✓ D. 12 Volts	✗ A. 0 Volts
At the instant the switch is closed, what is the current through resistor R?	✓ F. 0.80 Amperes	✗ A. 0 Volts
After the switch has been closed a very long time, so long that neither of the capacitors is still charging, what is the current through the resistor R?	✓ E. 0 Amperes	✗ A. 0 Volts
At the instant the switch is closed, what is the voltage across C_1?	✓ A. 0 Volts	✓ A. 0 Volts
At the instant the switch is closed, what is the charge on C_1?	✓ G. 0 Coulombs	✗ A. 0 Volts
After the switch has been closed a very long time, so long that neither of the capacitors is still charging, what is voltage across C_1?	✓ C. 6.7 Volts	✗ A. 0 Volts
After the switch has been closed a very long time, so long that neither of the capacitors is still charging, what is charge on C_1?	✓ H. 27 Coulombs	✗ A. 0 Volts

Feedback: Just for an infinitesimal time interval, starting at the first instant after the switch is closed, because the capacitors are uncharged, it is **so** easy to pull charge from one side of the capacitor and put it on the other that the capacitors act like pieces of wire--like perfect conductors. Replacing the capacitors, conceptually, with pieces of wire makes it so that the seat of EMF is connected directly across the resistor. So the voltage across the resistor, at the first instant in time after the switch is closed, is 12 Volts. It decreases steadily from there.

Question 4 **0 of 25 points**

Consider a pair of two identical capacitors. In which case is the capacitance of the pair greater?

Selected Answer: ✗ When they are connected in series with each other.

Correct Answer: ✓ When they are connected in parallel with each other.

Feedback: The effective capacitance of a pair of capacitors in series, C_s, is given by

$C_s = 1/(\ 1/C_1 + 1/\ 1/C_2\ )$

For the case of two capacitors with one and the same capacitance C:

$C_1 = C$

and

$C_2 = C$
so
$C_s = 1/(1/C + 1/C)$
$C_s = 1/(2/C)$
$C_s = C/2$.

The effective capacitance of a pair of capacitors in parallel, C_p, is given by
$C_p = C_1 + C_2$
For the case of two capacitors with one and the same capacitance C:
$C_1 = C$
and
$C_2 = C$
so
$C_p = C + C$
$C_p = 2C$.

Since $C_s = C/2$ and $C_p = 2C$ we have $C_p > C_s$. That is to say that the capacitance of the pair of identical capacitors is greater when the capacitors are connected in parallel.

OK

Review Assessment: q15

Name:	q15
Status :	Completed
Score:	0 out of 100 points
Instructions:	

Question 1 **0 of 15 points**

Which of the following conditions must be met in order for a uniform magnetic field to exert a force on a particle?

Selected Answers: ✓ The particle must be charged.

Correct Answers:
✓ The particle must be charged.
✓ The particle must be moving in a direction that is neither parallel to nor anti-parallel to the magnetic field.
✓ The particle must be in the magnetic field.

Feedback: A charged particle has to be in a magnetic field in order for that magnetic field to exert a force on the charged particle. That is why it makes no sense to say that a magnetic field attracts or repels a charged particle.

A uniform magnetic field exerts no force on an uncharged particle in that magnetic field.

Given a charged particle in a magnetic field, the charged particle has to be crossing some magnetic field lines in order for the magnetic field to exert a force on it. The charged particle is not crossing magnetic field lines if it is at rest, or if it is moving along a magnetic field line or in the exact opposite direction to that of the magnetic field line it is on.

The mathematical expression for the force exerted on a charged particle by a magnetic field must, of course, be consistent with the conceptual statements above. Indeed, the expression

$$\vec{F} = q\vec{v} \times \vec{B}$$

for the force exerted by a charged particle by a magnetic field, yields a force whose magnitude is given by

$$F = qvB\sin\theta$$

This is a product of four multiplicands. If any one of the multiplicands is zero, the force *F* exerted by the magnetic field on the particle in question, is also zero. That is, if the charge *q* is zero, the speed of the particle *v* is zero, the magnetic field *B* is zero (as it is outside the region where the magnetic field exists), or, the sine of the angle in between the velocity of the particle and the direction of the magnetic field is zero (as it is when θ is 0° or 180° corresponding to the velocity being parall el or anti-parallel to the magnetic field respectively), then the force exerted by the magnetic field, on the particle, is zero.

Question 2 **0 of 20 points**

Which of the following is true of magnetic fields?

Selected Answers: ✓ Magnetic fields are invisible.

Correct Answers:	✓ Magnetic fields are invisible. ✓ A magnetic field can be caused to exist by a permanent magnet or by electric current. ✓ The effect of a magnetic field is to exert a torque on a bar magnet that is in the magnetic field (but not aligned with the magnetic field) and to exert a force on a charged particle that is moving in the magnetic field (as long as the velocity of the particle is neither parallel to nor anti-parallel to the magnetic field). ✓ A magnetic field is the association of a vector with each point in the region of space where the magnetic field exists.

Question 3 **0 of 20 points**

A positively-charged particle is moving southward in a downward-directed uniform magnetic field. The magnetic force is the only force, if any, acting on the particle. During the next few centimeters of its travel,

Selected Answer: ✗ the particle speeds up.

Correct Answer: ✓ the particle keeps on going at the same speed.

Feedback: When a magnetic field does exert a force on a charged particle (and that only happens when the charged particle is moving in the magnetic field in some direction other than along, or in the exact opposite direction to, the magnetic field) the force is in a direction which is perpendicular to the magnetic field. The resulting acceleration, being perpendicular to the velocity, and continually changing its direction to always be perpendicular to the velocity, can never change the magnitude of the velocity.

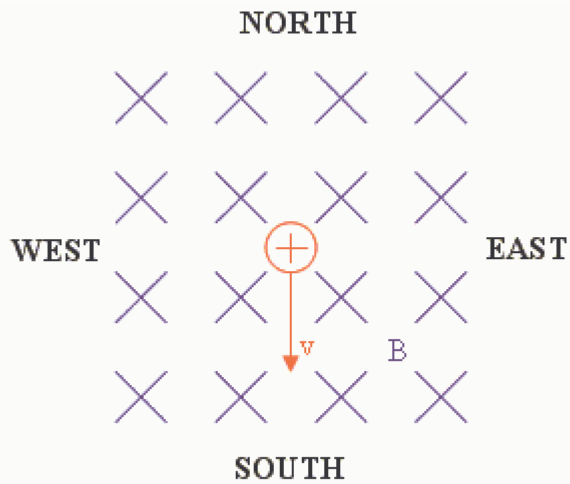
Question 4 **0 of 25 points**

A positively-charged particle is moving southward in a downward-directed uniform magnetic field. The magnetic force is the only force, if any, acting on the particle. What is the direction of the force exerted on the particle by the magnetic field?

Selected Answer: ✗ Northward.

Correct Answer: ✓ Eastward.

Feedback:



In the diagram just above we depict the downward-directed magnetic field by means of x's which are supposed to resemble the tail feathers of arrows that point into the screen which we define to be downward in the diagram.

The force on a charged particle that is moving in a magnetic field is given by

$$\vec{F} = q\vec{v} \times \vec{B}$$

We use the right-hand rule for the cross product of two vectors to determine the direction of

$$\vec{v} \times \vec{B}$$

To apply the right hand rule, we point the fingers of the right hand in the direction of the first vector (the velocity vector) and then orient the hand so that if we briefly close the fingers, they point in the direction of the second vector (the magnetic field vector). I find that if I arrange my right hand with the fingers pointed toward the bottom of the screen (the direction of the first vector, the velocity vector) and the palm facing toward the screen, then when I briefly close the fingers they do indeed point into the screen, in the direction of the second vector, the magnetic field vector. With the hand so oriented the thumb points toward the right side of the screen, which means the cross product of

$$\vec{v} \times \vec{B}$$

is eastward. But, in the expression for the force, there is a charge q multiplying

$$\vec{v} \times \vec{B}$$

In the case at hand, the charge is positive, so the direction of the force

$$\vec{F} = q\vec{v} \times \vec{B}$$

is the same as the direction of

$$\vec{v} \times \vec{B}$$

Question 5 **0 of 20 points**

What is the defining effect of a magnetic field?

Selected Answer:	✗ It exerts a force on a charged particle at rest in the magnetic field.
Correct Answer:	✓ It exerts a torque on a magnetic dipole (bar magnet) that is in the magnetic field as long as the magnetic dipole is not aligned with the magnetic field.
Feedback:	A magnetic field is an invisible entity that exists in a region of space that may be void of all matter, in the vicinity of a permanent magnet or an electric current. The magnetic field is a vector field, an infinite set of vectors, one at each point in the region of space where the magnetic field exists. The cause of a magnetic field is either a permanent magnet or an electric current. The defining effect of a magnetic field is to exert a torque on a magnetic dipole that is in the magnetic field, as long as the magnetic dipole is not parallel or anti-parallel to the magnetic field.

OK

Review Assessment: q16

Name: q16

Status : Completed

Score: 10 out of 100 points

Instructions:

Question 1 — **10 of 20 points**

In depicting vectors in a diagram on a piece of paper,

Question	Correct Match	Selected Match
What is the symbol for a vector directed into the page?	✓ A. An "x" with or without a circle around it.	✓ A. An "x" with or without a circle around it.
What is the symbol for a vector directed out of the page?	✓ B. A dot with a circle around it.	✗ A. An "x" with or without a circle around it.

Feedback: The "x" is supposed to represent your view of the tail feathers of an arrow that is going away from you. The dot with the circle around is supposed to represent your view of an arrow coming at you.

Question 2 — **0 of 20 points**

On a map, with northward being toward the top of the page on which the map is printed,

Question	Correct Match	Selected Match
Which way is eastward?	✓ C. Toward the right edge of the page.	✗ A. Toward the top of the page.
Which way is southward?	✓ B. Toward the bottom of the page.	✗ A. Toward the top of the page.
Which way is downward?	✓ E. Into the page.	✗ A. Toward the top of the page.
Which way is upward?	✓ F. Out of the page.	✗ A. Toward the top of the page.

Feedback: Please be careful not to mix up northward with upward, or, southward with downward.

Question 3 — **0 of 20 points**

A positively-charged particle is moving southward in a downward-directed uniform magnetic field. The magnetic force is the only force, if any, acting on the particle. Describe the trajectory of the particle assuming that it remains in the uniform magnetic field, and, that it's elevation does not change.

Selected Answer: ✗ The particle will keep on going straight for awhile and then begin to curve rightward.

Correct Answer: ✓ The particle will travel counterclockwise, as viewed from above, around a horizontal circle.

Feedback: Calling the direction in which the particle is traveling, at any instant in time, the forward direction, the force will, by the right-hand rule for the cross product of two vectors, always be leftward. Thus the particle will continually be in the process of making a left turn. Because the force is and always will be perpendicular to the velocity, the force will never change the velocity. A particle that is moving at a constant speed and is continually in the process of making a left turn, and indeed, always has the same value of acceleration which is always directed leftward, is moving in a circle. In the case in question, the particle is moving counterclockwise, as viewed from above, in a circle.

Question 4 — **0 of 20 points**

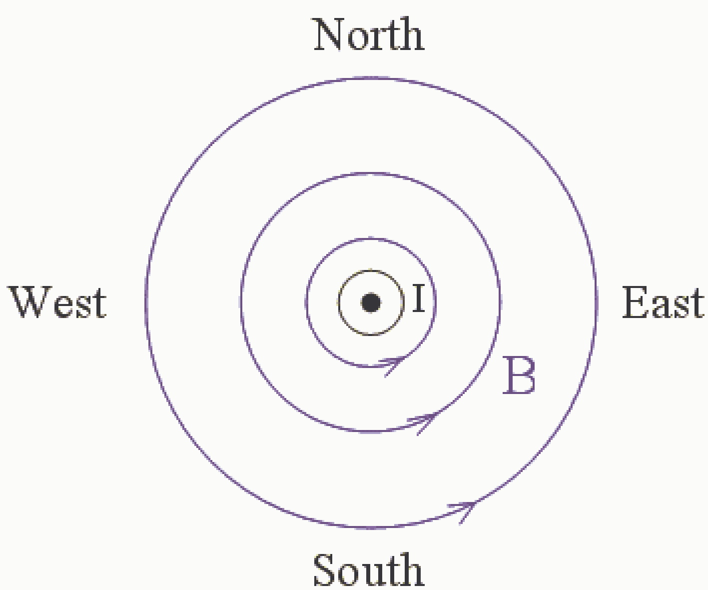
A straight vertical wire passes through a wooden table top. The wire carries an upward directed current. The direction of the magnetic field of the wire at a point, on the table top, due south of the wire is:

Selected Answer: Counterclockwise as viewed from above.

Correct Answer: Eastward.

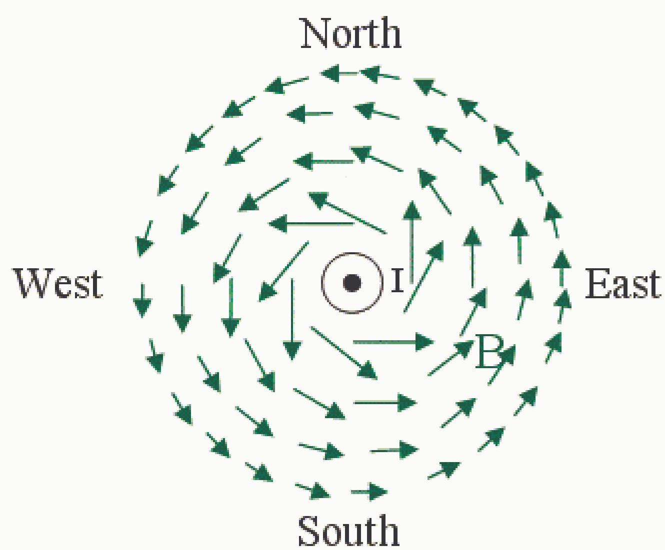
Feedback:

VIEW FROM ABOVE



Check out the diagram above. We have already put the magnetic field lines, established by means of the right hand rule for something curly something straight*, on the diagram.

It is important to realize that a magnetic field diagram is a graphical representation of a magnetic field and a magnetic field is an infinite set of vectors, one at each point in the region of space where the magnetic field exists. Consider the unconventional graphical representation of the same magnetic field in the diagram below.



In this diagram we represent the magnetic field by means of an arrow for each of many of the infinite set of points in the region of space where the magnetic field exists. Each arrow characterizes the magnetic field at the point at the tip of the tail of the arrow itself. The direction of the magnetic field, at the point at the tip of the tail of an arrow, is represented by the direction in which the arrow is pointing, and, the magnitude of the magnetic field is represented by the length of the arrow. This diagram illustrates what we are saying about the magnetic field vectors themselves when we say that the magnetic field lines form loops around the current.

Question 5 **0 of 20 points**

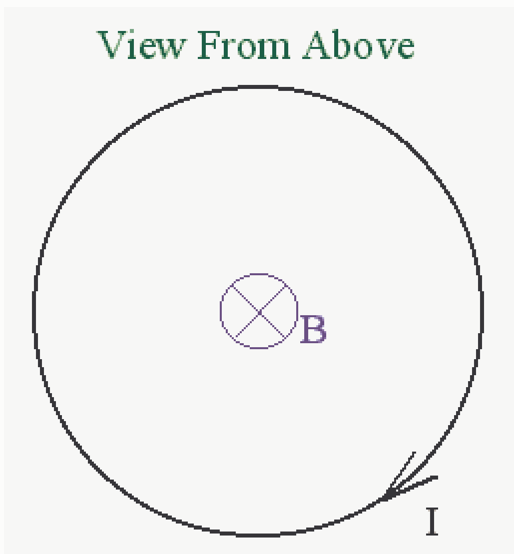
The direction of the magnetic field at the center of a horizontal current-carrying loop of wire is straight downward. The magnetic field is caused by the current in the loop. What is the direction of the current?

Selected Answer: ✗ Counterclockwise as viewed from above.

Correct Answer: ✓ Clockwise as viewed from above.

Feedback: Given a conducting wire in the form of a loop, and given the current in that loop, we can apply the right hand rule to determine the direction of the magnetic field at the center of that loop. All we have to do is to curl the fingers of the right hand around in the direction of the current and the extended thumb of the cupped right hand will point in the direction of the magnetic field inside at the center of the loop. Interestingly enough, this procedure is reversible. That is, if we are not told the direction of the current , but we know the direction of the magnetic field at the center of the loop, all we have to do is point the extended thumb of the cupped right hand in the direction of the magnetic field at the center of the loop and the fingers will indicate the direction in which the current must be flowing around the loop to produce such a magnetic field. In the case at hand, pointing the thumb downward (toward the center of the earth) we find that the fingers curl in the clockwise direction, as viewed from above. Thus the current is clockwise, in the loop, as viewed from above.

This is one of those problems in which we are given some information about the effect of something (the effect of the current in this case) and asked to find something about the cause (the current itself in this case). The right hand rule comes in "handy" for this one (pun intended).



OK

Review Assessment: q17

Name: q17

Status : Completed

Score: 0 out of 100 points

Instructions:

Question 1 **0 of 20 points**

Indicate all that is wrong about the statement, "The magnetic field lines of a stationary bar magnet move from the north pole of the bar magnet to the south pole of the bar magnet."

Selected Answers: ✗ There is no such thing as a bar magnet.

Correct Answers: ✓ The magnetic field lines do not "move" anywhere. They exist. They do have some extent in space so we do say that they extend from here to there but it is incorrect to say that they move from here to there. One should not say that they "go" from here to there either.
✓ Outside the bar magnet the magnetic field lines do extend from north pole to south pole, but, inside the bar magnet, the magnetic field lines extend from south pole to north pole. Without stating the location of the magnetic field lines being characterized, the given statement is ambiguous.

Feedback: Magnetic field lines exist in the vicinity of a magnet. They do have direction. Every magnetic field line is a closed loop. Starting at the south pole of a bar magnet, a magnetic field line is directed from the south pole to the north pole inside the magnet, and out through the north end of the magnet. From there is directed along a curved path which takes it back into the magnet via the south pole of the magnet, thus completing the loop.

If one states that the magnetic field extends from the south pole of the magnet to the north pole of the magnet, it important to say that this is the case **inside** the magnet.

If one states that the magnetic field extends from the north pole of the magnet to the south pole of the magnet, it important to say that this is the case **outside** the magnet.

Question 2 **0 of 15 points**

Match the name of the phenomenon with the description of the phenomenon.

Question	Correct Match	Selected Match
The presence of a substance in a region of space makes it so that the magnetic field in that region of space is slightly stronger than it would be if the region of space was empty.	✓ B. paramagnetism	✗ A. orthomagnetism
The presence of a substance in a region of space makes it so that the magnetic field in that region of space is much stronger than it would be if the region of space was empty.	✓ C. ferromagnetism	✗ A. orthomagnetism
The presence of a substance in a region of space makes it so that the magnetic field in that region of space is slightly weaker than it would be if the region of space was empty.	✓ D. diamagnetism	✗ A. orthomagnetism

Feedback: There is no such thing as orthomagnetism.

The prefixes can help you out with the answers to this matching exercise:
para- means along, as in "parallel".
ferro- means containing-iron and iron is indeed a metal that exhibits ferromagnetism. Note, however, that there are materials that contain no iron that have the magnetic property we refer to as ferromagnetism. Cobalt is an example.

dia- means against or in direct opposition to as in "diametrically opposed".

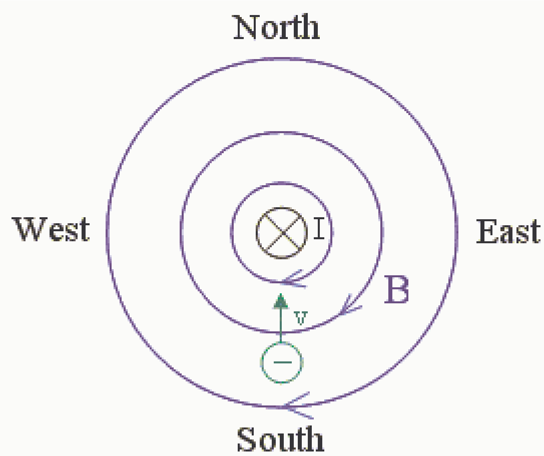
Question 3 **0 of 20 points**

A negatively charged particle is headed due north, straight toward a straight vertical wire which carries a downward current. What is the direction of the force, if any, exerted on the charged particle by the magnetic field of the current-carrying conductor?

Selected Answer: ✗ There is no force exerted on the charged particle.

Correct Answer: ✓ Downward.

Feedback:



The situation is depicted in the figure above. As viewed from above, the downward-directed current I is depicted as an x with a circle around it.

Using the right-hand rule for something curly something straight we realize that the magnetic field extends in circles, clockwise, as viewed from above, about the current-carrying conductor. At a specific point in space the magnetic field always has a straight-line direction. (It is nonsense to say that, at the location of the charged particle, the magnetic field is clockwise.) At the location of the negatively-charged particle we note that the magnetic field is westward.

The force on the charged particle is given by

$$\vec{F} = q\vec{v} \times \vec{B}$$

By the right-hand rule for the cross product of two vectors, the direction of $\vec{v} \times \vec{B}$ is upward (out of the screen in the diagram). Multiplying this by the negative charge of the particle flips the direction yielding downward for the direction of the force.

Question 4 **0 of 15 points**

The outer surface of a short, vertical segment of plastic pipe is hidden from view by wire wrapped around the pipe. Current flows clockwise, as viewed from above, in the wire. What is the direction of the magnetic field produced by the wire at a point inside the pipe?

Selected Answer: ✗ Radially outward from the axis of symmetry.

Correct Answer: ✓ None of the other answers are correct.

Feedback: We determine the direction of the magnetic field by means of the right hand rule for something curly something straight. We curl the fingers of our right hand around in the direction of the current. The thumb then points downward so the direction of the magnetic field is downward.

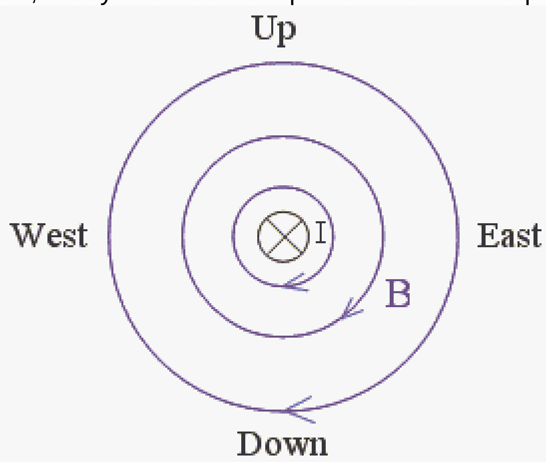
Question 5 **0 of 15 points**

What is the direction of the magnetic field at a point due east of a straight wire carrying a current due north?

Selected Answer: ✗ Northward.

Correct Answer: ✓ Downward.

Feedback: Check out the following view (looking northward) from the south. Note that "toward the top of the page" is upward and "into the page" is northward. The current is northward as depicted by the x with the circle around it, the symbol used to represent the "into the page" direction.



Using the right-hand rule for something curly something straight we realize that the magnetic field extends in circles, clockwise, as viewed from the south, about the current-carrying conductor. Thus, looking at the diagram, we see that, at a point due east of the wire, the magnetic field is downward.

Question 6 **0 of 15 points**

Where is the magnetic field due to a bar magnet strongest?

Selected Answer: ✗ At those points on that cyliner whose radius is equal to half the length of the magnet, which is centered on the center of the magnet, and, for which the magnet lies on the axis of symmetry of the cylinder.

Correct Answer: ✓ Inside the magnet.

Feedback: This is just an experimental fact.

OK

Review Assessment: q18

Name: q18

Status : Completed

Score: 45 out of 100 points

Instructions:

Question 1 **10 of 30 points**

Match the Name of the Law to the Law.

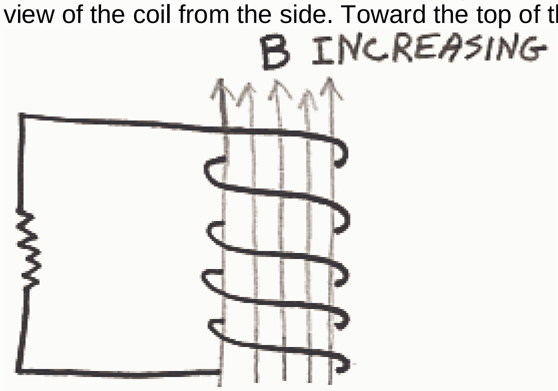
Question	Correct Match	Selected Match
Lenz's Law	✓ F. The magnetic field produced by the current that is induced to flow in a loop or coil by a change in the number of magnetic field lines through that loop or coil is in that direction which tends to keep the number of magnetic field lines through the loop or coil at its original value in the original direction.	✗ A. An electric current causes a magnetic field.
Ampere's Law	✓ A. An electric current causes a magnetic field.	✓ A. An electric current causes a magnetic field.
Faraday's Law of Induction	✓ D. A changing magnetic field causes an electric current.	✗ A. An electric current causes a magnetic field.

Feedback: Faraday's Law of Induction states that if the number of magnetic field lines through a loop or coil is changing, then a current will be induced in that loop or coil. Lenz's Law is the one that allows us to determine the direction of that current.

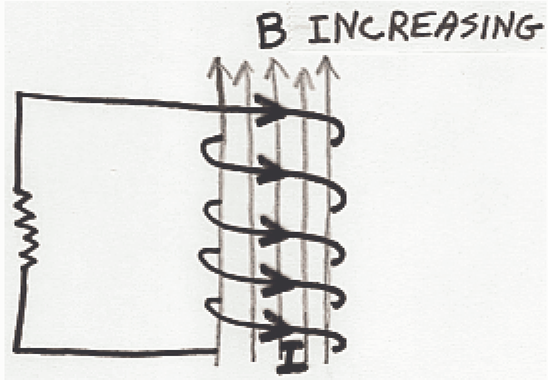
Ampere's law is simpler. It just states that electric current causes a magnetic field.

Question 2 **0 of 15 points**

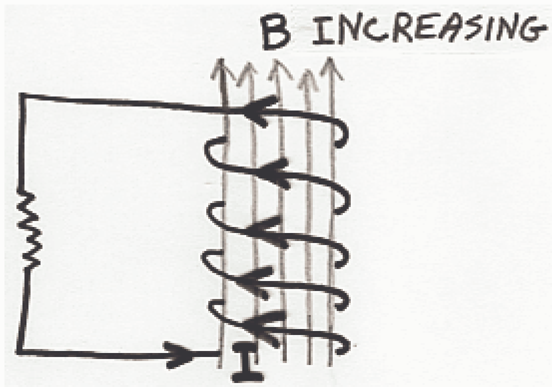
Indicate the direction of the current, if any, induced to flow in the coil by the changing magnetic field. (Depicted is a view of the coil from the side. Toward the top of the screen in the diagram, is upward.)



Selected Answer: ✗



Correct Answer: ✓

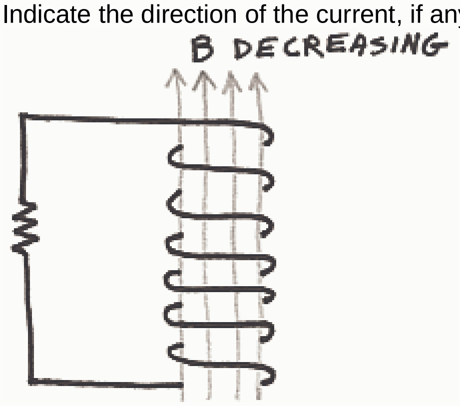


Feedback: The key to applying Lenz's Law is figuring out what change in the magnetic field through the coil is occurring and establishing what direction a new magnetic field would have to be in to fight that change. Here we have an **up-through-the-coil** magnetic field which is **increasing**. To fight that increase we need a down-through-the-coil magnetic field. Thus, $\mathbf{B}_{pin}$, the magnetic field produced by the induced current, must be down-through-the-coil.

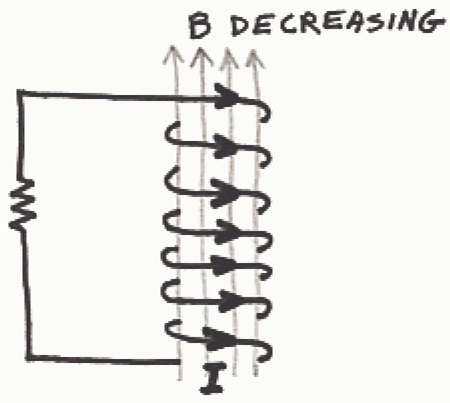
Now we have to ask our self, "In what direction must the current flow around in the coil in order to produce a downward-through-the-coil directed magnetic field. The magnetic field is the straight thing in this problem so we point our right thumb in the down-through-the-coil direction and note that our fingers then curl around in the clockwise, as viewed from above, direction.

Question 3 **15 of 15 points**

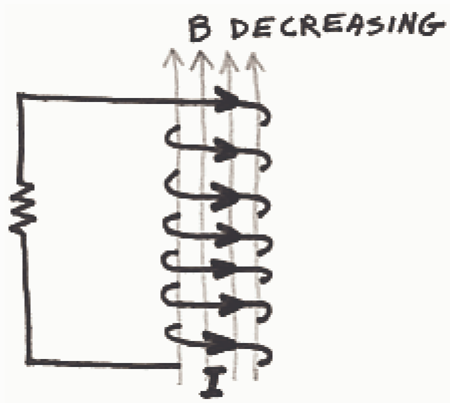
Indicate the direction of the current, if any, induced to flow in the coil by the changing magnetic field.



Selected Answer: ✓



Correct Answer: ✓

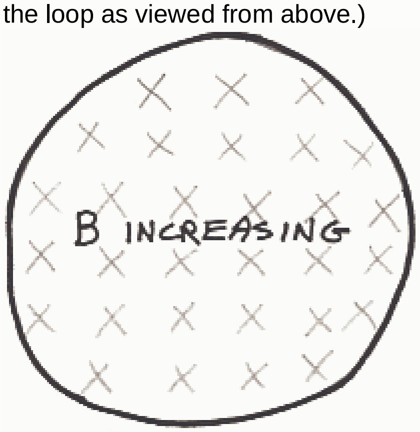


Feedback: Perfect!

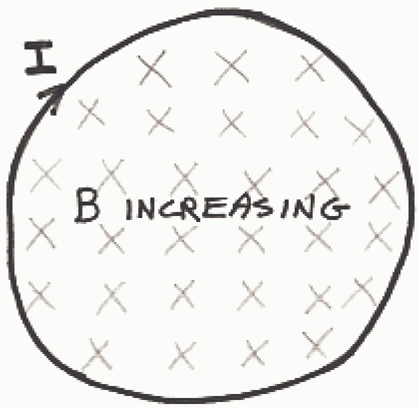
1. Given: Decreasing number of magnetic field lines upward through coil.
2. By Faraday's Law of Induction, 1 above induces current in coil.
3. By Ampere's Law, induced current produces new magnetic field B_{PIN} through coil.
4. By Lenz's Law, B_{PIN} is upward through the coil to make up for loss of upward magnetic field lines.
5. By right-hand rule for something curly something straight, induced current (referred to in step 2) must be counterclockwise, as viewed from above, to produce upward B_{PIN}.

Question 4 **0 of 20 points**

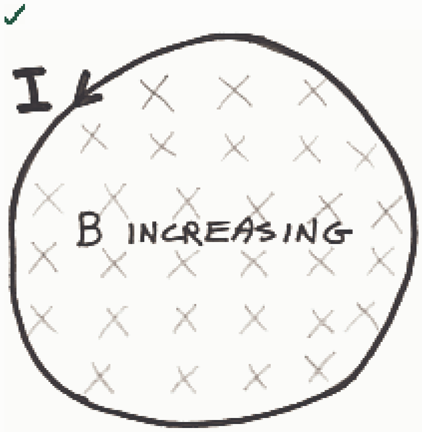
Indicate the direction of the current, if any, induced to flow in the loop by the changing magnetic field. (Depicted is the loop as viewed from above.)



Selected Answer: ✗



Correct Answer: ✓

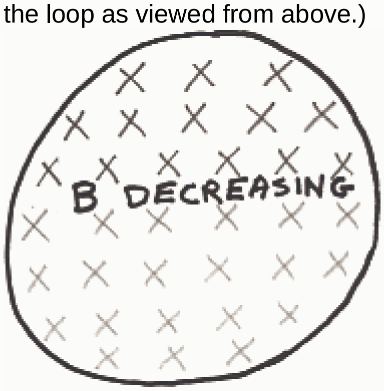


Feedback: Well done!

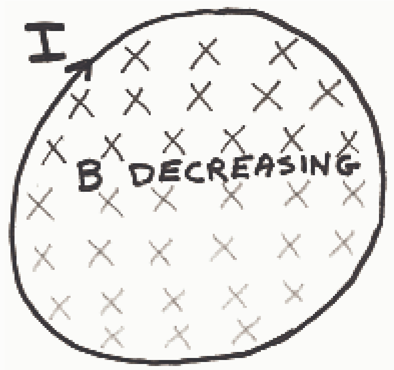
1. Given: Increasing number of magnetic field lines downward through loop.
2. By Faraday's Law of Induction, 1 above induces current in loop.
3. By Ampere's Law, induced current produces new magnetic field B_{PIN} through loop.
4. By Lenz's Law, B_{PIN} is upward (out of page) to cancel new downward magnetic field lines.
5. By right-hand rule for something curly something straight, induced current (referred to in step 2) must be counterclockwise, as viewed from above, to produce upward B_{PIN}.

Question 5 **20 of 20 points**

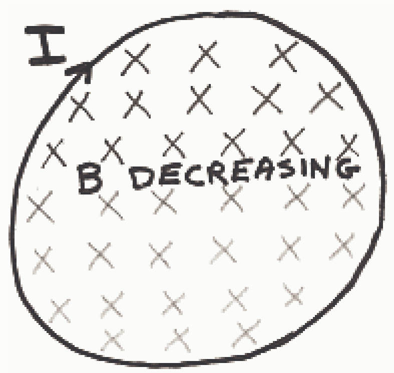
Indicate the direction of the current, if any, induced to flow in the loop by the changing magnetic field. (Depicted is the loop as viewed from above.)



Selected Answer: ✓



Correct Answer: ✓



Feedback: Nice work!

1. Given: Decreasing number of magnetic field lines downward through loop.
2. By Faraday's Law of Induction, 1 above induces current in loop.
3. By Ampere's Law, induced current produces new magnetic field B_{PIN} through loop.
4. By Lenz's Law, B_{PIN} is downward (into page) to make up for loss of downward magnetic field lines.
5. By right-hand rule for something curly something straight, induced current (referred to in step 2) must be clockwise, as viewed from above, to produce downward B_{PIN}.

OK

Review Assessment: q19

Name: q19

Status : Completed

Score: 40 out of 100 points

Instructions:

Question 1 **20 of 20 points**

A bar magnet is suspended vertically above a closed coil of wire. The bar magnet is released. It remains vertical as it approaches the coil, falls straight through the coil, and then continues to fall downward, away from the coil. Does the direction of the current induced to flow in the coil as a result of the motion of the magnet reverse itself as the magnet passes through the coil?

Selected Answer: ✓ Yes.

Correct Answer: ✓ Yes.

Feedback: Well done.

Suppose the bar magnet is initially suspended north end down. Then, the magnetic field is downward above, inside, and below the magnet. The magnetic field is strongest inside the magnet, weaker above and below the magnet, but everywhere downward. The number of downward-directed magnetic field lines through the loop thus increases as the magnet approaches the coil, is a maximum when the magnet is in the coil, and decreases as the magnet falls away from the coil. Because the magnetic field lines are always downward, but the change in the number of downward-directed field-lines-through-the-coil that is occurring, itself changes from increasing to decreasing, the current induced (in accordance with Faraday's Law) must reverse its direction in order for the magnetic field produced by the induced current to reverse, as, by Lenz's Law it must, to always be in that direction which tends to keep the number of magnetic field lines downward through the coil from changing.

Now suppose that the magnet is initially suspended north end up. Then the magnetic field is downward above, inside and below the magnet. The argument above still applies but with the word "downward" replaced by the word "upward" everywhere that it occurs.

Note that in either case, the direction of the current does indeed reverse itself.

Question 2 **20 of 20 points**

A bar magnet is suspended, north end up, well above a vertical coil of wire. The bar magnet is released. As it falls down toward the coil, it falls along a path that will take it straight through the coil. While it is falling downward toward the coil, is a current induced to flow in the coil as a result of the motion of the magnet?

Selected Answer: ✓ Yes.

Correct Answer: ✓ Yes.

Feedback: Nice work!

As time goes by, while the magnet is falling toward the coil, the coil becomes closer and closer to the magnet; not because of the motion of the coil, but rather, in this case, because of the motion of the magnet.

The closer the coil is to the magnet, the stronger the magnetic field, at the location of the coil, due to the magnet; and; with the given orientations and relative position of magnet and coil, that means, in this case, the greater the number of magnetic field lines through the coil.

By Faraday's Law of induction, a changing number of field lines through a closed loop or coil induces a current to flow in that loop or coil.

Because the coil becomes closer and closer to the magnet, the number of magnetic field lines through the coil is increasing with time, and, as a result of this changing magnetic-field-through-the-coil, there is indeed a current induced to flow in the coil.

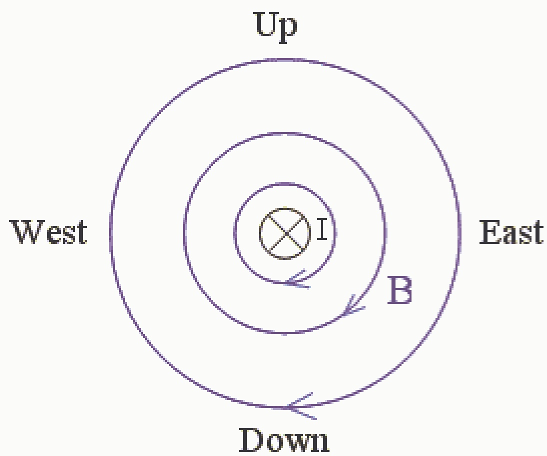
Question 3 **0 of 20 points**

A long straight piece of wire carries an increasing current due northward. Due east of, and very near the straight wire, at the same height as that of the straight wire, is a stationary horizontal loop of wire. What is the direction of the current, if any, induced to flow in the loop?

Selected Answer: Northward.

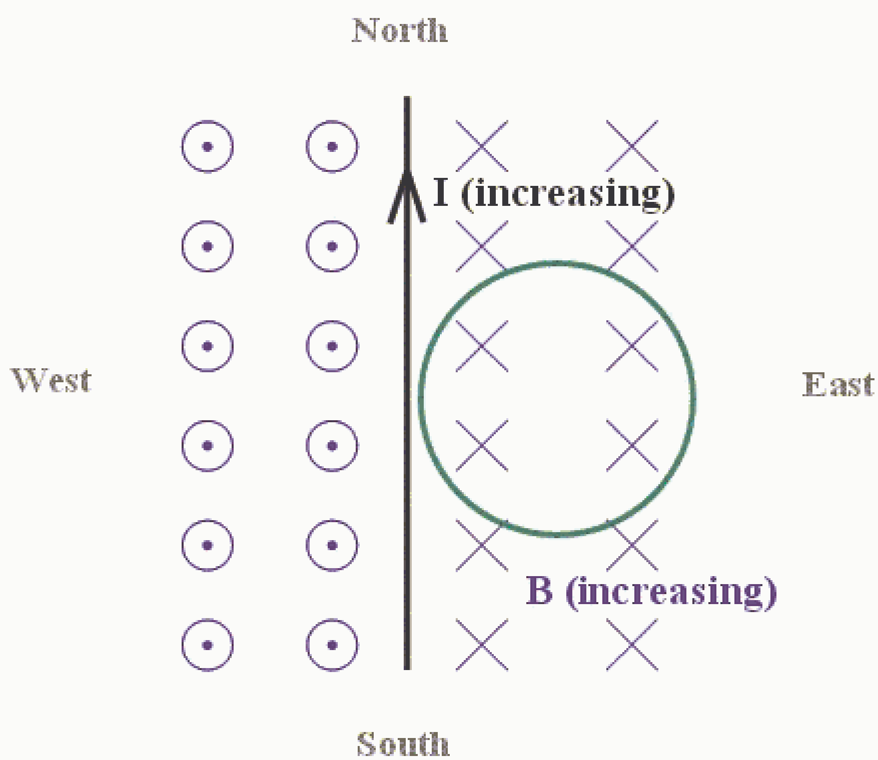
Correct Answer: Counterclockwise as viewed from above.

Feedback: Look at the straight wire by itself, from the south. In this view, toward the top of the page is up toward the sky, not northward.



By the right hand rule for something curly something straight, the magnetic field extends in clockwise, as viewed from the south, circles. Because the current is increasing the magnetic field is increasing. From this diagram, it is evident that at any position due east of the wire, the magnetic field due to the wire is downward (toward the center of the earth).

Now lets look at the same straight wire from above. This time we include the loop, mentioned in the question, in the picture.



In this picture, downward is into the page. We can see that the increasing current in the straight wire results in an increasing number of magnetic field lines downward through the loop.

1. Given: Increasing number of magnetic field lines downward through loop.
2. By Faraday's Law of Induction, 1 above induces current in loop.
3. By Ampere's Law, induced current produces new magnetic field B_{PIN} through loop.
4. By Lenz's Law, B_{PIN} is upward (out of page) through the loop to cancel new downward magnetic field lines.

Question 4 **0 of 20 points**

A wire loop and a bar magnet lie in one and the same horizontal plane. The bar magnet is outside of the loop. The bar magnet is spinning at a constant rate counterclockwise about a vertical axis through the center of the bar magnet. Consider an instant when the north pole of the bar magnet has just passed its closest point of approach to the loop and is distancing itself from the loop. At that instant, what is the direction of the current, if any, induced to flow in the loop?

Selected Answer: ✗ Upward.

Correct Answer: ✓ There is no current.

Feedback: Although the magnetic field at the location of the loop is indeed changing, none of the magnetic field lines pass through the loop at any time. The magnetic field lines meet the loop edge on. The number of magnetic field lines passing through the loop is zero and it never changes. Since it takes a changing number of magnetic field lines through the loop to induce a current to flow in the loop, there is no current in the loop.

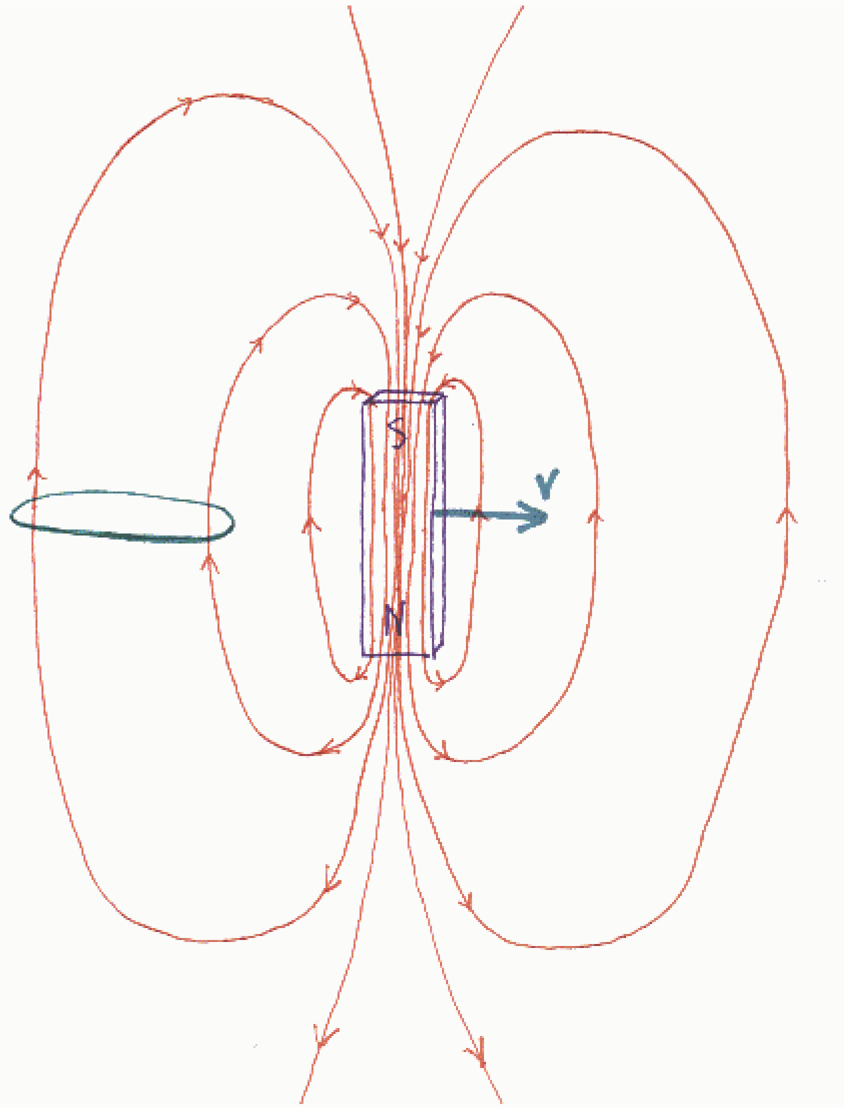
Question 5 **0 of 20 points**

A wire loop lies in a horizontal plane. Beside the loop is a vertical bar magnet, south end up. The bar magnet is bisected by the plane of the loop. A person is moving the bar magnet rapidly away from the loop. What is the direction of the current, if any, induced to flow in the loop?

Selected Answer: ✗ Upward.

Correct Answer: ✓ Counterclockwise as viewed from above.

Feedback: Refer to the diagram below:
1. The magnetic field lines extend out of the north end of a magnet and into the south end. (Nature of a bar magnet.)
2. With the north end of the magnet down, and the loop beside the magnet as shown, such magnetic field lines pass upward through the loop.
3. Magnetic field lines are more closely packed close to the magnet than they are far from the magnet.
4. The motion of the magnet causes the loop to be farther and farther from the magnet as time goes by.
5. Based on 2, 3, and 4 above, and the fact that a person is moving the bar magnet away from the loop (the person is moving the magnet to the right in the diagram above while the loop stays put), the number of upward magnetic field lines through the loop is decreasing with time.
6. By Faraday's Law, the changing number of magnetic field lines induces a current in the loop.
7. By Ampere's Law, the induced current produces a magnetic field.
8. By Lenz's Law, the magnetic field produced by the induced current is upward to make up for the diminishing number of upward directed magnetic field lines, from the magnet, through the loop.
9. By the right-hand rule for something curly, something straight, the induced current has to be counterclockwise in the loop, as viewed from above, in order to produce an upward-directed magnetic field.



OK

Review Assessment: q20

Name: q20

Status : Completed

Score: 36 out of 100 points

Instructions:

Question 1 **20 of 20 points**

Explain what light is.

Selected Answer: ✓ Electric and magnetic fields that vary sinusoidally both as a function of time and as a function of position.

Correct Answer: ✓ Electric and magnetic fields that vary sinusoidally both as a function of time and as a function of position.

Feedback: Well done.

Light is indeed electromagnetic radiation but the expression "electromagnetic radiation" is by no means an explanation of what light is. Light is a wave. That which is "waving" (varying in a repetitive fashion in both time and space) is an electric field and a magnetic field.

Light is not matter. An electric field is not matter. A magnetic field is not matter. Light consists of both electric and magnetic fields that vary in both time and space in a regular repetitive matter. Since electric and magnetic fields are not matter, light cannot be matter. Since light is not matter, it cannot consist of, and does not consist of, charged particles. Oscillating charged particles do cause light, but they themselves are not light.

Question 2 **0 of 20 points**

What causes electromagnetic radiation (a.k.a. light, a.k.a. electromagnetic waves)? Choose the one BEST answer.

Selected Answer: ✗ Electric and magnetic fields that vary in time and space.

Correct Answer: ✓ Oscillating charged particles.

Feedback: Note the important distinction between what light is, and what causes light. Oscillating charged particles cause light. But light itself is not oscillating charged particles.

Question 3 **0 of 20 points**

What is the fundamental difference between X-rays and visible light?

Selected Answer: ✗ X-rays pass through human tissue but visible light does not.

Correct Answer: ✓ The frequency of X-rays is greater than that of visible light. Equivalently, the wavelength of X-rays is shorter than that of visible light.

Feedback: X-rays and visible light are both electromagnetic radiation (a.k.a. light).

Question 4 **4 of 28 points**

Put the different kinds of light in order from lowest frequency to highest frequency.

Correct Answer	Selected Answer
✓ 1. radio waves	✗ 1. gamma rays

✓ 2. microwaves	✗ 1. X rays
✓ 3. infrared radiation	✗ 1. ultraviolet light
✓ 4. visible light	✗ 1. visible light
✓ 5. ultraviolet light	✗ 1. infrared radiation
✓ 6. X rays	✗ 1. microwaves
✓ 7. gamma rays	✓ 1. radio waves

Feedback: These are all examples of electromagnetic radiation. Electromagnetic radiation, a.k.a. light, consists of electric and magnetic fields that vary in a periodic fashion in both time and space.

Question 5 **12 of 12 points**

Light can travel through vacuum.

Selected Answer: ✓ True
Correct Answer: ✓ True

Feedback: Nice job.

In classical physics, light (electromagnetic radiation) is the only kind of wave that does not need a medium. For sound waves in air, the air is the medium. It is the "air" that is waving. In the case of light, it is the electric and magnetic fields that do the waving, and they are the light itself.

OK

Review Assessment: q21

Name: q21

Status : Completed

Score: 0 out of 100 points

Instructions:

Question 1 **0 of 20 points**

Electromagnetic radiation, a.k.a. light, consists of two kinds of fields each produced by the changing of the other. What are those two kinds of fields?

Selected Answers: ✗ Gravitational Fields

Correct Answers: ✓ Electric Fields
✓ Magnetic Fields

Feedback: A changing electric field causes a magnetic field. A changing magnetic field causes an electric field.

If the changing electric field is an oscillating electric field then it will create an oscillating magnetic field which will in turn create an oscillating electric field, which will in turn create an oscillating magnetic field, etc. ad infinitum. The electric and magnetic fields not only oscillate (a repetitive variation in time) but vary with position in a regular repetitive fashion as well.

Question 2 **0 of 20 points**

What are the angles between the direction of travel of light, the electric field, and the associated magnetic field?

Selected Answers: ✗ They are all in the same direction, hence the angles between them are all zero.

Correct Answers: ✓ They are each at an angle of 90 degrees with respect to each of the other two.

Feedback: The magnetic field produced by a changing electric field is always at right angles to the electric field itself.

The electric field produced by a changing magnetic field is always at right angles to the magnetic field itself.

Light consists of electric and magnetic fields that vary in an oscillatory fashion, in both time and space. The changing electric field produces the magnetic field. The magnetic field produced is changing itself and its changing produces an electric field which itself is changing, ...

Hence, the electric and magnetic fields of which light consists, are always at right angles to each other.

Furthermore the direction in which light travels is the direction of the vector **E**×**B**. From the definition of the cross product, this direction is perpendicular to both **E** and **B**.

Question 3 **0 of 20 points**

What is the color of the shortest wavelength visible light?

Selected Answer: ✗ yellow

Correct Answer: ✓ violet

Feedback: Keeping in mind the fact that the higher the frequency the shorter the wavelength, the names of the kinds of electromagnetic radiation on either side of visible light in the electromagnetic spectrum may help keep the order of the colors in terms of wavelengths or frequencies in mind.

Ultraviolet, meaning "above" violet gets its name because its frequency is even higher than the frequency of violet light, the highest frequency (and therefore the shortest wavelength) in the visible spectrum.

Infrared, meaning "below" red gets its name because its frequency is even lower than the frequency of red light, the lowest frequency (and therefore the longest wavelength) in the visible spectrum.

Question 4 **0 of 20 points**

What is the medium in which light waves travel?

Selected Answer: ✗ Air

Correct Answer: ✓ Light requires no medium.

Feedback: Light is the only kind of wave that doesn't require a medium. Evidence that light will travel through vacuum is the fact that light from the sun, and other stars, reaches us despite the intervening vacuum of space.

Question 5 **0 of 20 points**

What kind of waves are electromagnetic waves?

Selected Answer: ✗ Longitudinal Waves

Correct Answer: ✓ None of the other answers is correct.

Feedback: Electromagnetic waves are transverse waves. The oscillations of the electric and magnetic fields are at right angles to the direction in which the light is traveling.

OK

Review Assessment: q22

Name: q22

Status : Completed

Score: 20 out of 100 points

Instructions:

Question 1 **0 of 30 points**

In carrying out the Young's Double Slit experiment:

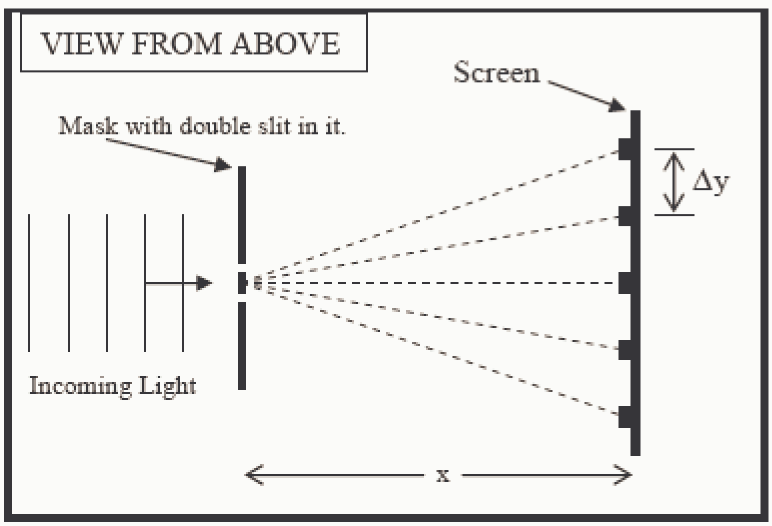
Question	Correct Match	Selected Match
What happens if the slit spacing is decreased?	✓ C. The spacing between the bright fringes that appear on the screen increases.	✗ A. The spacing between the bright fringes that appear on the screen decreases.
What happens if the slit-to-screen distance is increased?	✓ C. The spacing between the bright fringes that appear on the screen increases.	✗ A. The spacing between the bright fringes that appear on the screen decreases.
What happens if the wavelength of the monochromatic light illuminating the double slit is increased?	✓ C. The spacing between the bright fringes that appear on the screen increases.	✗ A. The spacing between the bright fringes that appear on the screen decreases.

Feedback:

The equation $m\lambda = d\sin\theta$ solved for $\sin\theta$ yields $\sin\theta = \frac{m\lambda}{d}$.
Since the slit spacing d is in the <u>denominator</u> of the expression for $\sin\theta$, a decrease in d results in an increase in $\sin\theta$.

In that θ is the angle from the straight ahead direction (the direction perpendicular to the mask with the two slits in it), any angle greater than 90° would be inconsistent with the interference phenomenon in question—an angle greater than 90° would mean that the light impinging on the double slit, bounces off of it rather than going through it. For values of θ between 0 and 90°, an increase in θ corresponds to an increase in $\sin\theta$.

Hence, a decrease in d results in an increase in θ. From the geometry of the Young's double slit configuration, an increase in the angle θ for each bright fringe, results in a greater bright-fringe spacing (the distance labeled Δy in the diagram below) on the screen.



In that λ is in the <u>numerator</u> of the expression $\sin\theta = \frac{m\lambda}{d}$, an increase in the value of λ has the exact same effect that a decrease in the value of d has. That is to say, that an increase in the value of the wavelength λ of the incoming light also results in a greater bright-fringe spacing Δy.

The distance x in the diagram above is the distance from the mask with the two slits in it to the screen. Note that this distance does not appear in the interference equation $\sin\theta = \frac{m\lambda}{d}$. There is no convention for the symbol used to represent this distance. People typically use D, L, or, as in the diagram above, x, to represent this distance. It should never be confused with the distance d which is the slit separation, the distance from the center of one slit in the mask to the center of the other slit in the mask. The change in the bright-fringe spacing that occurs when the slit-to-screen distance x,

Question 2 **0 of 10 points**

Are light waves the only kind of waves that undergo interference?

Selected Answer: Yes.

Correct Answer: No.

Feedback: Interference takes place in all kinds of waves.

Question 3 **0 of 20 points**

In optics, what is meant by the expression "constructive interference."

Selected Answer: When light of one frequency, from two different sources, illuminates the same point in space, the electric field at that point in space is the vector sum of the electric field due to one source and the electric field do to the other. If the two electric fields are out of synchronization with each other they add up to a smaller electric field than that contributed by one of the sources by itself, resulting in light that is less intense than that due to the one source by itself. Constructive interference is the name given to this phenomenon.

Correct Answer: When light of one frequency, from two different sources, illuminates the same point in space, the electric field at that point in space is the vector sum of the electric field due to one source and the electric field do to the other. If the two electric fields are in synchronization with each other they add up to a bigger electric field than that contributed by either individual source, resulting in light that is more intense than that due to either source by itself. Constructive interference is the name given to this phenomenon.

Feedback: This is true for any kind of waves. Any time you have coherent waves of the same kind and frequency, from at least two different sources, impingent upon one and the same point in space, the waves will interfere. When they interfere constructively, the result is a wave whose amplitude is greater than the amplitude of either of the contributors.

Question 4 **20 of 20 points**

What is monochromatic light?

Selected Answer: Light of a single wavelength.

Correct Answer: Light of a single wavelength.

Feedback: Nice work.

Breaking the word down: "mono" means one and "chromatic" means "of color" so a fairly literal translation for the adjective "monochromatic" would be "having one color." The color of light is determined by its wavelength so it makes sense that monochromatic light is light of a single wavelength.

Because the speed of light in vacuum is constant and that speed is related to wavelength and frequency by $c = \lambda f$, specifying the frequency of light is essentially equivalent to specifying its wavelength. So, monochromatic light can also be defined to be light of a single frequency.

Question 5 **0 of 20 points**

When white light is normally incident on a diffraction grating, the first order maximum for which color of light occurs at the greatest angle with respect to the straight ahead direction?

Selected Answer: white

Correct Answer: red

Feedback: The length of the path that light must travel to get to a point on the screen from one slit in the diffraction grating must differ by one wavelength from the distance that light must travel to the same point from an adjacent slit in order to get maximal constructive interference. The greater the wavelength, the bigger the path difference needed. Further, from plane geometry, the bigger the angle, the bigger the path difference. Hence, we get first order interference at the biggest angle for the light with the longest wavelength. Red light has the longest visible light wavelength. Thus red light yields the biggest angle for the first interference maximum.

We can also get at this mathematically using the equation for the angles (relative to the straight ahead direction) of the interference maxima. The equation reads:

$$m\lambda = d \sin\theta$$

For first order interference, m=1 and the equation becomes:

$$\lambda = d \sin\theta$$

Note that for a given diffraction grating, with a given slit separation *d*, the greater the wavelength, the greater the sinθ. Now, interference maxima occur at angles between 0 and 90 degrees to either side of the straight-ahead direction. In that range of angles, the bigger the sinθ, the bigger the angle θ itself. With red being the visible light having the longest wavelength λ, and with the longest wavelength interference maximum occurring at the biggest sinθ which in turn corresponds to the biggest θ, we have a red light interference maximum occurring at the biggest angle of interference relative to the straight-ahead direction.

OK

Review Assessment: q23

Name: q23

Status : Completed

Score: 30 out of 100 points

Instructions:

Question 1 **0 of 40 points**

In a diffraction experiment, monochromatic light which passes through a single slit illuminates a screen. A pattern of fringes appears on the screen. The pattern includes a central bright fringe. What happens to the width of the central bright fringe if the slit is replaced by a more narrow slit?

Selected Answer: ✗ The width of the central bright fringe decreases.

Correct Answer: ✓ The width of the central bright fringe increases.

Feedback: First we have to remember that monochromatic light is light of a single wavelength. Next, that in your physics course, we use the symbol *w* to represent the width of a single slit.

The equation $m\lambda = w\sin\theta$, (with m being 1, 2, 3, ...) relates the angle at which minima occur, in the case of single-slit diffraction, to the wavelength λ of the light, and, the width of the slit *w*.

The central diffraction maximum extends from the minimum that is just to the left of center, all the way to the minimum that is just to the right of center. So, the width of the central diffraction maximum is the distance between the two minima. Setting $m = 1$ in the expression for the diffraction minima allows us to get the angular separation between the straight-ahead direction and the direction for either first minimum. Hence, for any one slit-to-screen distance, the greater the angle θ for the case $m = 1$, the greater the width of the central maximum. Setting $m = 1$ in the diffraction equation $m\lambda = w\sin\theta$ and solving for $\sin\theta$ we find $\sin\theta = \lambda/w$. Since w is in the denominator, the smaller *w* is, the bigger $\sin\theta$ is. And for the range of angles under consideration (0 to 90 degrees), the bigger $\sin\theta$ is, the bigger θ itself is, and hence, the wider the central maximum is.

Question 2 **0 of 30 points**

Diffraction is a phenomenon that is strictly associated with light. That is to say that light, and, only light undergoes diffraction. (By light here, we mean any form of electromagnetic radiation--not just visible light.)

Selected Answer: ✗ True

Correct Answer: ✓ False

Feedback: Diffraction is a wave phenomenon and it occurs for all kinds of waves. For instance, waves in the surface of water undergo diffraction. So do sound waves in air.

Question 3 **30 of 30 points**

Diffraction is the spreading of light that occurs when it pass through a thin slit or small hole or passes by an obstacle.

Selected Answer: ✓ True

Correct Answer: ✓ True

Feedback: Nice work!

Diffraction is the spreading of any kind of wave that occurs upon passage of that wave by an obstacle or through a thin slit or small hole. Light is a kind of wave, so the statement is true.

OK

Review Assessment: q24

Name: q24

Status : Completed

Score: 0 out of 100 points

Instructions:

Question 1 **0 of 50 points**

In terms of the wavelength of the relevant light, how thick must the layer of transparent optical coating on a transparent medium be in order to create maximum destructive interference of the reflected light, thus maximizing transmission? (Choose the answer that is appropriate for the case in which light that is traveling in air is approaching a piece of glass along a path that is normal to the surface of the glass, and the coating, whose index of refraction is between that of air and that of glass, is to be placed on the first surface of the glass to be encountered by the light, in order to minimize reflection from that surface.)

Selected Answer: ✗ 0 wavelengths of the light in air.

Correct Answer: ✓ 1/4 wavelength of the light in the transparent medium of which the optical coating is made.

Feedback: We need the path length difference, between light that bounces off the air-coating interface and the light that bounces off the coating-glass interface, to be one-half a wavelength, in order to get destructive interference. The light that goes through the first interface (the air-coating interface) travels through the thickness of the coating, bounces off the coating-glass interface, and travels back through the thickness of the coating again, before passing back out through the air-coating interface to join the light that bounced off the air-coating interface. The extra distance that the light that goes through the first interface travels is thus twice the thickness of the coating. For that distance to be half a wavelength, the thickness of the coating must be a quarter of a wavelength. Since the extra traveling that the light that goes through the air-coating interface does, is in the coating material, it is the wavelength that the light has when it is in the coating material that matters, not the wavelength that the light has when it is in the air.

Question 2 **0 of 50 points**

It is desired to minimize the reflection of light by the outer surfaces of the objective lenses of a pair of binoculars. These surfaces are the first surfaces that light hits on entering the binoculars. The lenses are made of crown glass. To minimize the reflection, the lenses should be coated with a transparent medium of the right thickness and of the right index of refraction. For maximum destructive interference of the reflected light, the value of the index of refraction of the coating:

Selected Answer: ✗ should be greater than that of crown glass.

Correct Answer: ✓ should lie between the index of refraction of air and that of crown glass, but closer to that of air than that of crown glass.

Feedback: Okay, we want to put a quarter-wave thickness of optical coating on the lens to cause a path difference of half a wavelength so that we get destructive interference between the light, "path 1 light", that reflects off the first interface (the air/coating interface) and the light, "path 2 light" that reflects off the second interface (the coating/glass interface).

What we usually don't talk about in discussing thin-film interference is the amplitudes. But, to get the most destructive interference, where they do interfere, we want the amplitudes to be the same. Then a crest of path 1 light is totally cancelled by a trough of path 2 light.

Now the bigger the difference between the indices of refraction of the two media on either side of an interface, the greater the amount of reflection from that interface.

Suppose we had the index of refraction of the coating exactly midway between that of air and that of the crown class. Further suppose that 10% of the light is reflected off each surface. The value is not important but the fact that both values are the same is reasonable since the difference $n_{coating} - n_{air}$ is, under the given circumstances, the same as the difference $n_{glass} - n_{coating}$. If 10% is reflected off the first surface, only 90% gets through. Then 10% of that 90%, which is only 9% of the original intensity is reflected off the second surface and only 90% of that, or 8.1% of the original intensity makes it back out through the first surface. So where the light from the two paths joins together again back in the air, after reflection, we have 10% of the original intensity interfering with 8.1% of the original intensity so the cancellation will not be perfect (even if the coating is of the perfect thickness). If we decrease the index of refraction of the coating a little bit, making it a little closer to the index of refraction of air, we decrease the reflection at the first surface and increase the amount that gets through that surface and the percentage of that amount that is reflected off the second surface and then makes it back through the first surface. With the right choice of the coating index of refraction, extrapolating upon the given example, we can bring that 10% down and the 8.1% up just enough to have them meet in the middle. If they are both equal, we can get perfect destructive interference.

Thus, to maximize the destructive interference of the reflected light, we need the index of refraction of the coating to be in between the n_{air} and n_{glass}, and we need it to be a little bit closer in value to n_{air} than it is to n_{glass}.

OK

Review Assessment: q25

Name: q25

Status : Completed

Score: 20 out of 100 points

Instructions:

Question 1 **0 of 20 points**

(polarization) A polarizer consists of long-chain polymers aligned in a preferred orientation. How does that orientation compare with the direction of polarization of the polarizer?

Selected Answer: ✗ There is no correlation between the direction of polarization and the orientation of the polymers. The direction of polarization is established by means of a set of ruled, parallel, lines.

Correct Answer: ✓ The direction of polarization is at right angles to the direction in which the long chained polymers are oriented.

Feedback: Charged particles within the long-chain polymers that make up polarizing material can respond to electric fields directed along the polymers. In so doing, work is done on the charged particles by the electric field of the light. Thus the light imparts some of its energy to the charged particles in the long molecules of the polymer. In giving its energy to the particles, the light is absorbed.

The charged particles within the long molecules of the polymer are not able to move in directions perpendicular to the molecules. Hence they cannot respond to electric fields that are perpendicular to the molecules. Hence light whose electric field oscillates in directions defined by a line that is perpendicular to the long molecules of the polymer is not absorbed.

The so-called polarization direction of polarized light is really two directions that are opposite each other. The electric field oscillates back and forth along the line defining these two directions. Hence light that is polarized along the direction in which the polymers in a polarizer are aligned is absorbed. Light that is polarized perpendicular to the direction in which the polymers in a polarizer are aligned gets through. Hence the polarization direction of a polarizer, the direction which is depicted in diagrams of a polarizer, is at right angles to the direction in which the long chain polymers in the polarizer are aligned.

Question 2 **0 of 20 points**

Completely unpolarized light of intensity I_o is incident on a polarizer whose polarization direction makes an angle of 15.0 degrees with respect to the vertical. What is the intensity of the light that makes it through the polarizer?

Selected Answer: ✗ 0

Correct Answer: ✓ $.5\ I_o$

Feedback: Well done.

When randomly-polarized light (a.k.a. completely randomly-polarized light, unpolarized light, and completely-unpolarized light) is *normally incident*[1] upon a polarizer (and the reader is to assume that the light is normally incident upon the polarizer unless information to the contrary is provided) *half the light*[2] gets through.

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[1]Light that is **normally incident** upon a surface is light that is traveling along a path that is perpendicular to the surface when said light encounters the surface.

[2]The intensity of the light that gets through is half the intensity of the light traveling toward the polarizer. The other half of the light is absorbed.

Question 3 **0 of 20 points**

When light is vertically polarized, what is it about the light that is "vertical"?

Selected Answer: ✗ The direction of travel of the light.

Correct Answer: ✓ The orientation of the electric field--it is alternating between upward, zero, and downward.

Feedback: It is the electric field, rather than the magnetic field, that gets most of the attention when one considers the interaction of light with matter, because it is, by far, the electric field that interacts most strongly with matter.

Note that the answer referring to the oscillation of charged particles is nonsense. Light does not consist of oscillating charged particles. It consists of electric and magnetic fields that oscillate, and, vary as a periodic function of position as well.

Question 4 **0 of 20 points**

Which of the fields that make up light interact most strongly with matter?

Selected Answer: ✗ The football field.

Correct Answer: ✓ The electric field.

Feedback: Light consists of electric and magnetic fields that vary in both time and space in a periodic fashion. Of these two, it is the electric field that interacts most strongly with matter.

Question 5 **20 of 20 points**

Why are polarized sunglasses effective?

Selected Answer: ✓ Light which undergoes plane mirror reflection from various horizontal parts of the surface of the earth, is horizontally polarized. Such light is glare. It has a "blinding" effect which makes it difficult for one to see clearly. The "lenses" of polarized sunglasses are vertically polarized. As such they tend to absorb the glare. They let the vertically polarized light, resulting from diffuse reflection and necessary for seeing anything, through. To be sure, half the diffusely reflected light itself is horizontally polarized, and it is absorbed by the lenses too. This results in a dimming of the view, a side effect.

Correct Answer: ✓ Light which undergoes plane mirror reflection from various horizontal parts of the surface of the earth, is horizontally polarized. Such light is glare. It has a "blinding" effect which makes it difficult for one to see clearly. The "lenses" of polarized sunglasses are vertically polarized. As such they tend to absorb the glare. They let the vertically polarized light, resulting from diffuse reflection and necessary for seeing anything, through. To be sure, half the diffusely reflected light itself is horizontally polarized, and it is absorbed by the lenses too. This results in a dimming of the view, a side effect.

Feedback: Way to go!

If it were not for the fact that surfaces that produce glare have a tendency to absorb vertically polarized light and reflect horizontally polarized light, polarized sunglasses would have no advantage over unpolarized sunglasses.

OK

Review Assessment: q26

Name: q26

Status : Completed

Score: 36 out of 100 points

Instructions:

Question 1 **0 of 24 points**

For a plane mirror, which is true of the normal?

Selected Answers: ✓ It is at right angles to the surface of the mirror.

Correct Answers:
- ✓ It is at right angles to the surface of the mirror.
- ✓ It is normal to the surface of the mirror.
- ✓ It is perpendicular to the surface of the mirror.
- ✓ It makes an angle of 90 degrees with the surface of the mirror.
- ✓ It is an imaginary line.
- ✓ It passes through the point of incidence.
- ✓ It is the line with respect to which the angle of incidence is measured.
- ✓ It is the line with respect to which the angle of reflection is measure.

Feedback: The normal is an imaginary line that passes through the point of incidence and is perpendicular to the surface of the mirror. The angle of incidence is the angle that the incident ray makes with the normal. The angle of reflection is the angle that the reflected ray makes with the normal.

Question 2 **20 of 20 points**

A person is attempting to locate the image of an object of a plane mirror by means of a ray-tracing diagram. The person draws a ray, from the object, which strikes the mirror at right angles to the surface of the mirror. Where does the ray go from there?

Selected Answer: ✓ It reverses its direction at the surface of the mirror and travels straight back upon itself.

Correct Answer: ✓ It reverses its direction at the surface of the mirror and travels straight back upon itself.

Feedback: Nice work.

According to the law of reflection, the angle of reflection is equal to the angle of incidence. In the case at hand, the angle of incidence is zero. Hence, the angle of reflection must be zero, meaning, that the reflected ray travels along the normal. It was given that the incoming ray was traveling toward the mirror along the normal, and, we have deduced that the reflected ray travels away from the mirror along the normal. Hence, the ray must reverse its direction at the surface of the mirror.

Question 3 **0 of 20 points**

According to the law of reflection, the angle of reflection is equal to the angle of incidence. An angle is always an angular separation between two planes, a direction and a plane, or two directions. The angle of reflection is the angle between what and what?

Selected Answer: ✗ The incident ray and the plane of the mirror.

Correct Answer: ✓ The reflected ray and the normal.

Feedback: By definition, the angle of reflection is the angle that the reflected ray makes with the normal.

Question 4 **16 of 16 points**

Assuming that it is understood that the object is in front of the mirror and anything on the other side of the mirror is behind the mirror, is the following statement sufficient to unambiguously specify the correct location of the image, formed by a plane mirror, of that object?

"The image is exactly as far behind the mirror as the object is in front of the mirror."

Selected Answer: ✓ Yes.

Correct Answer: ✓ Yes.

Feedback: Well done.

Question 5 **0 of 20 points**

In forming the image, does light from the object necessarily pass through the location of the image?

Selected Answer: ✗ Yes.

Correct Answer: ✓ No.

Feedback: No. In fact, in the case of a plane mirror (defining the object to be *in front of* the mirror and anything on the other side of the mirror to be *behind* the mirror, the image is always behind the mirror. Light from the object can't get through the mirror to where the image is, so, no light from the object ever passes through the image.

OK

Review Assessment: q27

Name: q27

Status : Completed

Score: 20 out of 100 points

Instructions:

Question 1 **0 of 20 points**

A ray of light in air is incident upon a flat piece of glass. How does the path that the light travels along when it is in the glass compare with the path in the air?

Selected Answer: ✗ The light does not enter the glass.

Correct Answer: ✓ The path in the glass makes a smaller angle with the normal.

Feedback: The phrase used to memorize this fact is, "On going from less dense to more dense, the light is bent toward the normal." While this is a useful memory device, it should not be taken too literally. For one thing, mass density is not relevant. The word "dense" in this context refers to "optical density" which is an expression sometimes used to characterize a transparent material. A material that is less optically dense than another material is actually one that has a smaller index of refraction. A material that is more optically dense than another material is actually one that has a greater index of refraction.

Next, light is not something that can be bent. The bent part refers to the fact that when light that is traveling in a transparent medium with one index of refraction passes through an interface between that transparent medium and a transparent medium with a greater index of refraction, the light, which had been traveling along one straight line path, abruptly, at the interface, adopts a new straight line path, a path that makes a smaller angle with the normal. The normal is an imaginary line perpendicular to the interface and passing through the interface at the point at which the incident ray hits the interface.

Question 2 **0 of 20 points**

A ray of light, traveling in air, passes through a flat plate of glass. Refraction occurs. Where does the refraction take place?

Selected Answer: ✗ In the glass.

Correct Answer: ✓ At the glass-to-air interface where the light enters the glass, and, at the glass-to-air interface where the light exits the glass.

Feedback: Refraction occurs when light traveling in one transparent medium encounters the interface between that transparent medium and a second transparent medium. The refraction occurs at the interface.

Question 3 **0 of 20 points**

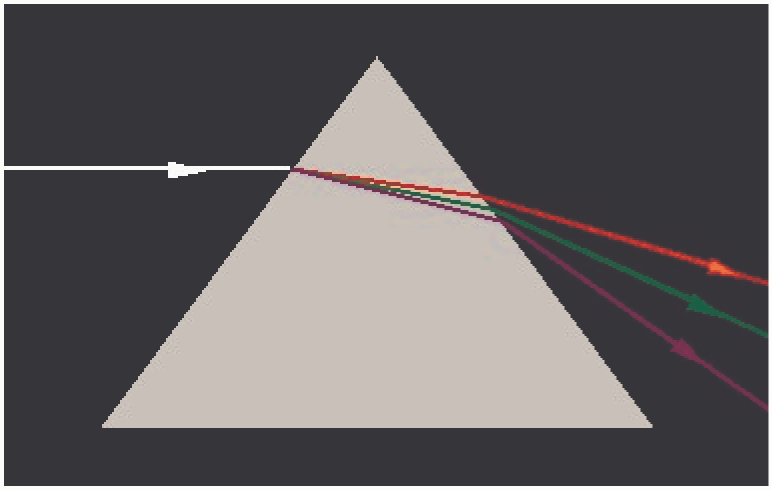
A ray of white light in air passes through a glass plate. Refraction occurs. The direction in which the light is traveling changes. For what color of light is the change in direction greater, red or blue?

Selected Answer: ✗ That depends on which interface is under consideration. On passing from air to glass, the blue light is refracted more (experiences the bigger change in direction of travel). But, in going from glass to air, the red light is refracted more.

Correct Answer: ✓ The blue light is refracted more (experiences the bigger change in direction of travel) at both interfaces.

Feedback: The index of refraction of a transparent medium is typically pretty much the same for every visible wavelength, but, not quite. The fact that the index of refraction does depend on the wavelength of the light is what makes it so that a prism breaks up white light into a rainbow of colors. When white light (a mix of all the visible wavelengths) enters a glass or quartz prism from air for instance, the violet light gets refracted a little bit more toward the normal than the other colors, and, on leaving the prism it gets refracted a little bit more away from the normal than the other colors. The effect occurs for all the wavelengths, with the shorter wavelengths being refracted more and the longer wavelengths be refracted les. The effect is the rainbow of colors that we see when white light passes through a prism.

Here we show the effect for the case of a prism, but, we leave out all the colors except for red, green, and violet.



Question 4 **20 of 20 points**

On passing from a medium with one index of refraction to a medium with a different index of refraction, light is typically both reflected and refracted. Under some circumstances however, all of the light is reflected—none of it gets through the interface. The phenomenon is called "Total Internal Reflection." In which case, if either, can total internal reflection occur—when light is already in the medium with the greater index of refraction and encounters the boundary between the two media, or, when light is already in the medium with the smaller index of refraction and encounters the boundary between the two media?

Selected Answer: ✓ When light is already in the medium with the greater index of refraction and encounters the boundary between the two media.

Correct Answer: ✓ When light is already in the medium with the greater index of refraction and encounters the boundary between the two media.

Feedback: Lovely performance!

The fact that the light has to be *inside* the medium with the larger index of refraction in order to experience total internal reflection is where total *internal* reflection gets its name.

So for instance, in an experiment involving a prism, if light is to experience total internal reflection at the surface of the prism, the light has to be traveling inside the prism as it approaches that surface.

Question 5 **0 of 20 points**

The index of refraction of a particular medium is almost the same for all wavelengths, hence we often associate a single value, the average value of the index of refraction, to the medium. There is, however, some variation in the value of the index of refraction, with wavelength. As a result the angle of refraction that occurs when light enters or exits such a medium is slightly different for different wavelengths of visible light. What is the name of this phenomenon?

Selected Answer: ✗ Diffraction.

Correct Answer: ✓ Dispersion.

Feedback: The dispersion of light is the spreading out of light and that is exactly what occurs when the colors that make up white light are split up by a prism as a result of the slight dependence of the index of refraction of a transparent medium, on the wavelength of the light.

OK

Review Assessment: q28

Name: q28

Status : Completed

Score: 30 out of 100 points

Instructions:

Question 1 **0 of 9 points**

Which of the following is a principal ray for the case of an actual physical object and a convex (converging) lens? Indicate all that apply.

Selected Answers:
✓ A ray departing from the object along a line parallel to the principal axis of the lens, at the plane of the lens, adopts a path that takes it through the focal point on the other side of the lens.

Correct Answers:
✓ A ray departing from the object along a line parallel to the principal axis of the lens, at the plane of the lens, adopts a path that takes it through the focal point on the other side of the lens.
✓ A ray departing from the object along a line that takes it through the center of the lens, at the plane of the lens, continues along that same path.
✓ A ray departing from the object along a line passing through the focal point on the same side of the lens as the object, at the plane of the lens, adopts a path parallel to the principal axis of the lens.

Feedback: In the thin lens approximation used to determine the nature, orientation, and position of the image formed by a lens, there are 3 principle rays from any point on the object. For convenience, we use an object which is an upright arrow, perpendicular to the axis of the lens, whose tail is on the principle axis of the lens; and; we chose the point from which the principle rays originate to be the head of the arrow.

The numbering of the principle rays is arbitrary.

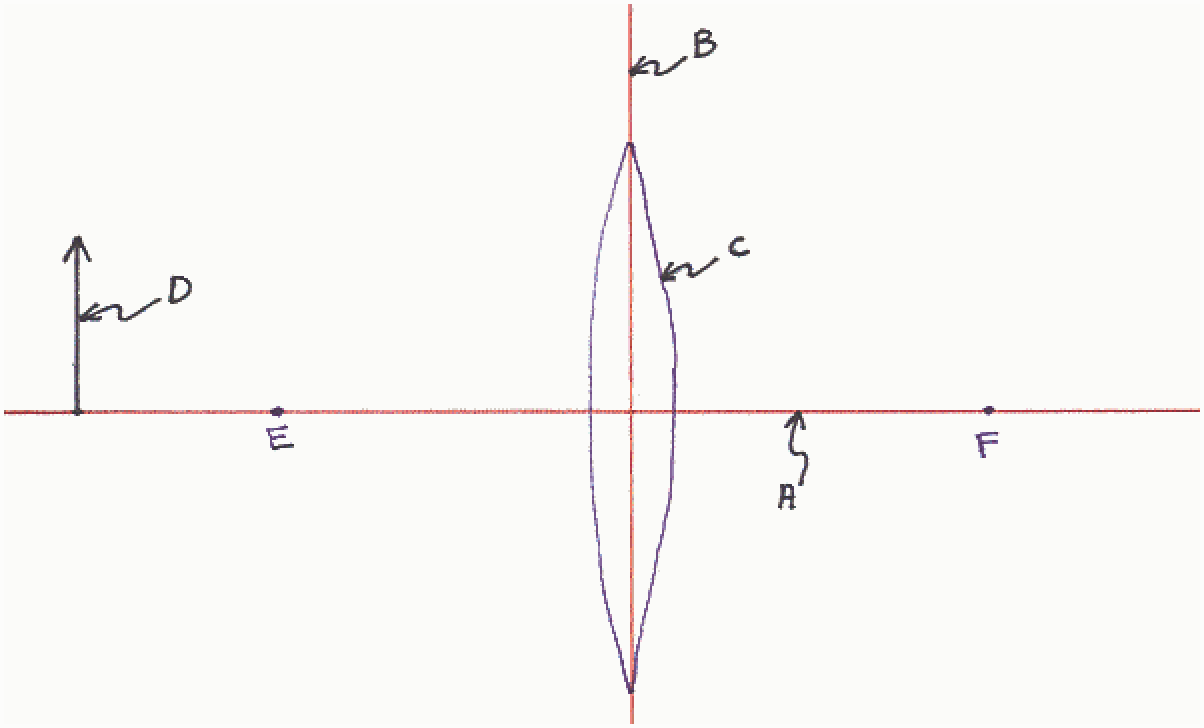
Principle Ray I: The easy one. It hits the lens smack dab in the middle and passes straight on through.

Principle Ray II: Starting on the object side of the lens, ray II heads toward the plane of the lens along a line that is parallel to the principle axis of the lens. At the plane of the lens it abruptly adopts a path along a line that takes the ray through the focal point on the other side of the lens.

Principle Ray III: Starting from the head of the arrow that the object is, ray III travels toward the plane of the lens along a line that passes through the focal point on the same side of the lens as the object. This ray passes through that focal point only if the object is farther from the lens than the focal point itself is. In any case, ray III travels toward the plane of the lens. At the plane of the lens, the ray abruptly adopts a new path which is parallel to the principle axis of the lens.

Question 2 **3 of 18 points**

Match the name of each item given in the list below to the label pointing to that item in the diagram.

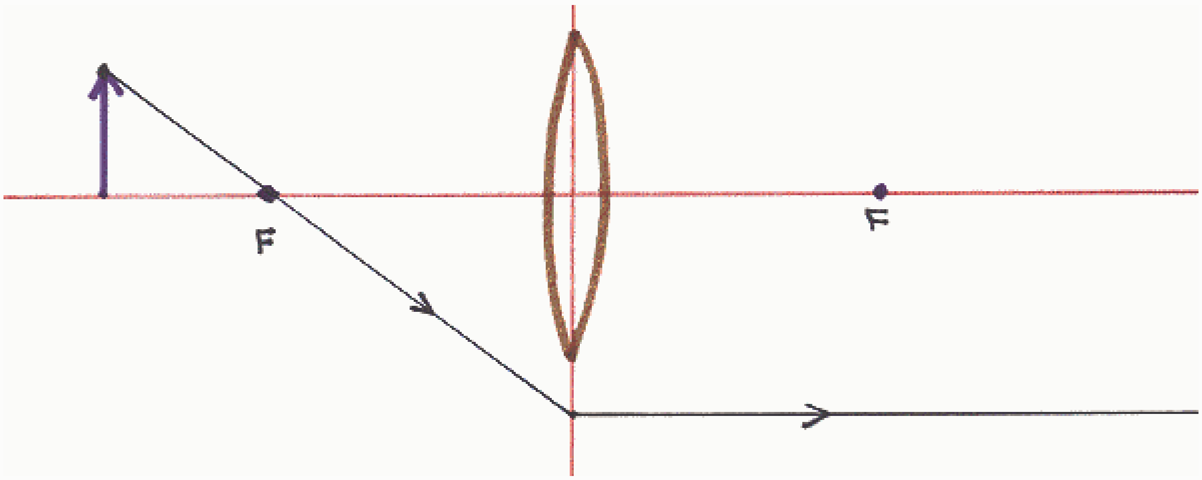


Question	Correct Match	Selected Match
That focal point on the opposite side of the lens as the object.	✓ F. [None]	✗ A. [None Given]
That focal point on the same side of the lens as the object.	✓ E. [None]	✗ A. [None Given]
The plane of the lens.	✓ B. [None]	✗ A. [None Given]
The principal axis of the lens.	✓ A. [None]	✓ A. [None Given]
An icon representing the lens.	✓ C. [None]	✗ A. [None Given]
The object.	✓ D. [None]	✗ A. [None Given]

Feedback: I guess the only point I want to stress here is that the lens depicted in a ray tracing diagram is just an indicator to the reader as to what kind of lens is being analyzed. All abrupt changes in ray path are drawn as occurring at the plane of the lens, not at the surface of the lens. Principle rays are not required to appear to pass through the lens in the ray-tracing diagram. Whether or not they appear to pass through the lens just depends on how big the person drawing the icon of the lens chose to draw it, a consideration that is irrelevant in determining the position and characteristics of the image.

Question 3 **9 of 9 points**

A person is attempting to determine the characteristics of an image formed by a converging lens by means of a ray tracing diagram. The person has drawn one principal ray. What is wrong with the principal ray?



Selected Answer: ✓ Nothing.

Correct Answer: ✓ Nothing.

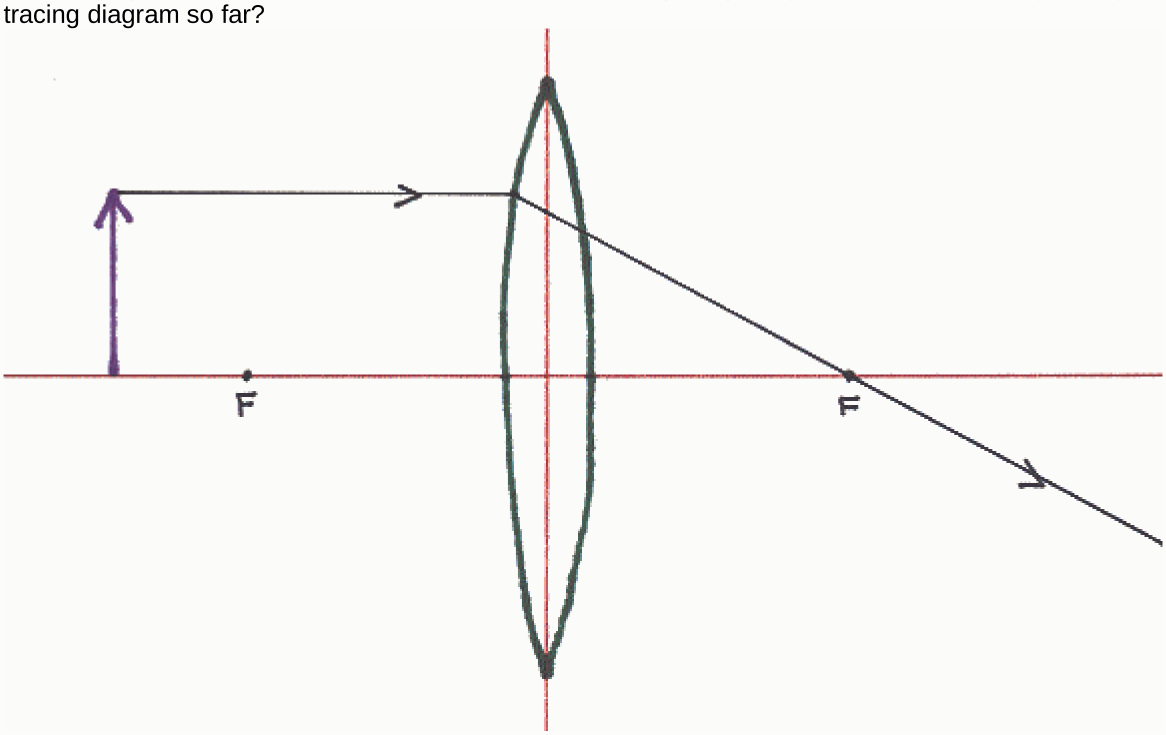
Feedback: Well done.

For a converging lens, there is indeed a principal ray that leaves the object and from there, travels toward the plane of the lens along a line that passes through the focal point on the same side of the lens as the object. For the case of an object farther from the lens than the focal point, this ray will indeed pass through the focal point on its way to the plane of the lens.

At the plane of the lens, this ray abruptly changes to a path that is parallel to the principal axis of the lens.

Question 4 **0 of 9 points**

A person is creating a ray tracing diagram to determine the characteristics of an image formed by a converging lens. So far, the person has gotten as far as drawing one of the principal rays. What is necessarily wrong with the ray tracing diagram so far?



Selected ✗ Nothing is necessarily wrong with the diagram so far.

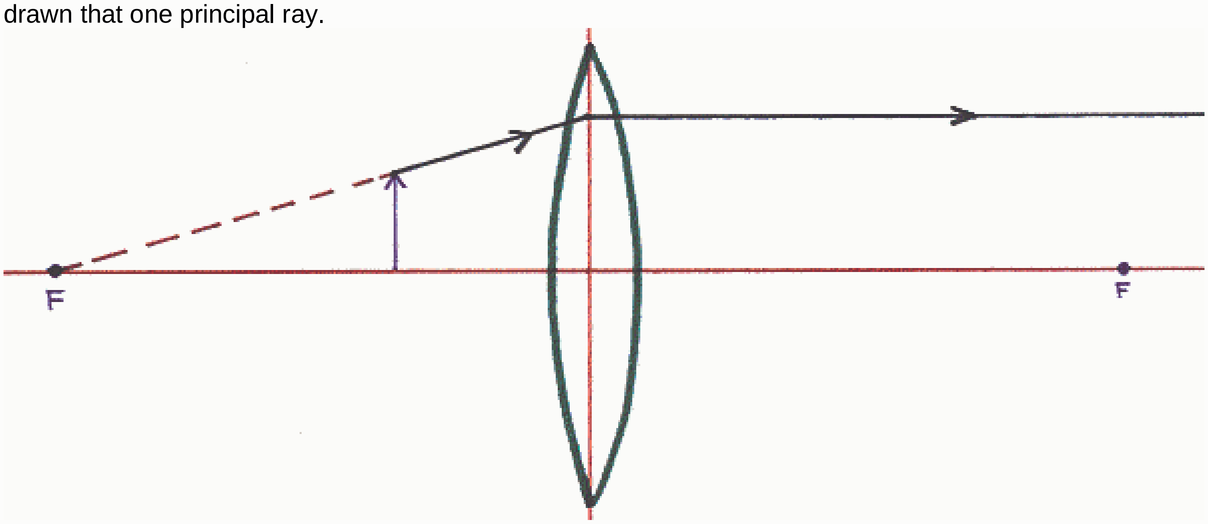
Answer:

Correct Answer: ✓ The principle ray is depicted as changing its path at the surface of the lens. In the thin lens approximation central to thin lens ray tracing diagrams, the change of path is supposed to occur at the plane of the lens.

Feedback: The outline of the lens is just an icon telling the reader what kind of lens one is dealing with. Its boundaries are never to be taken as the actual outline of the lens.

Question 5 **9 of 9 points**

A person is determining the characteristics of the image formed by a converging lens by means of a ray tracing diagram. The person has gotten as far as drawing one principal ray. What is wrong with the way the person has drawn that one principal ray.



Selected Answer: ✓ Nothing.

Correct Answer: ✓ Nothing.

Feedback: Well done!

The principal ray in question here is the one that travels along a line that passes through the focal point on the same side of the lens as the object. In the case at hand, the object is closer to the lens than the focal point, so, the ray leaves the object and travels directly away from the focal point in order to be on that line, and, to be traveling toward the plane of the lens.

At the plane of the lens this principle ray adopts a new straight line path. The new path is parallel to the principal axis of the lens.

Question 6 **0 of 9 points**

Which of the following is a principal ray for the case of an actual physical object and a concave (diverging) lens? Indicate all that apply.

Selected Answers: ✗ A ray departing from the object along a line parallel to the principal axis of the lens, at the plane of the lens, adopts a path that takes it through the focal point on the other side of the lens.

Correct Answers:
✓ A ray departing from the object along a line parallel to the principal axis of the lens, at the plane of the lens, adopts a path along the line that passes through the focal point on the same side of the lens as the object.
✓ A ray departing from the object along a line that takes it through the center of the lens, at the plane of the lens, continues along that same path.
✓ A ray departing from the object along a line that passes through the focal point on the other side of the lens, at the plane of the lens, adopts a path parallel to the principal axis of the lens.

Feedback: As in the case of the converging lens, there are three principle rays for the diverging lens.

Principle Ray I. The easy one. Just as in the case of the converging lens, this ray goes straight through the center of the lens (through the point of intersection of the plane of the lens and the principle axis of the lens) with no change in direction of the ray.

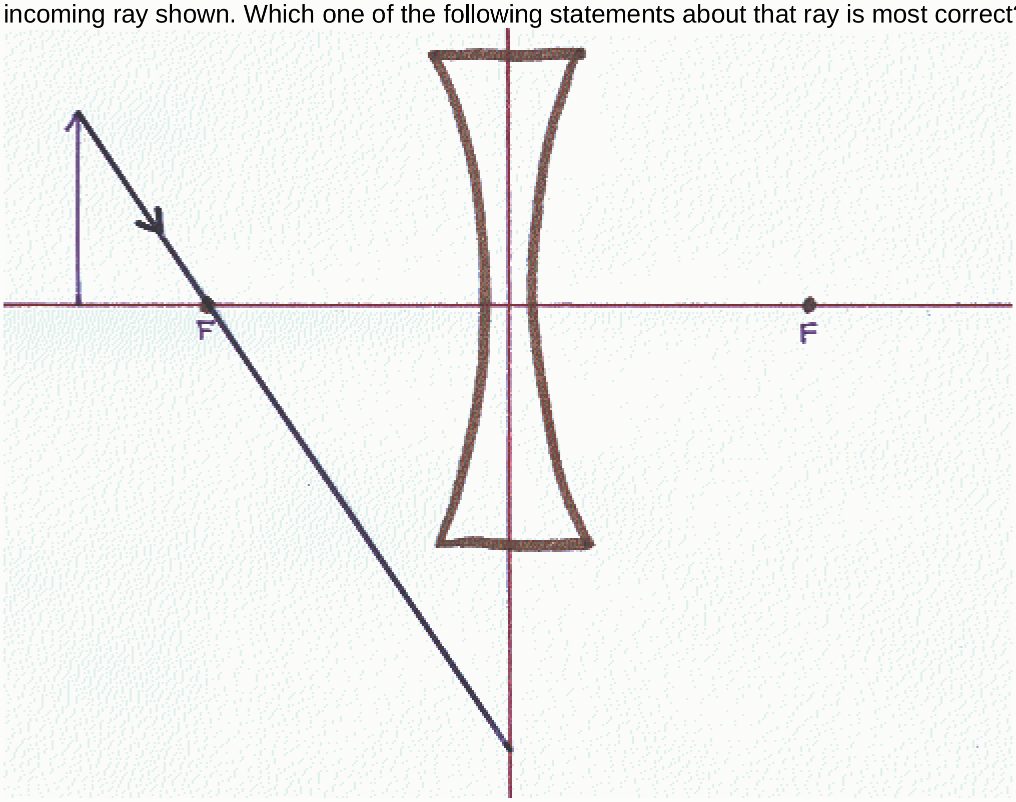
Principle Ray II. Starting on the object side of the lens, ray II heads toward the plane of the lens along a line that is parallel to the principle axis of the lens. At the plane of the lens it abruptly adopts a path that takes it directly away from the focal point that is on the same side of the lens as the object. If you trace that ray straight back, the trace-back line passes through said focal point.

Principle Ray III. Starting from the head of the arrow that the object is, ray III travels directly toward the focal point on the other side of the lens. But, at the plane of the lens, the ray abruptly adopts a path that is parallel to the principle axis of the lens, and away from the object.

Tip: In every case, a principal ray travels from the head of the object to the plane of the lens. It passes through the plane of the lens, and continues traveling into the space on the other side of the plane of the lens (the side opposite that on which the object resides). In depicting principal rays, one must include at least one arrowhead (pointing toward the plane of the lens, on the ray segment that extends from the head of the object to the plane of the lens; and; at least one arrowhead (pointing away from the plane of the lens) on the ray segment on the other side of the lens (the side opposite that on which the object resides).

Question 7 **9 of 9 points**

A person is tasked with creating a ray diagram to determine the characteristics of the image, of an object, formed by a concave lens. The person has correctly drawn the principal axis of the lens, the plane of the lens, the object, a lens icon to specify the kind of lens, and correctly drawn and labeled the focal points. Then the person draws the incoming ray shown. Which one of the following statements about that ray is most correct?



Selected Answer: ✓ That ray is not a principal ray.

Correct Answer: ✓ That ray is not a principal ray.

Feedback: Way to go.

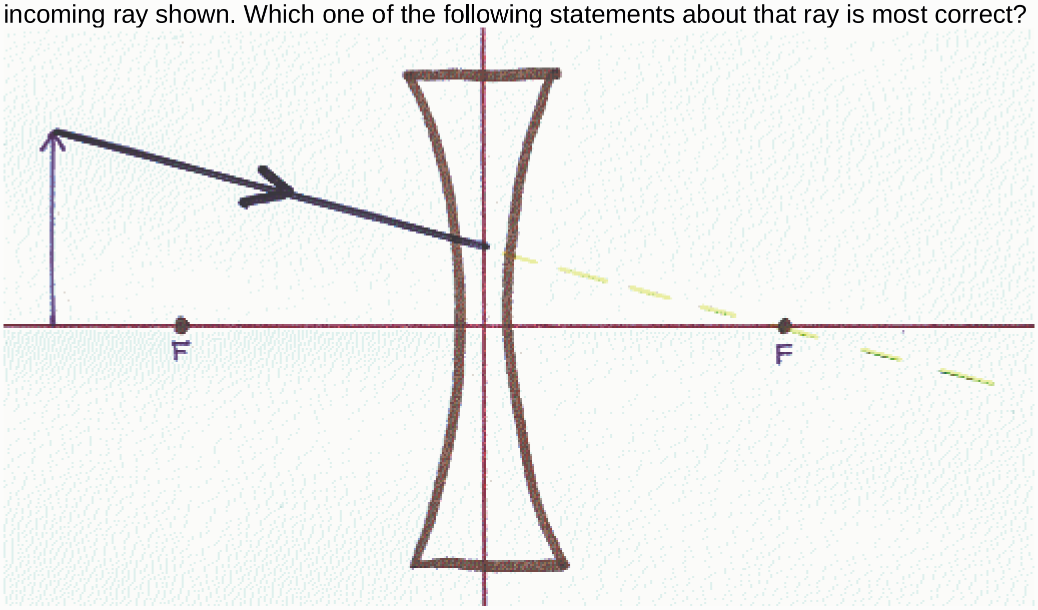
The lens depicted in the diagram is a concave lens, a diverging lens.

The given ray would be a principal ray for a converging lens, but, such a ray is diverging (from the principle axis of the lens) as it approaches the lens and the diverging lens will cause it to diverge even more. At the plane of the lens, the ray abruptly adopts a new path that makes a larger angle with the principle axis of the lens. We have no diagrammatic means of establishing the new path, that is, we don't know exactly where the light goes from there (from the point at which it "hits" the plane of the lens), hence, the ray in question is not a principle ray.

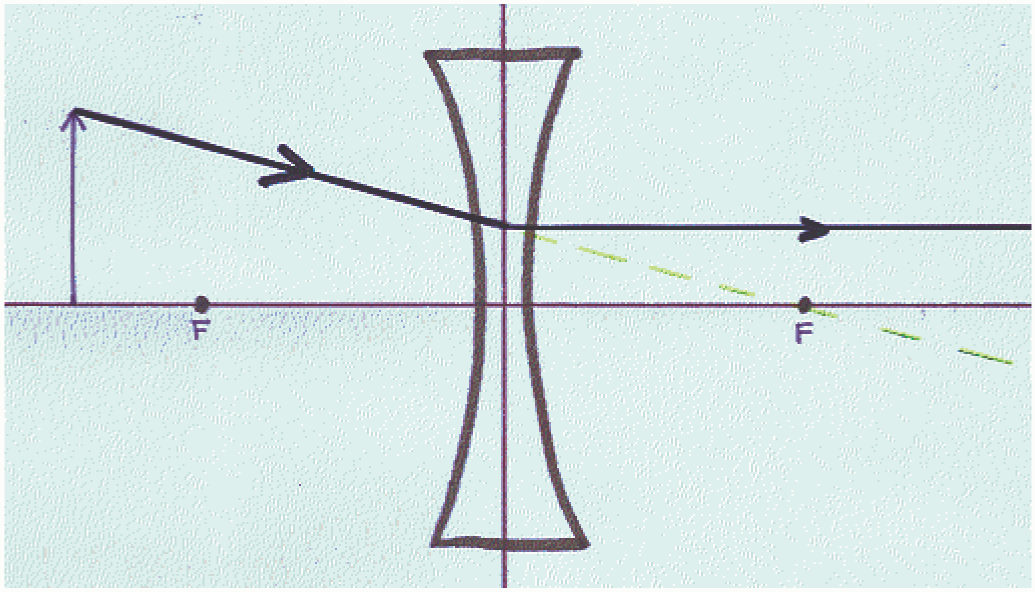
Note: The fact that the ray misses the "lens" does not rule it out as a principle ray. For one thing, the lens depicted in a principal ray diagram is just an icon, telling the reader what kind of lens is under investigation. It is not a scale size representation of the lens itself. Secondly, it doesn't matter whether the principle ray goes through the lens or not (although it **must** pass through the plane of the lens). The image formed by the rays that *do* pass through the lens will be in the same location that the principle rays predict, whether or not the diameter of the lens is great enough for the principle rays to actually contribute to the image.

Question 8 **0 of 9 points**

A person is tasked with creating a ray diagram to determine the characteristics of the image of an object formed by a concave lens. The person has correctly drawn the principal axis of the lens, the plane of the lens, the object, a lens icon to specify the kind of lens, and correctly drawn and labeled the focal points. Then the person draws the incoming ray shown. Which one of the following statements about that ray is most correct?



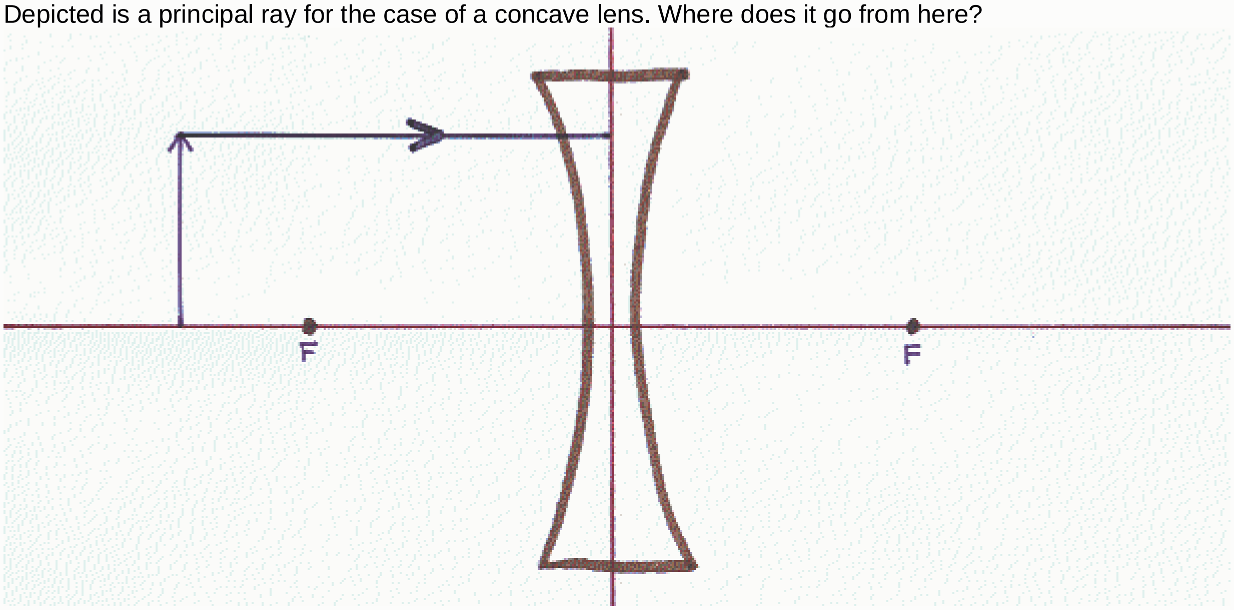
Selected Answer:	✗ That ray is not a principal ray.
Correct Answer:	✓ For purposes of determining the location of the image, the ray is to be drawn as if it continues as shown here:



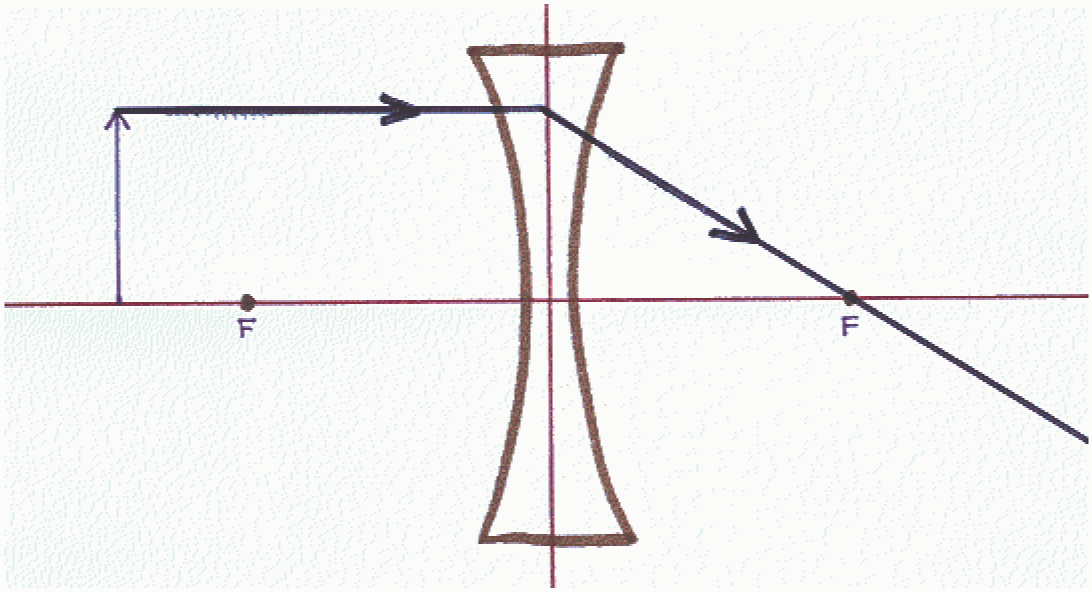
Feedback: In the case of a diverging lens, one of the principal rays is a ray that leaves the object and travels directly toward the focal point on the other side of the lens. At the plane of the lens, this ray abruptly changes its direction of travel to one which is parallel to the principal axis of the lens.

Question 9 **0 of 9 points**

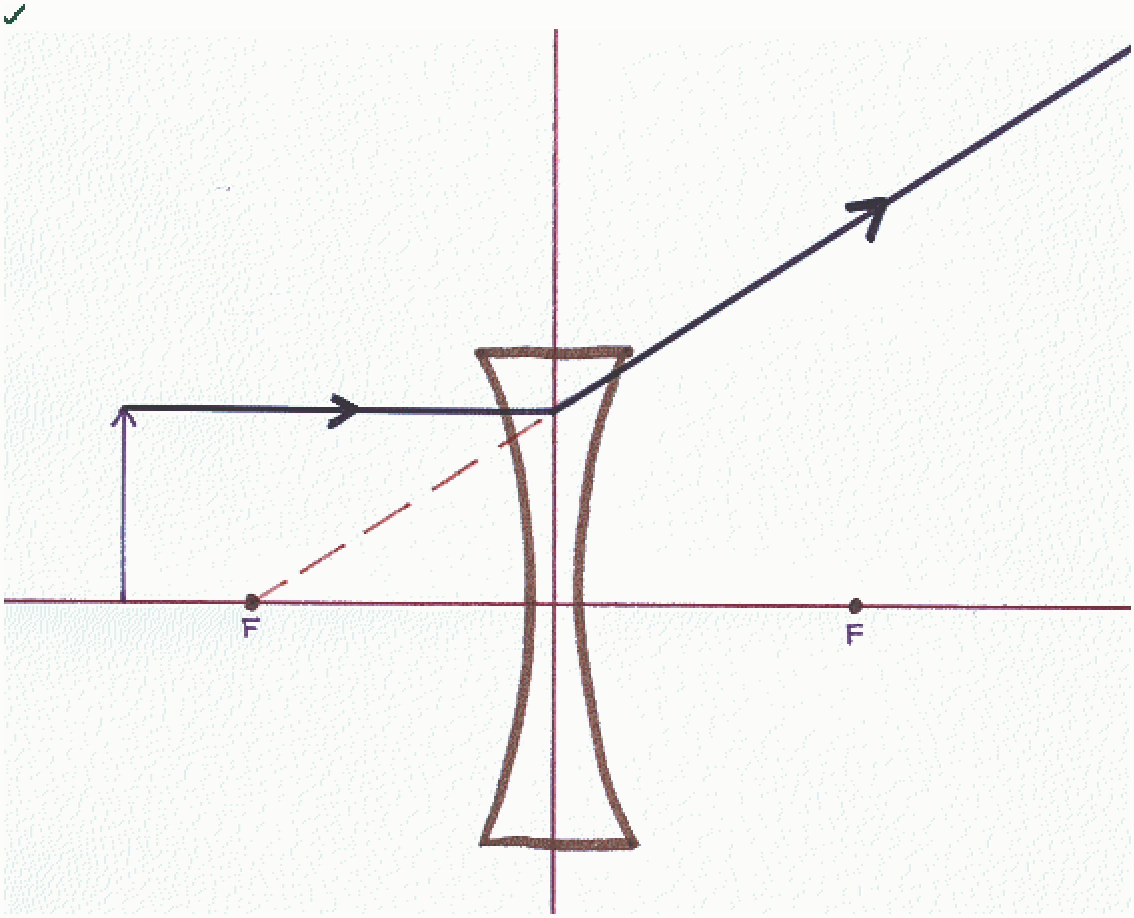
Depicted is a principal ray for the case of a concave lens. Where does it go from here?



Selected Answer: ✕



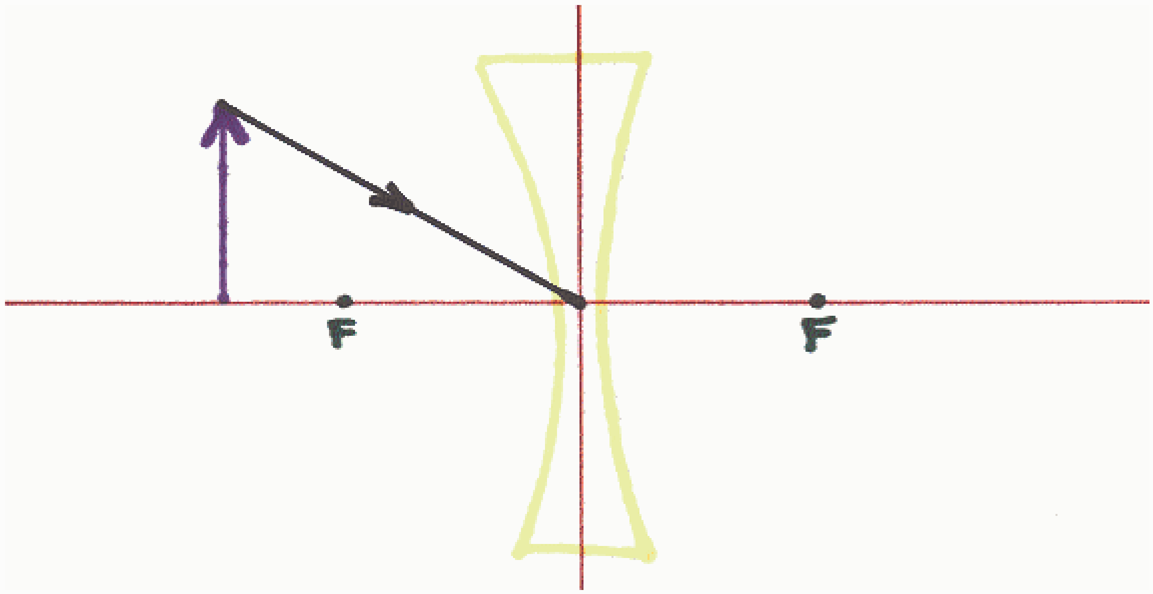
Correct Answer: ✓



Feedback: In the case of a diverging lens, there is a ray that approaches the plane of the lens along a line that is parallel to the principal axis of the lens. At the plane of the lens, that ray jumps onto a path, which, if traced back through the lens, can be seen to be on a line that passes through the focal point on the same side of the lens as the object.

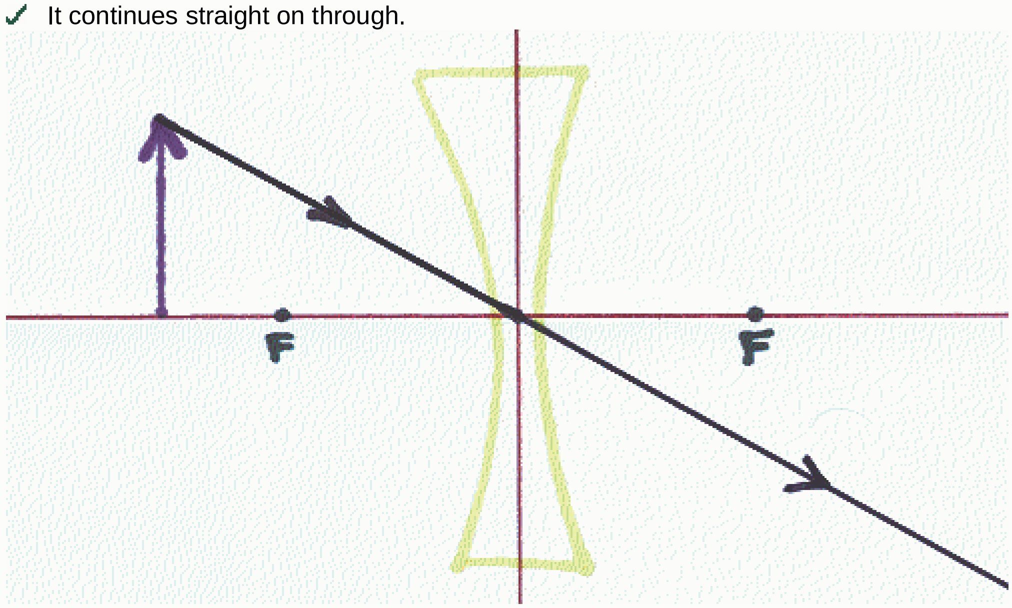
Question 10 **0 of 10 points**

Depicted is a ray from an object which heads toward and then into a lens. If the ray is a principal ray, where does it go from there?



Selected Answer: ✗ It is not a principal ray.

Correct Answer: ✓ It continues straight on through.



Feedback: This is the easy principal ray. It is the only principal ray that is the same for both a converging lens and a diverging lens. It is the principal ray that leaves the object and heads straight toward the center of the lens, that is, straight toward the point at which the plane of the lens and the principal axis of the lens intersect. That principal ray keeps on going straight through the lens.

OK

Review Assessment: q29

Name: q29

Status : Completed

Score: 30 out of 100 points

Instructions:

Question 1 **0 of 20 points**

A single lens is used to form an image of an actual physical object. You calculate the image position *i* and find that it has a negative value. What does the negative sign tell you about the image? Indicate all that apply.

Selected Answers: ✗ It is real.

Correct Answers: ✓ It is virtual.
✓ The image is on the same side of the lens as the object.

Feedback: The symbol *i* is used to represent the physical quantity referred to as the image position. The absolute value of *i* is the distance that the image is from the plane of the lens. The sign of *i* conveys information on whether the image is real or virtual.

If *i* is negative, the image is virtual. In the case of a virtual image, the light forming the image of any point of the object is not concentrated to a point at the location of the corresponding point on the image, but rather, light from the point on the object diverges, so that from the point of view of a person looking toward the object through the lens, the light appears to be coming from the corresponding point on the image, a point that is on the same side of the lens as the object itself.

If *i* is positive, the image is real. In the case of a real image, the light from the image of any point of the object is indeed, on passing through the lens, concentrated by the lens, to a point at the location of the image. The image in this case, is on the opposite side of the lens as the object.

Question 2 **0 of 20 points**

Suppose you are asked to find the characteristics of the image of an actual physical object formed by a single lens and you obtain a negative value for the magnification. What does this tell you about the image? (Indicate all that apply.)

Selected Answers: ✗ It is smaller than the object.

Correct Answers: ✓ It is inverted.

Feedback: This is simply a human-established convention. A negative value for the magnification means that the image is upside down (inverted).

Question 3 **10 of 20 points**

Match.

Question	Correct Match	Selected Match
Has a negative focal length.	✓ A. a concave lens	✓ A. a concave lens
Has a positive focal length.	✓ B. a convex lens	✗ A. a concave lens
Causes light to diverge.	✓ A. a concave lens	✓ A. a concave lens

Causes light to converge. ✓ B. a convex lens ✗ A. a concave lens

Feedback: A **concave** lens is one whose surfaces curve inward, making it **thinner at the center** then it is around the rim.

A **convex** lens is one whose surfaces curve outward, making it is **fatter at the center** then it is around the rim.

Question 4 **0 of 20 points**

Suppose that you are asked to find the image position in a problem involving a lens. You are given the object position and you are told that the lens is a concave lens whose focal point is 12 cm from the plane of the lens. What value should you use for the focal length f of the lens?

Selected Answer: ✗ .012 m

Correct Answer: ✓ -.12 m

Feedback: This is just a human-established convention. The focal length of a concave (diverging) lens is the *negative* of the distance from the plane of the lens to the focal point.

If we were talking about a convex (converging) lens, the algebraic sign of the focal length would be positive.

Question 5 **20 of 20 points**

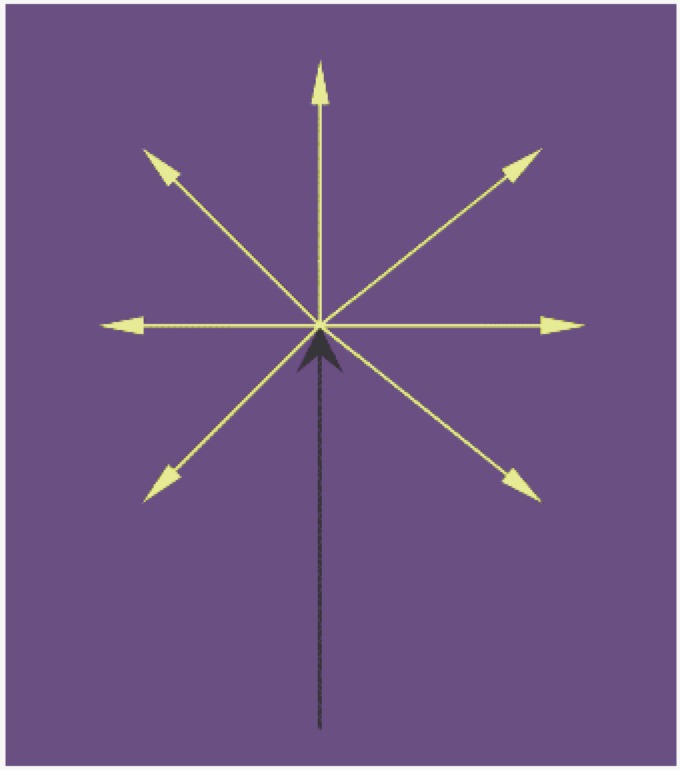
Which is true of the light from an actual physical object whose image is formed by a single thin lens?

Selected Answer: ✓ The rays of light coming from the object diverge as they approach the lens.

Correct Answer: ✓ The rays of light coming from the object diverge as they approach the lens.

Feedback: Well executed!

That's what light does when it leaves a point on an object. It diverges. Consider two (light) wave crests leaving a point on the object, at the same time, each on a different straight line path away from the point. The more time those wave crests have been traveling, the farther they are, not only from their common point of origin, but from each other.



This is a geometric effect, more a property of space than of light. Consider two people starting, as close as possible, from the same point in the middle of a flat level field. Let each walk away from the starting point along a different straight line. Even if the angle between the two lines is small, the farther the people walk away from their common starting point, the farther they are from each other. We say that the lines the two people are walking along diverge from each other, just as light rays from one and the same point on an object diverge from each other.

OK

Review Assessment: q30

Name: q30

Status : Completed

Score: 20 out of 100 points

Instructions:

Question 1 — **0 of 20 points**

What is linear charge density? (Choose the one BEST answer.)

Selected Answer: ✗ It is the charge density that lies along a line.

Correct Answer: ✓ In the case of a distribution of charge in which all the charge is on a line, it is the charge-per-length characterizing any element of the line (with units of Coulombs per meter).

Feedback: Note that the answer "In the case of a distribution of charge in which all the charge is on a line, it is the total amount of charge on that line divided by the length of the line" is okay for the case of a uniform charge distribution, but, for any other kind of charge distribution (e.g. where the charge is more "bunched up" in some regions along the line than it is in other regions) the total charge divided by the total length just gives the average linear charge density rather than the charge density itself.

Question 2 — **20 of 20 points**

A linear charge distribution of linear charge density $\lambda(x')$ extends from $x' = 0$ to $x' = L$ on the x-axis of a Cartesian coordinate system. A student is asked to find the electric field as a function of x, valid for points on the x-axis at points for which $x > L$.

Notes:

a) x' and x are both used as the position variable for points on the x-axis. x' is used to specify the position of a bit of the charge that is causing an electric field to exist elsewhere, whereas x is used to specify the location at which the electric field (due to all the charge) is being calculated.

b) $\lambda(x')$ is to be read "lambda of x-prime" indicating that the linear charge density is a function of position.

The student arrives at the following integral for the x-component of the electric field at x, in the course of solving the problem:

$$E_x(x) = k\int_0^L \frac{\lambda(x')}{(x - x')}$$

Is there anything that is obviously wrong with the integral?

Selected Answer: ✓ Yes.

Correct Answer: ✓ Yes.

Feedback: Nice work.

The given integral is obviously in error because it has no differential in it. It must, must, must include *dx´* .

Every integral must include a differential. In the case at hand *dx´* must appear under* the integral sign. A differential is an infinitesimal (something that is vanishingly small). An integral is a sum of an infinite number of terms. If the terms are finite (not vanishingly small but not infinite either) then the infinite sum will yield infinity. For the infinite sum to be finite, each term must include an infinitesimal (the differential). Without a differential, an integral is nonsense.

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*The word "under" is not to be taken literally in the expression "under the integral sign". The integral sign is the integral sign with or without limits of integration. That which is considered to be under the integral sign is that which immediately follows the integral sign up to the end of the expression.

More jargon: Every integral must include the integral sign $\int$ (with or without limits) and a differential; the rest of the integral is called the *integrand*. The integral sign is always the first item in an integral. Typically, but not always (the differential can actually be written anywhere to the right of the integral sign) the differential is the last item (reading from left to right) in an integral. In such cases, the integrand is everything between the integral sign and the differential. The integrand is a function of the variable of integration (the variable appearing after the *d* in the differential).

The integrand is the function that is being integrated.

The expression, " The integral is an integral over *x´* " means that *x´* is the variable of integration.

Question 3 **0 of 20 points**

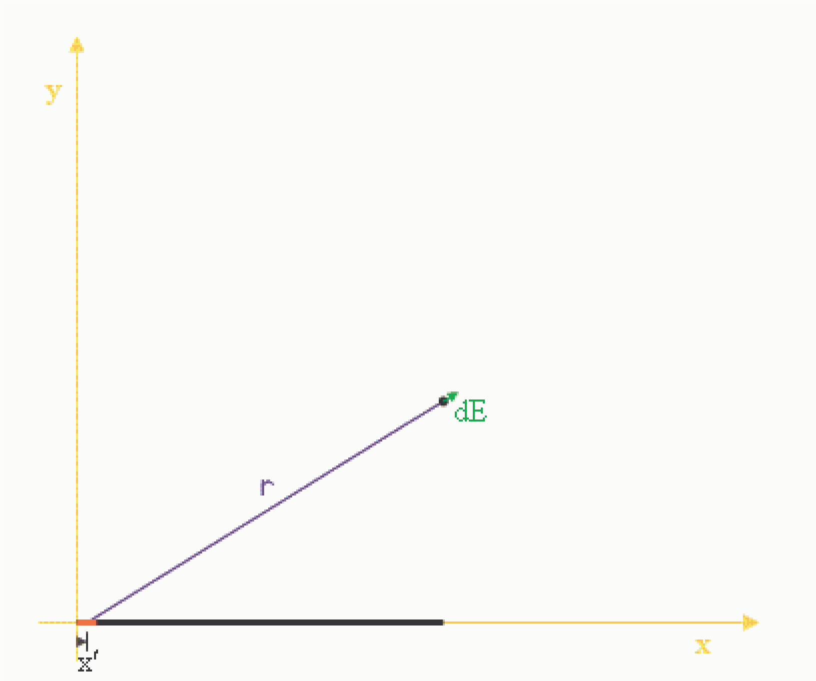
Suppose you are asked to find the electric field at point P, whose coordinates are (L,y) for the case of a uniform line segment of charge, which extends from x=0 to x=L on the x axis of a Cartesian coordinate system. One must integrate Coulombs law for the electric field at point P due to each charge dq on the line segment. In the denominator of the integrand is a the square of a distance (written as r^2 in Coulomb's Law). In Coulombs law for the electric field due to a point charge, the distance in question is the distance from the point charge to the point in space at which the electric field is being calculated. What distance do we use for the distance in question in the integrand?

Selected Answer: ✗ The distance from the left end of the linear charge distribution to point P.

Correct Answer: ✓ None of the above.

Feedback: The integral is the sum of the contributions to the electric field at point P, due to each infinitesimal bit of charge on the line segment. The distance in question is different for each bit of charge. For each infinitesimal bit of charge, the distance in question is the distance from the infinitesimal bit of charge to point P.

The following (incomplete, looping) gif animation shows how the distance in question (labeled *r* in the diagram) varies with the position of the infinitesimal bit of charge whose contribution to the electric field is under consideration.



Question 4 **0 of 20 points**

In calculating the electric field, at some point P in the x-y plane of a Cartesian coordinate system, due to a linear charge distribution in the x-y plane, each contribution to the electric field at point P, from each infinitesimal element of the charge distribution, is a vector.

Hence, to find the total electric field $\vec{E}$, one must do a vector sum of an infinite number of infinitesimal vectors $d\vec{E}$. How does one deal with such an enormous vector addition problem?

Selected Answer: ✗ The premise of the question is wrong. The electric field is a scalar, not a vector.

Correct Answer: ✓ None of the other answers is correct.

Feedback: Nice job.
What one does is to find the x-component of the electric field at point P due to an infinitesimal element of the linear charge distribution and sum up all such x-components to get the total x-component. A second, similar procedure yields the total y-component of the electric field at point P. The two components of $\vec{E}$ can be added like vectors to yield the total electric field.

Question 5 **0 of 20 points**

A student is asked to find the x-component of the electric field on the x-axis, due to charge Q that is uniformly distributed along a line segment that extends along the y-axis from y=0 to y=L. The student has worked hard to arrive at the expression

$$E_x = \int_0^L k \frac{Q}{L(y' + x)} dy'$$

and would like to do a quick check to see if it has the right units before actually doing the integral. (If the units don't work out, the expression is wrong.) Is there such a check, and, if so, does the check show that the expression has the correct units or does it show that the expression has the incorrect units?

Selected Answer: ✗ No. One cannot check the units in the given expression.

Correct Answer: ✓ Yes. One can do a units check. The expression fails the units check.

Feedback:

The check can be done rather quickly. From Coulomb's law for the electric field

$$E = \frac{kq}{r^2}$$

it is clear that the electric field has units of k times units of charge divided by units of length-squared.

In the given expression

$$E_x = \int_0^L k \frac{Q}{L(y' + x)} dy'$$

it is important to recognize that dy' has units of length (e.g. meters). The integration symbol $\int_0^L$ has no units. Hence the given expression has units of k times units of charge times *units of length* divided by units of length-squared. There is an extra "*units of length*" in this expression (as compared to Coulomb's law for the electric field) so the units do not work out. The expression is incorrect.

Units checking is an activity which falls under the heading of "dimensional analysis". An expression for which the units do not work out is said to be "dimensionally inconsistent". The student was wise to check the units before doing the integral.

OK

Review Assessment: q31

Name: q31

Status : Completed

Score: 20 out of 100 points

Instructions:

Question 1 **0 of 20 points**

In terms of the conventional graphical representation of an electric field, which of the following conceptual statements best represents what is meant by "the electric flux through a closed surface"?

Selected Answer: ✗ It is the algebraic sum of the number of electric field line passages through the surface where a passage of one line through the surface counts as +1 passage whether the passage is from inside to out or from outside to in.

Correct Answer: ✓ It is the algebraic sum of the number of electric field line passages through the surface where a passage of one line through the surface from inside to outside counts as +1 passage, whereas, a passage of one line through the surface from outside counts as –1 passage.

Feedback:

Recalling that the density of the electric field lines (how closely packed they are drawn) in an electric field diagram corresponds to the magnitude of the electric field $\vec{E}$, and that the direction in which they point corresponds to the direction of the electric field $\vec{E}$, we can turn the tables and consider $\vec{E}$ itself to be a measure of the direction and density of the electric field lines. Consider a surface that is perpendicular to the electric field $\vec{E}$. Where the electric field passes through that surface, a measure of the density of electric field lines would be the number-of-field-lines-per-area. Conceptually, E is this measure of the density of the electric field lines. Thus, for an infinitesimal area element dA, the dot product $\vec{E}\cdot d\vec{A}$, which we call the flux through dA is, conceptually, the number of electric field lines passing through the area element dA as long as we consider the vector $d\vec{A}$ to be a vector with magnitude dA and direction normal to the area element itself and outward (assuming dA to be an area element of a closed surface so that "outward" has meaning). The dot product can be written as $E\,dA\cos\theta$ with θ being the angle between $\vec{E}$ and $d\vec{A}$ thus making $dA\left|\cos\theta\right|$ the component of the area element dA that is perpendicular to $\vec{E}$. Adding up the outward flux through the entire closed surface that we have assumed dA to be a part of, we reach the understanding that, conceptually, the total flux, $\oint\vec{E}\cdot d\vec{A}$, representing said "adding up" of outward flux, can be interpreted as the total number of outward-directed electric field lines through the closed surface under discussion.

Question 2 **20 of 20 points**

What are the units of electric flux?

Selected Answer: ✓ Nm^2/C

Correct Answer: ✓ Nm^2/C

Feedback: Nice work.

The defining equation for electric flux is

$$\Phi_E = \oint \vec{E} \cdot d\vec{A}$$

The electric field $\vec{E}$ is force-per-charge and hence has units of N/C. The area element $d\vec{A}$ is just that, an area, and as such, has units of m^2. Neither the fact that $d\vec{A}$ is an *infinitesimal* area element, nor the fact that it is a vector, has anything to do with its units. An area is an area whether it be infinitesimal, finite, or infinite and the SI units of area are m^2. No integral sign has units so the units of electric flux are (N/C) times m^2 which can be written Nm^2/C.

Question 3 **0 of 20 points**

What kind of integral is

$$\oint \vec{E} \cdot d\vec{A}$$

(the integral which appears in the defining equation for electric flux $\Phi_E = \oint \vec{E} \cdot d\vec{A}$ and in Gauss's law $\oint \vec{E} \cdot d\vec{A} = \frac{Q_{IN}}{\epsilon_o}$)?

Selected Answer: ✗ A line integral.

Correct Answer: ✓ An integral over a surface.

Feedback: The integral in Gauss's Law is an integral over* a closed surface, an imaginary shell which completely encloses some region, some volume, of space. As such, the integral is an integral over an area.

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*The word "over" in this context is mathematical jargon. It means "involving every element of". Thus, an integral over x from 0 to L is an integral involving every element of that part of the x axis extending from 0 to L. More to the point, for the case at hand, the fact that the integral

$$\oint \vec{E} \cdot d\vec{A}$$

is an integral over an area means that it is an integral involving every area element of a surface. (Note that the little circle on the integral sign means that the surface in question is a closed surface.)

Question 4 **0 of 20 points**

The area element that appears in the integral $\oint \vec{E} \cdot \vec{dA}$ is a vector. Area, as an amount of "coverage" would seem to be a scalar quantity. What is the direction of the area element $\vec{dA}$?

Selected Answer: ✗ The direction of the area element is defined to be the direction along one edge of the area element.

Correct Answer: ✓ The direction is the direction in which the area is facing. For a closed surface this actually only narrows it down to two possible directions, the area element could be said to be facing inward (toward the inside region of the closed surface), and, the it could be said to be facing outward. So, to be more specific, the direction of the area element is the outward direction in which the area is facing.

Feedback: The area element direction is perpendicular to the surface of the area element and outward. This is exactly what is meant by "the outward direction in which the area element is facing".

Question 5 **0 of 20 points**

3.50 nC of charge is uniformly distributed in a solid Styrofoam ball of radius 2.00 cm centered at x = 2.00 cm on the x-axis of a Cartesian coordinate system. –1.25 nC of charge is uniformly distributed on a fiberglass spherical shell of radius 5.00 cm centered on the origin of the same coordinate system. What is the value of the electric flux through an imaginary spherical shell of radius 6.00 cm centered on the origin of the coordinate system in question.

Selected Answer: ✗ 2.25 nC

Correct Answer: ✓ None of the above.

Feedback:

First off, please recall that a nC is $1 \times 10^{-9}\,\mathrm{C}$ (exactly, where the C stands for coulombs).

Now take a look at the two Gauss's-Law-related equations on your formula sheet. The defining equation for electric flux:

$$\Phi_E = \oint \vec{E} \cdot d\vec{A}$$

and Gauss's law itself:

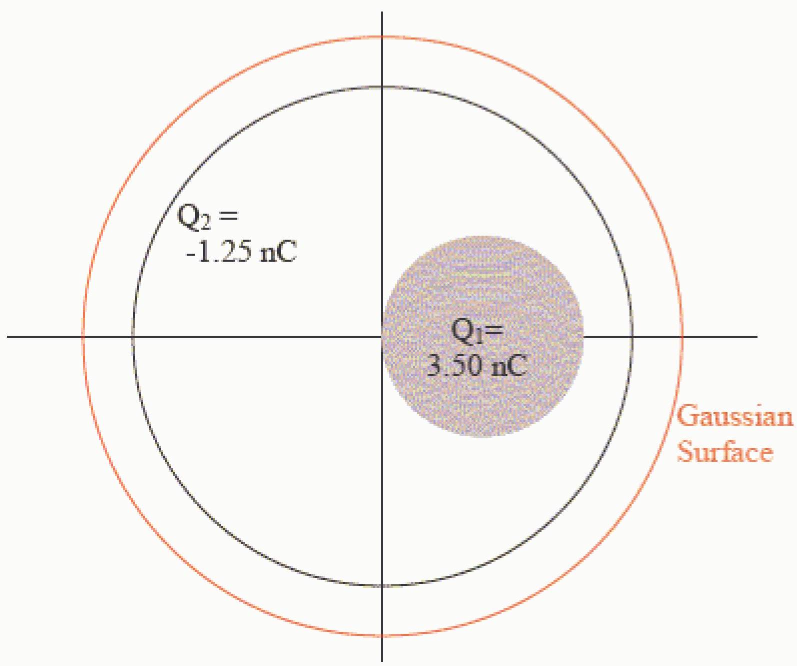
$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{\mathrm{IN}}}{\epsilon_{\mathrm{o}}}$$

These two equations can be combined so that Gauss's law appears as:

$$\Phi_E = \frac{Q_{\mathrm{IN}}}{\epsilon_{\mathrm{o}}}$$

This is a cause and effect equation written in reverse. The cause is on the right and the effect is on the left. Charge within an imaginary closed surface causes electric flux through that surface.

This cause and effect equation known as Gauss's Law gives us a way to calculate the flux through a closed surface in a way that is much easier than actually doing the integral; namely; add up the charge inside the closed surface and divide that sum by the constant ϵ_{o}.



In the case at hand, both charged objects are completely enclosed by the Gaussian surface in question (the imaginary surface through which we are supposed to determine the flux). Thus:

$$Q_{\mathrm{IN}} = Q_1 + Q_2$$

OK

Review Assessment: q32

Name: q32

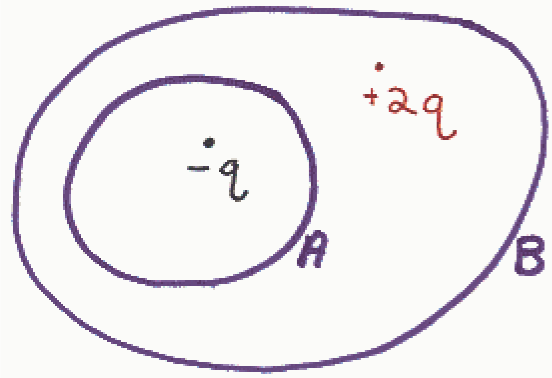
Status : Completed

Score: 40 out of 100 points

Instructions:

Question 1 **20 of 20 points**

In the diagram below, the closed curves A and B represent closed surfaces. What is the total flux through the closed surface A?



Selected Answer: ✓ $-\frac{q}{\varepsilon_0}$

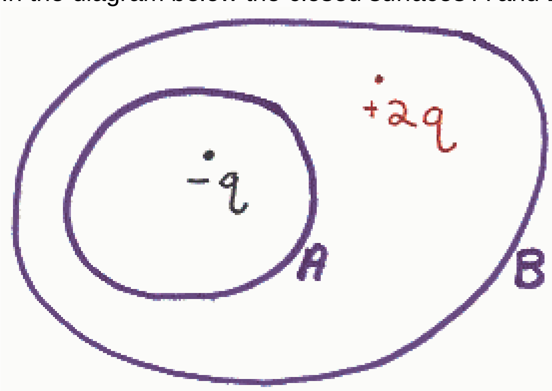
Correct Answer: ✓ $-\frac{q}{\varepsilon_0}$

Feedback: Nice work.

In accord with Gauss's Law, the net outward flux through a closed surface is equal to one-over-epsilon-zero times the charge enclosed by that surface.

Question 2 **0 of 20 points**

In the diagram below the closed surfaces A and B appear as closed curves. Find the flux through closed surface B.



Selected Answer: ✗

$-\frac{q}{\varepsilon_0}$

Correct Answer: ✓

$\frac{q}{\varepsilon_0}$

Feedback:

Inside surface B we have two charged particles, one with charge +2q and the other with charge -q. Adding these up we get +q for the total amount of charge enclosed by surface B.

Now by Gauss's Law, the total outward electric flux Φ_E through the closed surface B, is $\frac{1}{\epsilon_0}$ times the charge enclosed by the surface, which, in this case yields:

$$\Phi_E = \frac{1}{\epsilon_0} q$$

which can of course be written

$$\Phi_E = \frac{q}{\epsilon_0}$$

Question 3 **0 of 20 points**

Gauss's Law

$$\oint \vec{E} \cdot \overrightarrow{dA} = \frac{Q_{IN}}{\epsilon_0}$$

can be considered a "cause and effect" equation. When so considered, on which side of the equation is the "cause" and on which side is the "effect?"

Selected Answer: ✗ The cause is on the left and the effect is on the right.

Correct Answer: ✓ The cause is on the right and the effect is on the left.

Feedback: Gauss's law is a statement that "charge causes electric field." (It is more than that too--it is a relation between the charge and the electric field.) As written above, we have the charge, the cause of the electric field, on the right and the effect, the electric field itself, on the left. To be sure, the electric field is inside the integral on the left. The integral is the flux. By causing the electric field to exist at the Gaussian surface enclosing the charge, the charge also causes electric flux through that surface.

Question 4 **0 of 20 points**

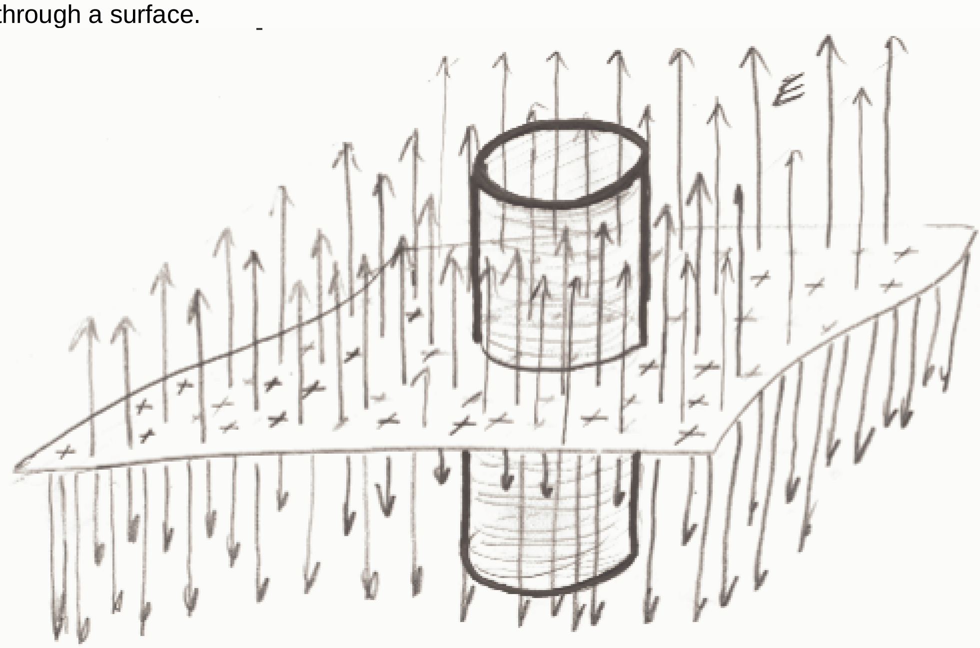
Consider charge of uniform surface density (charge-per-area) everywhere on an infinite horizontal plane. In calculating the electric field due to such a charge distribution one can use a Gaussian surface in the shape of a tin can whose top is above and parallel to the plane in question and whose bottom is below and parallel to the plane.

How can one tell that the electric flux through the walls of the can is zero? (If you remove the top of a can and the bottom of the can, that which is left, a piece that looks like a short length of pipe, is what we are calling the "walls" of the can.)

Selected Answer: ✗ At any point on the walls of the can, due to symmetry, the electric field through one side of the can will be equal but opposite to the electric field through the other side of the can, thus the two contributions to the flux cancel each other out, yield a total flux of zero.

Correct Answer: ✓ The electric field is parallel to the surface of the walls of the can, hence no electric field lines are poking through the walls of the can.

Feedback: Keep in mind that the "can" is an imaginary surface. No electric field lines "poking through" the surface means no flux. This way of looking at it shows a strong conceptual understanding of the outward flux through a surface.



One can also look at it more mathematically. The flux is

$$\oint \vec{E} \cdot d\vec{A}$$

Recalling that the direction associated with any area element $d\vec{A}$ of the wall of the can is perpendicular to the wall of the can. From the diagram above, one can deduce that any such vector is perpendicular to the electric field. Hence the dot product $\vec{E} \cdot d\vec{A}$ appearing in the integral above for the flux, is zero for every area element $d\vec{A}$. Thus, the integral itself has to be zero.

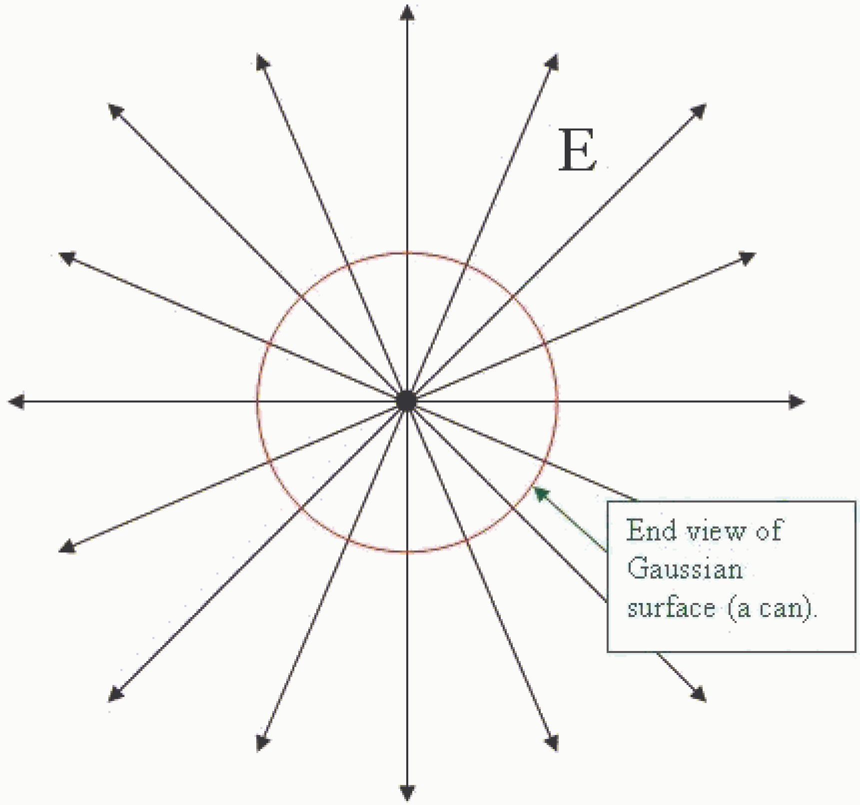
Question 5 **20 of 20 points**

Which of the following would be a good choice of a Gaussian surface to use to find an expression for the electric field due to an infinite line of positive charge with a uniform linear charge density.

Selected Answer: ✓ A can whose axis of symmetry lies on the line of charge.

Correct Answer: ✓ A can whose axis of symmetry lies on the line of charge.

Feedback: Well done.
Note that the axis of symmetry of a can is a line passing through the center of both the top and bottom of the can. Here is an end view of the line of charge. It is a bit hard to imagine looking at the actual line of charge from this point of view since the line of charge extends to infinity in both directions, but, we picture it from an end view nonetheless, and recognize that, from that point of view, the line of charge, extending both directly toward us and directly away from us, looks like a dot.



The pattern of the electric field has already been drawn to the extent that it can be established based on symmetry. Symmetry arguments can be used to establish the fact that the electric field is everywhere perpendicular to the line of charge, and, that the magnitude of the electric field is the same at all points that are one and the same distance from the line of charge. Thus the can is the ideal Gaussian surface. The integral

$$\oint \vec{E} \cdot d\vec{A}$$

can essentially be done by inspection. The fact that the choice of a can whose axis of symmetry is on the line of charge makes it so that the integral can be done by inspection is what makes the so-called "can" the ideal choice for the Gaussian surface for the uniform infinite linear charge distribution.

OK

Review Assessment: q33

Name: q33

Status : Completed

Score: 20 out of 100 points

Instructions:

Question 1 — **0 of 20 points**

Why is it generally considered easier to determine the electric potential at a given point in space or at a given set of points in space due to a continuous charge distribution than it is to determine the electric field at the same point or set of points in space due to the same charge distribution?

Selected Answer: ✗ The electric potential can be determined algebraically whereas to determine the electric field, calculus is required.

Correct Answer: ✓ The electric potential is a scalar quantity whereas the electric field is a vector quantity.

Feedback: In the case of the electric field, every infinitesimal element of the source charge makes a contribution to the electric field at the point in question. Since each contribution is a vector, to find the total electric field at the point in question, one must do a vector sum of the infinite set of infinitesimal vector contributions to the electric field at that point.

Question 2 — **0 of 20 points**

Finding the electric potential due to a continuous distribution of charge involves doing an integral. An integral is an infinite sum of terms. In calculating the electric potential due to a continuous distribution of charge, what is it that one is summing? In other words, what does each term in the infinite sum represent?

Selected Answer: ✗ One sums the charge in the continuous distribution of charge so that one can use it in the formula $V = kQ/r$.

Correct Answer: ✓ Each term in the infinite sum is the electric potential, at the point at which one is calculating the electric potential, due to one infinitesimal bit of the charge in the given charge distribution.

Feedback: Each term in the infinite sum can be expressed as kdq/r where k is the Coulomb constant, dq is an infinitesimal bit of charge from the overall distribution of charge under consideration and the r is the distance from the particular bit of charge under consideration to the one point at which one is calculating the net electric potential due to every bit of charge in the charge distribution.

Question 3 — **0 of 20 points**

In the case of charge distributed on a line segment, what do we mean by the expression "linear charge density $\lambda(x)$"? Note that $\lambda(x)$ is to be read "lambda of x" meaning that the linear charge density is a function of x, where x is the position along the line segment in question.

Selected Answer: ✗ The linear charge density is the amount of charge in a meter of the line segment.

Correct Answer: ✓ The linear charge density is a charge packing index. Where λ is big, the charges are closely packed. Where lambda is small, the charges are sparsely packed.

Feedback: Any definition that starts out with "the amount of charge" has got to be wrong. Linear charge density is definitely not an amount of charge.

Dividing the total charge on the line segment by the length of the line segment does give the *average* charge density, but the average charge density is of about as much use in determining the electric potential as the average speed of a motorist who has been pulled over for doing 80 mph in a 40 mph zone is to the motorist. "But officer, I left my house at noon and it's 1 pm now. I am now 40 miles from my house, so clearly my average speed is 40 mph," does not cut it with the officer and treating the average charge density as if it were the actual charge density does not cut it in physics.

The linear charge density is indeed a charge packing index, a value (with units of course) which indicates how closely packed the charges are.

Question 4 **0 of 20 points**

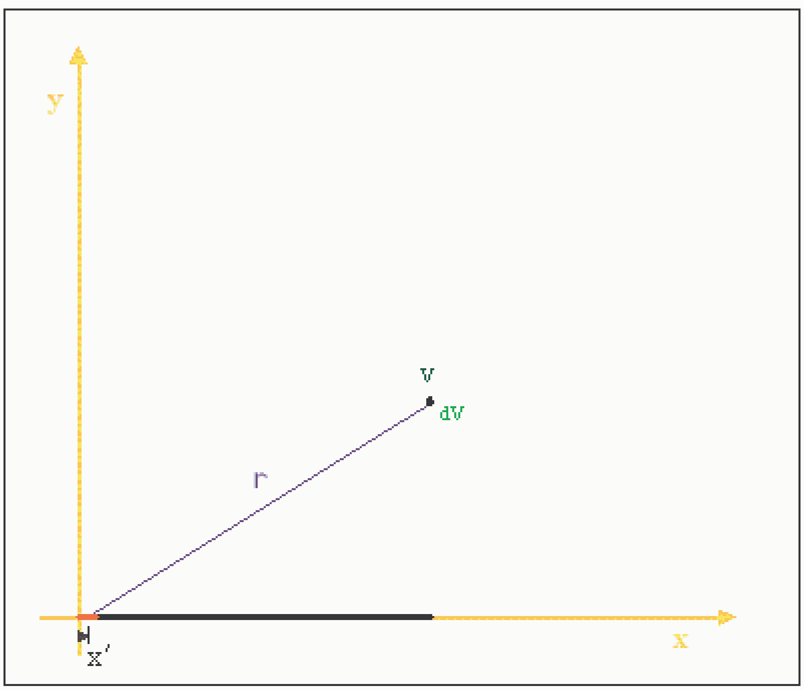
Charge Q is uniformly distributed on a line segment that extends along the x-axis of a Cartesian coordinate system from the origin to x=L. (Hey, this is one of those situations in which the linear charge density is the same everywhere on the line segment, and the linear charge density is everywhere equal to the average charge density.) One is asked to find the electric potential valid for points on the positive y-axis. What should one use for the distance "r" that appears in the equation for V below (copied directly from your formula sheet)?

$$V = \frac{kq}{r}$$

Selected Answer: ✗ *y*

Correct Answer: ✓ The r varies with the infinitesimal element of charge under consideration. For each element of charge making up the charge distribution, the "r" is the distance from that element of charge to the point (0,y).

Feedback: Let x' be the distance that a particular infinitesimal charge element is from the origin. x' is the variable of integration. x' takes on values from 0 to L. For a given charge element on the x-axis the distance r is $\sqrt{x'^2+y^2}$. Note that *r* is a function of the variable of integration.



Question 5 **20 of 20 points**

When one is calculating the electric potential at a particular point in space due to a continuous charge distribution, what exactly is one calculating?

Selected Answer: ✓ The electric-potential-energy-per-charge for the empty point in space in question.

Correct Answer: ✓ The electric-potential-energy-per-charge for the empty point in space in question.

Feedback: Nice job.

The electric potential V characterizes an empty point in space. V is a value of electric-potential-energy-per-charge. If a particle of charge q was placed at the point at which V is calculated, said particle would have potential energy qV.

OK

Review Assessment: q34

Name: q34

Status : Completed

Score: 60 out of 100 points

Instructions:

Question 1 **0 of 20 points**

Given the electric potential, as a function of the Cartesian coordinates x, y, and z; how does one determine the electric field?

Selected Answer: ✗ By means of a single integration.

Correct Answer: ✓ The x-component of the electric field is determined by taking the negative of the derivative of the electric potential with respect to x. The y-component of the electric field is determined by taking the negative of derivative of the electric potential with respect to y. The z-component of the electric field is determined by taking the negative of the derivative of the electric potential with respect to z.

Feedback: If the electric potential is known as a function of x, y, z; and one is asked to find the electric field at a specified point in space, such as at (0.14m, .25m, -1.00m) it is important to take all three derivatives first and substitute the values of x, y, and z after the components of the electric field, in terms of x, y, and z have been determined.

Question 2 **20 of 20 points**

Suppose that you are given an expression for the electric potential V(x,y) as a function of x and y valid for points in the first quadrant of a Cartesian coordinate system and asked to find the x-component of the electric field at (4.00cm,5.00cm). How do you find it?

Selected Answer: ✓ Take the negative of the derivative of V(x,y) with respect to x, holding y constant. Substitute x = 0.0400 m and y = 0.0500 m into the result, and evaluate.

Correct Answer: ✓ Take the negative of the derivative of V(x,y) with respect to x, holding y constant. Substitute x = 0.0400 m and y = 0.0500 m into the result, and evaluate.

Feedback: Nice work.

If you substitute the given values of x and y into V(x,y) first, the result is a constant. The derivative of a constant is always zero.

A side note. The given values are written with three significant figures. Upon converting them to meters, they should still have three significant figures.

Given the coordinates (4.00cm,5.00cm) with three significant figures, write them with three significant figures as (0.0400m,0.0500m), **not** with two significant figures as (0.040m,0.050m) and **not** with one significant figure as (0.04m,0.05m).

Question 3 **0 of 20 points**

Consider a Cartesian coordinate system on which the electric potential due to an unspecified distribution of charge is a function of x only. A graph is made of V(x) vs. x. The electric field, at a particular value of x, is what characteristic of the graph?

Selected Answer: ✗ The slope of the curve at the value of x in question.

Correct Answer: ✓ None of the other answers are correct.

Feedback: E_x = -dV/dx which is the negative of the slope of V vs. x.

Question 4 **20 of 20 points**

Is it possible for the electric field to be non-zero at a point in space where the electric potential is zero?

Selected Answer: ✓ Yes

Correct Answer: ✓ Yes

Feedback: Excellent.

Consider for instance the case of an electric potential given that is only a function of x and is given by:

V(x) = 5volts - (5volts/m)x

V is thus 0 at x=1m but E_x = -dV/dx which is 5 volts/m everywhere, including at x=1m. Hence, V being zero does not mean that E is zero.

Question 5 **20 of 20 points**

The x-component of the electric field characterized by an electric potential V(x,y,z) can be expressed as -dV/dx holding y and z constant. This would suggest that the units of E would be the units of V divided by the units of x, that is, in SI units, volts per meter. Are the units of E volts per meter? If not, what is wrong with the argument above?

Selected Answer: ✓ Yes.

Correct Answer: ✓ Yes.

Feedback: Well done.

dV is an infinitesimal electrical potential difference. It may be infinitesimal, but the difference between two values of electric potential has the same units as a single value of electric potential, namely volts, whether it is infinitesimal or not. A similar case can be made for the infinitesimal difference in position dx. The quantity dx is a distance, infinitesimal though it may be. As such, it has units of distance. Note that the units of electric field are indeed N/C but this does not rule out V/m as units of electric field. In fact a volt is a J/C, and, since a joule is a Nm, a volt is also a Nm/C. Replacing the V (volts) with Nm/C in the units V/m (volts per meter) yields (Nm/C)/m which is equivalent to N/C, the SI units that we normally think of the electric field as having. In summary a V/m is a N/C so the argument that E can't have units of V/m because it has units of N/C is clearly wrong.

OK

Review Assessment: q35

Name: q35

Status : Completed

Score: 40 out of 100 points

Instructions:

Question 1 **0 of 20 points**

Given the expression below valid for points in the x-y plane, what is the y-component of the electric field valid for points on the y-axis?

$$V = \frac{kQ}{L}\ln\left[\frac{L - x + \sqrt{(L-x)^2 + y^2}}{-x + \sqrt{x^2 + y^2}}\right]$$

Selected Answer: ✗

$$-\frac{kQ}{Ly}$$

Correct Answer: ✓

$$\frac{kQ}{L}\left[\frac{1}{y} - \frac{y}{L^2 + y^2 + L\sqrt{L^2 + y^2}}\right]$$

Feedback: Way to go!

$$V = \frac{kQ}{L}\ln\left[\frac{L - x + \sqrt{(L-x)^2 + y^2}}{-x + \sqrt{x^2 + y^2}}\right]$$

$$V = \frac{kQ}{L}\ln\left\{L - x + \left[(L-x)^2 + y^2\right]^{1/2}\right\} - \frac{kQ}{L}\ln\left[\left(x^2 + y^2\right)^{1/2} - x^2\right]$$

$$E_y = -\frac{\partial V}{\partial y}$$

$$E_y = -\frac{kQ}{L}\left\{L - x + \left[(L-x)^2 + y^2\right]^{1/2}\right\}^{-1}\frac{1}{2}\left((L-x)^2 + y^2\right)^{-1/2} 2y$$
$$- - \frac{kQ}{L}\left[\left(x^2 + y^2\right)^{1/2} - x^2\right]^{-1}\frac{1}{2}\left(x^2 + y^2\right)^{-1/2} 2y$$

$$E_y = -\frac{kQy}{L}\left\{L - x + \left[(L-x)^2 + y^2\right]^{1/2}\right\}^{-1}\left((L-x)^2 + y^2\right)^{-1/2}$$
$$+ \frac{kQy}{L}\left[\left(x^2 + y^2\right)^{1/2} - x^2\right]^{-1}\left(x^2 + y^2\right)^{-1/2}$$

This is the expression for the y-component of electric field valid at all points in space. We are asked for the y-component of the electric field on the y-axis, that is to say, at x=0. Before simplifying the above expression any further, we go ahead and substitute x=0.

$$E_y(0, y) = -\frac{kQy}{L}\left\{L + \left[L^2 + y^2\right]^{1/2}\right\}^{-1}\left(L^2 + y^2\right)^{-1/2} + \frac{kQy}{L}\frac{1}{y}\frac{1}{y}$$

$$E_y(0, y) = \frac{kQ}{Ly}\left\{1 - \frac{y^2}{\left(L + \sqrt{L^2 + y^2}\right)\sqrt{L^2 + y^2}}\right\}$$

$$E_y(0, y) = \frac{kQ}{Ly}\left\{1 - \frac{y^2}{L^2 + y^2 + L\sqrt{L^2 + y^2}}\right\}$$

Question 2 **20 of 20 points**

Is it possible for the electric field to be zero in a region of space where the electric potential is not zero?

Selected Answer: ✓ Yes

Correct Answer: ✓ Yes

Feedback: Excellent!
As long as the electric potential has one and the same value throughout a region of space,

$-\frac{\partial V}{\partial x}$, $-\frac{\partial V}{\partial y}$, and $-\frac{\partial V}{\partial z}$ are all zero (and these are E_x, E_y, E_z respectively) so E is zero. Consider for instance a solid, perfectly-conducting sphere, at an electric potential of 125 volts. We know that the electric field everywhere inside the sphere is zero. Furthermore, the value of 125 volts is the value of electric potential at every point in and on the sphere. Thus, the space occupied by a solid conducting sphere at an electric potential of 125 volts represents an example of a case in which the electric potential is not zero while the electric field is zero.

Question 3 **0 of 20 points**

Consider a volume of space in which the electric potential is 125,000 volts (at every point in the volume of space). What is the electric field in that region of space.

Selected Answer: ✗ The electric field is downward and is equal to 125,000 volts divided by the height of the volume.

Correct Answer: ✓ 0.

Feedback: In any region of space we can establish a Cartesian coordinate system. In terms of the position variables x, y, z of that coordinate system, the electric field components E_x, E_y, and E_z depend on the electric potential V as:

$$E_x = -\frac{\partial V}{\partial x}$$

$$E_y = -\frac{\partial V}{\partial y}$$

$$E_z = -\frac{\partial V}{\partial z}$$

Because V is a constant*, all three derivatives yield zero. This means that every component of the electric field is zero. If every component of the electric field is zero, then the electric field is zero.

Question 4 **20 of 20 points**

What does it mean to say that the electric potential is a function of x only. More specifically, what does the equipotential diagram (in 3-dimensional space) look like in the case of an electric potential that is a function of x only.

Selected Answer: ✓ The equipotential diagram is a set of planes parallel to the y-z plane.

Correct Answer: ✓ The equipotential diagram is a set of planes parallel to the y-z plane.

Feedback: Nice work.

An equipotential diagram is a picture indicating, for each value from a set of values of electric potential, that region of space for which all points have that value of electric potential.

When we say that the electric potential depends on x only we are saying that all those points in space whose coordinates have one and the same value of x will have one and the same value of electric potential. In other words, for a given value of x, the electric potential will have a certain value, no matter what the values of y and z are.

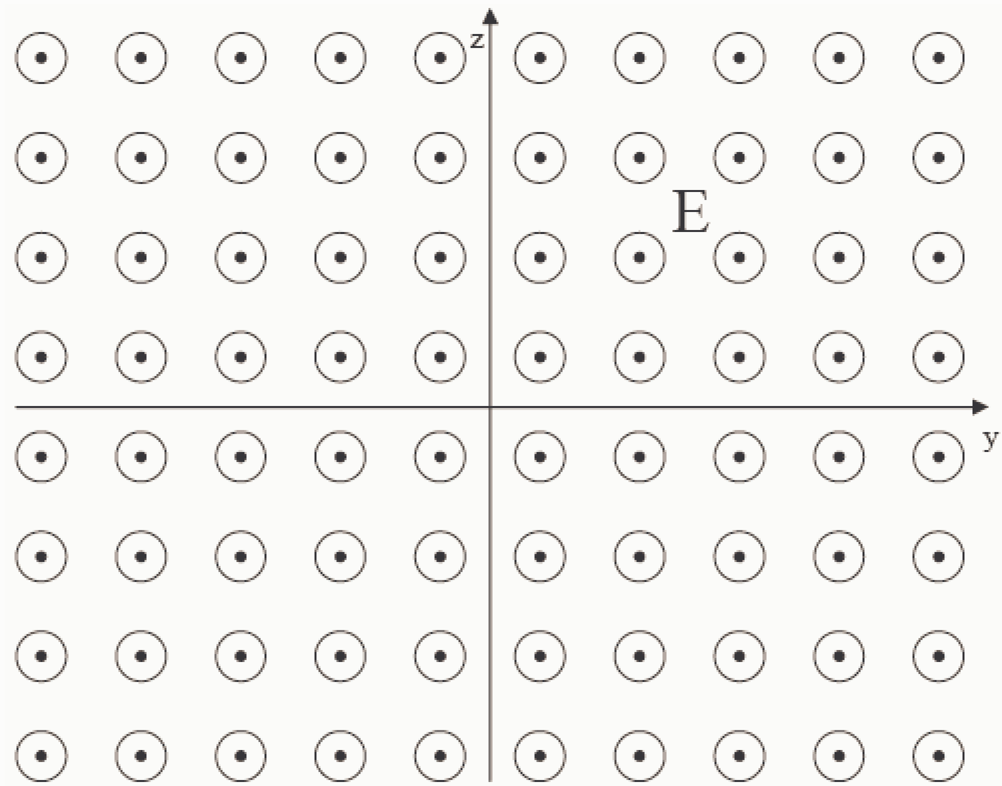
Now the locus (the infinite set) of points in space that all have the same x coordinate, form a plane that is parallel to the y-z plane and is in fact a distance x from the y-z plane. Since all these points have one and the same value of electric potential, the equipotential regions in the case of a potential which is a function of x only, are planes, parallel to the y-z plane.

Question 5 **0 of 20 points**

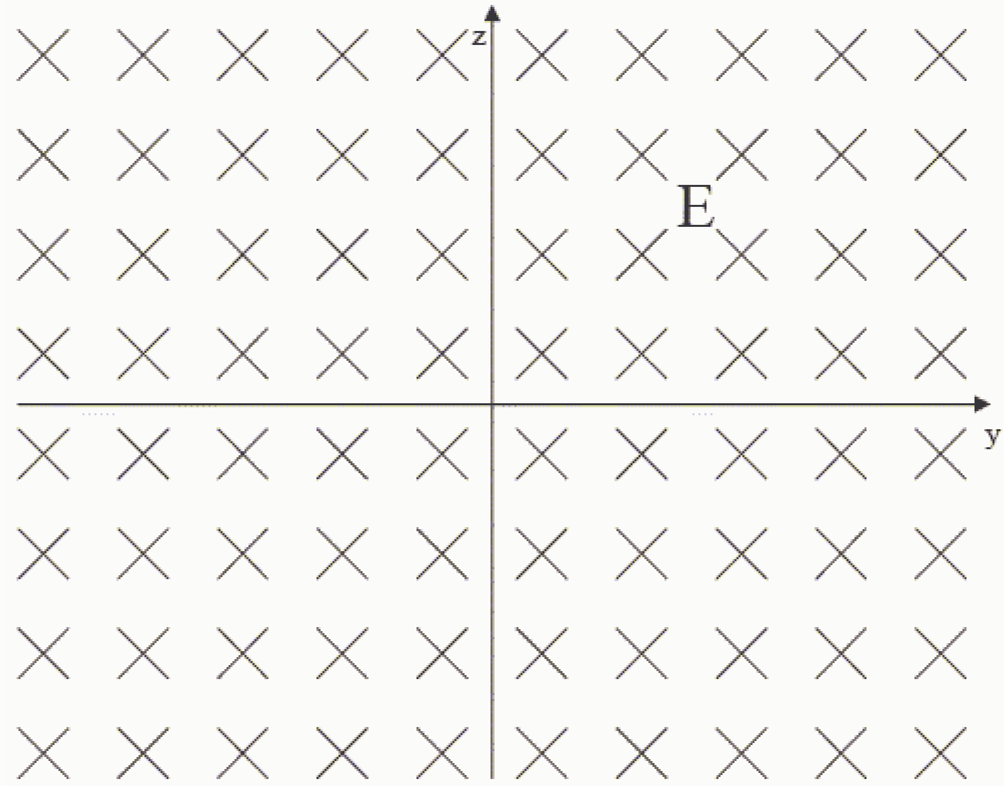
Draw the electric field diagram, as viewed by a person positioned on the positive x-axis who is looking back toward the origin for the case of an electric field characterized by the electric potential:

$$V = 5.00\,\frac{\text{volts}}{\text{meter}}\,x$$

Selected Answer: ✗



Correct Answer: ✓



Feedback:

$E_x = -\frac{\partial V}{\partial x}$, $E_y = -\frac{\partial V}{\partial y}$, and $E_z = -\frac{\partial V}{\partial z}$ yield, for the given V,

E_x = -5.00 volts/meter,
E_y = 0, and,
E_z = 0.

So the electric field, everywhere, is in the negative x direction.

OK

Review Assessment: q36

Name: q36

Status : Completed

Score: 60 out of 100 points

Instructions:

Question 1 — **20 of 20 points**

The integral in Ampere's Law (see the equation below) is an integral...

$$\oint \vec{B} \cdot d\vec{\ell} = \mu_o I$$

Selected Answer: ✓ along a path.

Correct Answer: ✓ along a path.

Feedback: Nice work.

The integral is an integral over (along) a closed path (curve).

Question 2 — **20 of 20 points**

In evaluating the integral one evaluates in applying Ampere's Law one is

Selected Answer: ✓ evaluating an infinite sum over different points in space at which there exists a magnetic field due to a current in a wire that, in many cases, does not occupy any of these points in space.

Correct Answer: ✓ evaluating an infinite sum over different points in space at which there exists a magnetic field due to a current in a wire that, in many cases, does not occupy any of these points in space.

Feedback: Way to go.

The integral in Ampere's Law is a path integral. The path is an imaginary closed curve.

Question 3 — **0 of 20 points**

Conceptually, Ampere's Law,

$$\oint \vec{B} \cdot d\vec{\ell} = \mu_o I$$

is a statement of the fact that:

Selected Answer: ✗ A changing magnetic field causes an electric field.

Correct Answer: ✓ An electric current causes a magnetic field.

Question 4 — **0 of 20 points**

Ampere's Law is a relation between cause and effect. When Ampere's law is written in the form below, on which side of the equation is the cause, and on which side of the equation is the effect?

$$\oint \vec{B} \cdot d\vec{\ell} = \mu_o I$$

Selected Answer: ✗ Both the cause and the effect are on the left.

Correct Answer: ✓ The cause is on the right and the effect is on the left.

Feedback: The current, on the right hand side of the equation, causes the magnetic field (inside the integral on the left side of the equation) to exist at those points on the Amperian loop on which the integration is carried out.

Question 5 **20 of 20 points**

What is an amperian loop?

Selected Answer: ✓ The imaginary closed loop on which the integration appearing on the left side of Ampere's Law

$$\oint \vec{B} \cdot d\vec{\ell} = \mu_o I$$

is carried out.

Correct Answer: ✓ The imaginary closed loop on which the integration appearing on the left side of Ampere's Law

$$\oint \vec{B} \cdot d\vec{\ell} = \mu_o I$$

is carried out.

Feedback: Nice work.

OK

Review Assessment: q37

Name: q37

Status : Completed

Score: 20 out of 100 points

Instructions:

Question 1 **0 of 20 points**

In evaluating the integral that one evaluates in applying the Biot-Savart Law, one is

Selected Answer: ✗ evaluating an infinite sum over different points in space at which there exists a magnetic field due to a current in a wire that, in many cases, does not occupy any of these points in space.

Correct Answer: ✓ evaluating an infinite sum of the contributions to the magnetic field at one point in space due to each infinitesimal segment of the current-carrying conductor that is producing the magnetic field.

Feedback: The Biot-Savart Law itself, written in differential form, gives the infinitesimal magnetic field, at a point, call it point P, due to an infinitesimal element of current. For instance, if the magnetic field is due to a current in a thin wire, then the infinitesimal magnetic field in question is due to a specified infinitesimal length of the wire. In calculating the total magnetic field at point P, we add up the contributions from each and every infinitesimal length of the wire. We are thus integrating (summing) over the wire.

Question 2 **0 of 20 points**

What does the $\vec{r}$ in the Biot-Savart Law

$$d\vec{B} = \frac{\mu_o I \, d\vec{l} \times \vec{r}}{r^3}$$

represent?

Selected Answer: ✗ the radius of the amperian loop used in evaluating the Biot-Savart Law. It's direction is established by means of the right-hand rule.

Correct Answer: ✓ None of other answers are correct.

Feedback: The Biot-Savart Law gives the magnetic field, due to an infinitesimal piece of a current-carrying conductor, at an empty point in space a distance r from the infinitesimal piece of the current-carrying conductor. The vector $\vec{r}$ is the position vector of the empty point in space, relative to the infinitesimal piece of current-carrying conductor.

Question 3 **0 of 20 poi**

The r^3 in the denominator of the Biot-Savart Law:

$$d\vec{B} = \frac{\mu_o I \, d\vec{l} \times \vec{r}}{r^3}$$

suggests that the Biot-Savart Law is an inverse cube law. Is the magnetic field at some point P, due to an infinitesim current element, indeed proportional to the reciprocal of the cube of the distance that point P is from the current elem

Selected Answer: ✗ Yes

Correct Answer: ✓ No

Feedback:

The vector $\vec{r}$ in the numerator has magnitude r which cancels one r in the denominator. Thus, the Biot-Savart law is actually an inverse square law.

Question 4 **20 of 20 points**

What is the direction of the infinitesimal vector $d\vec{\ell}$ in the Biot-Savart Law?

Selected Answer: ✓

$d\vec{\ell}$ is in the direction of the current.

Correct Answer: ✓

$d\vec{\ell}$ is in the direction of the current.

Feedback: Well done.

Question 5 **0 of 20 points**

Points O, A, and P lie in one and the same vertical plane. Point A is 4.0 cm due east of point O. Starting at point O, one can arrive at point P by going 6.0 cm due east, and from there, 3.0 cm straight upward (not northward, upward). At point A there is an infinitesimal wire segment carrying current due east. What is the direction of the infinitesimal magnet field vector at point P produced by the current-carrying wire segment at point A?

Selected Answer: ✗ Northward.

Correct Answer: ✓ Southward.

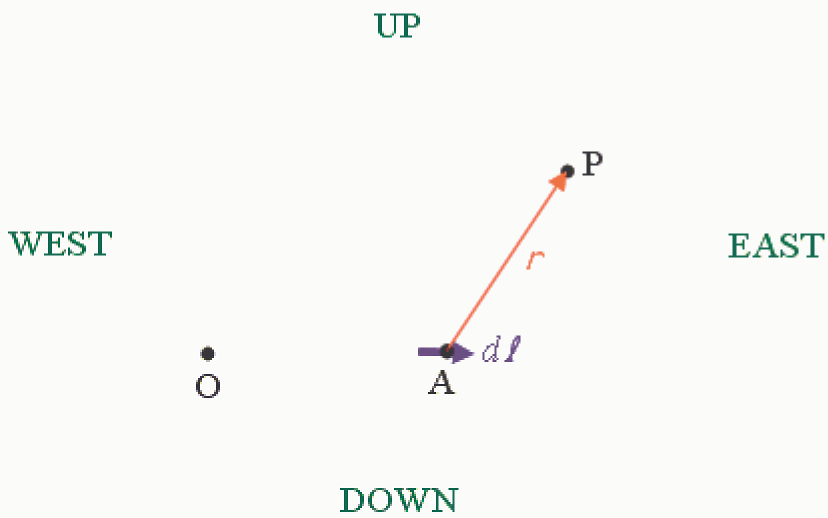
Feedback: According to the Biot-Savart Law,

$$d\vec{B} = \frac{\mu_\circ I \, d\vec{\ell} \times \vec{r}}{r^3}$$

the direction of the magnetic field is in the direction of the cross product

$$d\vec{\ell} \times \vec{r}$$

A sketch will help us determine the direction of that cross product.



Note that the viewpoint for this sketch is "looking northward". So upward is toward the top of the screen Northward is into the screen and southward is out of the screen.

Now we use the right-hand rule for the cross product of two vectors to determine the direction of the cross product.

We point the fingers of the right-hand rule in the direction of the first vector $d\vec{\ell}$. Then we rotate the hand about that direction (making sure that the fingers continue to point in the direction of $d\vec{\ell}$) until the hand is so oriented that if we close the fingers (just quickly for a test and then re-extend them) they point in the direction of the second vector, namely $\vec{r}$. We find that if the palm is facing upward (toward the top of the screen in the diagram) then the fingers do point in the direction of $\vec{r}$ when we close them (part way) With the hand thus oriented, the extended thumb points out of the screen, the direction in the diagram which we have identified as being **southward**.

OK

Review Assessment: q38

Name: q38

Status : Completed

Score: 0 out of 100 points

Instructions:

Question 1 — **0 of 60 points**

Match the name of the law with the corresponding characterization of the integration that is carried out when the law is applied.

Question	Correct Match	Selected Match
The Biot-Savart Law	D. One integrates all the contributions to the magnetic field at a given point in space of the infinite set of infinitesimal current-carrying conductor segments making up the current distribution that is causing the magnetic field.	A. One integrates all the contributions to the electric field at one point in space by all the infinitesimal bits of charge making up the charge distribution.
Gauss's Law	E. Over a closed surface one integrates the component of the electric field that is perpendicular to the closed surface treating outward directed electric field as positive and inward as negative.	A. One integrates all the contributions to the electric field at one point in space by all the infinitesimal bits of charge making up the charge distribution.
Ampere's Law	C. For all the infinitesimal segments making up an imaginary closed curve, one integrates the dot product of the infinitesimal length of segment and the magnetic field at the location of the segment.	A. One integrates all the contributions to the electric field at one point in space by all the infinitesimal bits of charge making up the charge distribution.

Feedback:

Answer A represents an application of Coulomb's-Law-for-the Electric-Field in the case of a continuous charge distribution.

Answer B is nonsense. Current causes a magnetic field, not an electric field.

Ampere's law states that the integral, along a closed loop, of $\vec{B} \cdot d\vec{l}$, is the product of the magnetic permitivity of free space μ_o, and the current through the loop. Answer C describes the integral in Ampere's law, hence, answer C matches up with Ampere's Law.

The $d\vec{B}$ in the Biot Savart Law $d\vec{B} = \frac{\mu_o}{4\pi}\frac{I\,d\vec{l} \times \vec{r}}{r^3}$ is the infinitesimal contribution, at a point in space, call it point P, to the magnetic field due to the infinitesimal length of a conductor carrying current I, where $\vec{r}$ is the position vector of point P. Summing up all such contributions to the magnetic field at point P is exactly what is described in answer D. So answer D matches up with the Biot Savart Law.

The integral $\oint E \cdot dA$ in Gauss's Law $\oint E \cdot dA = \frac{Q_{IN}}{\epsilon_o}$ is exactly what is described in answer E. Thus, answer E matches up with Gauss's Law.

Question 2 **0 of 20 points**

In calculating the electric field at a point, call it point P, in the first quadrant of a Cartesian coordinate system due to a continuous charge distribution from 0 to L on the x-axis, we must take into account the fact that each element of charge makes a vector contribution to the electric field at point P that is in a different direction than that of the vector contribution from any other charge element. The vector contributions must be added as vectors and we typically deal with this by adding the x-components of all the vector contributions to get the x-component of the total electric field at point P, then adding the y-components to get the y-component of the total electric field, and finally, putting the components together to write an expression for the total electric field.

Now suppose that we are calculating the magnetic field at point P to a wire segment that carries current along the x-axis from 0 to L. Does the fact that the contribution to the magnetic field due to each infinitesimal element of the current-carrying conductor is a vector lead to the same complications that we find in the case of the electric field due to a line segment of charge?

Selected Answer: ✗ Yes

Correct Answer: ✓ No

Feedback:

The direction of any given contribution to the magnetic field at point P is determined by the cross product $d\vec{\ell} \times \vec{r}$. Now the cross product of two vectors, when not zero, is always perpendicular to each of the vectors in the cross product, thus it is perpendicular to the plane defined by the two vectors. In the case at hand, both $d\vec{\ell}$ and $\vec{r}$ lie in the x-y plane so every $d\vec{B}$ due to the current in the wire will be in the +z or −z direction.

A bunch of vectors that are all parallel to one and the same line add like scalars. Hence, the difficulties that arise in the case of the electric field do not arise in the specified case of the magnetic field.

Question 3 **0 of 20 points**

Regarding cases involving the application of the Biot-Savart Law to calculate the magnetic field due to an electric current, which of the following statements about why it is relatively easy to calculate the magnetic field due to a circular current loop, at the center of that loop, is most correct?

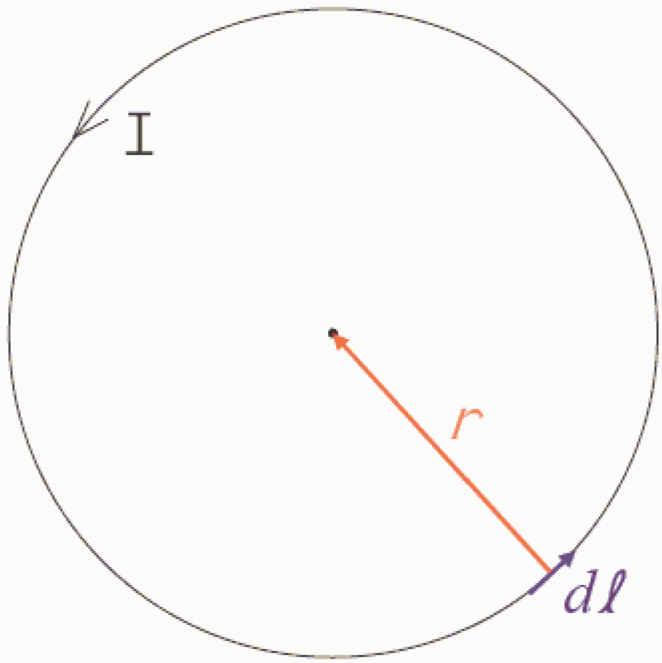
Selected Answer: ✗

The $d\vec{\ell}$ and the $\vec{r}$ in the cross product $d\vec{\ell} \times \vec{r}$ are always at right angles to each other so the magnitude of the cross product is simply $r\, d\ell$, but, one still has to deal with the fact that the vector $\vec{r}$ has a different magnitude for different elements of the current loop.

Correct Answer: ✓

For the case in question, $\vec{r}$ has the same magnitude for every current element, and, $d\vec{\ell} \times \vec{r}$ reduces to $r\, d\ell$.

Feedback:



By the definition of what a circle is, every current element is the same distance from the center of the circle, namely the radius of the circle. Hence r in this case is just the radius of the circle. Furthermore every $d\vec{\ell}$ is tangent to the circle while the vector $\vec{r}$ from the element in question to the center of the circle is along a radius. A radial vector is perpendicular to a tangential vector so the magnitude of $d\vec{\ell}\times\vec{r}$ is indeed $r\,d\ell$ for every $d\vec{\ell}$ on the circle.

Starting with the Biot-Savart Law:

$$d\vec{B} = \frac{\mu_o}{4\pi}\frac{I\ d\vec{\ell}\times\vec{r}}{r^3}$$

We have, for the magnitude of dB:

$$dB = \frac{\mu_o}{4\pi}\frac{I\ r\,d\ell}{r^3}$$

$$dB = \frac{\mu_o}{4\pi}\frac{I\ d\ell}{r^2}$$

$$\oint dB = \oint \frac{\mu_o}{4\pi}\frac{I\ d\ell}{r^2}$$

Because the r is a constant we can pull it outside the integral yielding:

$$B = \frac{\mu_o}{4\pi}\frac{I}{r^2}\oint d\ell$$

The integral of $d\ell$ is, of course, just the circumference of the circle, so:

$$B = \frac{\mu_o}{4\pi}\frac{I}{r^2}2\pi r$$

OK