From the 2018 Administration

AP® CollegeBoard

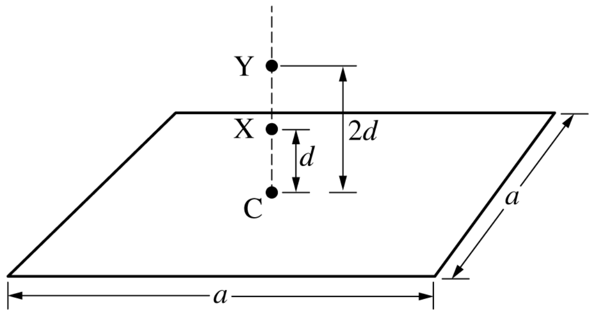
AP Physics C: Electricity and Magnetism

Practice Exam

PHYSICS C: ELECTRICITY AND MAGNETISM
SECTION I
Time—45 minutes
35 Questions

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and then fill in the corresponding circle on the answer sheet.

Questions 1-2



Note: Figure not drawn to scale.

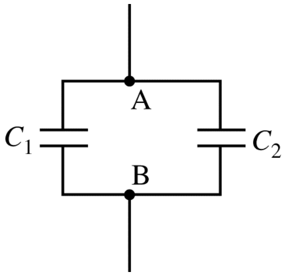
The figure above shows a thin, square, nonconducting sheet of positive charge uniformly distributed over its area. The length of each side of the sheet is a. Point C is at the center of the sheet. Point X is a distance d above the center of the sheet, and point Y is a distance $2d$ above the center of the sheet. Assume $a >> d$. The effect of gravity is negligible.

1. If the magnitude of the electric field at point X is E, what is the magnitude of the electric field at point Y?

   (A) $E/4$
   (B) $E/2$
   (C) E
   (D) $2E$
   (E) $4E$

2. A positive point charge $+q$ is released from rest at point X. If the magnitude of the electric field at point X is E, what is the kinetic energy of the charge at point Y?

   (A) qEd
   (B) $\sqrt{2}qEd$
   (C) $2qEd$
   (D) $2\sqrt{2}qEd$
   (E) $4qEd$



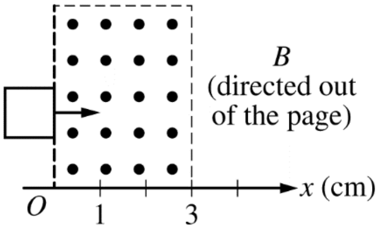
3. Capacitors C_1 and C_2 are connected as shown in the circuit above. The capacitance of C_1 is C, and the capacitance of C_2 is $C/3$. The equivalent capacitance between points A and B is C_{EQ}. A dielectric is inserted into capacitor C_2, and the equivalent capacitance between points A and B is now $2C_{\mathrm{EQ}}$. What is the value of the dielectric constant for this dielectric?

   (A) 2
   (B) 3
   (C) 4
   (D) 5
   (E) The value cannot be determined without knowing the value of C.

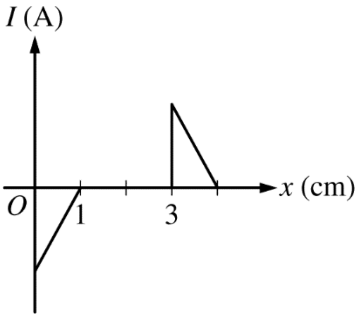
4. Which of the following could be true for a Gaussian surface through which the net flux is zero?

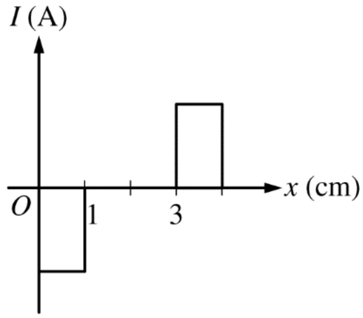
   I. There are no charges inside the surface.
   II. The net charge enclosed by the surface is zero.
   III. The electric field is zero everywhere on the surface.

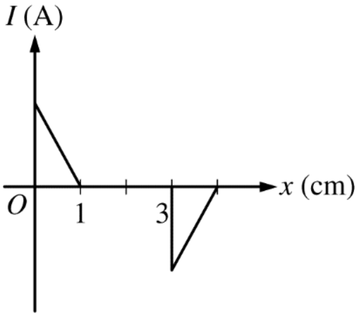
   (A) I only
   (B) II only
   (C) III only
   (D) I and II only
   (E) I, II, and III

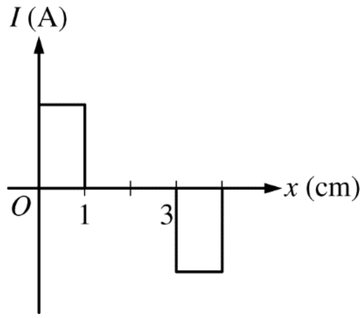


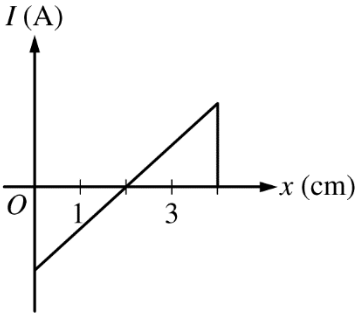
5. A square coil with sides of length 1.0 cm is moved through a region of uniform magnetic field at a constant speed, as shown in the figure above. Which of the following graphs best shows the current I in the coil as a function of the position x of the right edge as the coil moves through the magnetic field, where counterclockwise current is positive?

(A) 

(B) 

(C) 

(D) 

(E) 

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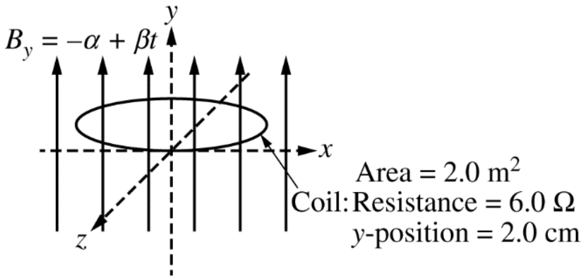
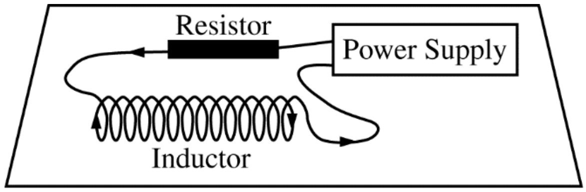


6. The y-component of the magnetic field B is given as a function of time t by the equation $B_y = -\alpha + \beta t$, where $\alpha = 4.0$ T and $\beta = 3.0$ T/s. A coil of wire with an area of $2.0\ \text{m}^2$ and a resistance of $6.0\ \Omega$ is placed in this field, parallel to the xz-plane at y= 2.0 cm. The current in the coil at time t = 1.2 s is most nearly

(A) 0
(B) 0.60 A
(C) 1.0 A
(D) 3.6 A
(E) 6.0 A



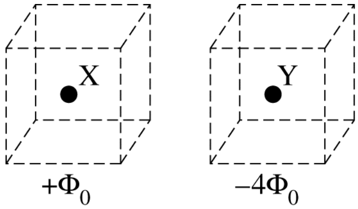
7. An inductor with inductance $L = 0.30$ H is connected in series with a resistor and both are connected to a power supply, as shown above. The power supply generates a current I that is given as a function of time t by the equation $I = I_0(1 - t/k)$, where $I_0 = 4.0$ A and $k = 2.0$ s. What is the magnitude of the potential difference across the inductor induced by the changing current?

(A) 0.15 V
(B) 0.30 V
(C) 0.60 V
(D) 1.2 V
(E) 2.4 V

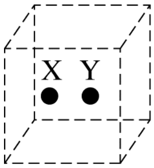
8. A parallel plate capacitor with air between the plates is charged and then disconnected from the source of emf. If the space between the plates is now filled with a dielectric, what happens to the capacitance of the capacitor and the magnitude of the electric field between the plates?

	Capacitance	Magnitude of the Electric Field
(A)	Increases	Increases
(B)	Increases	Remains constant
(C)	Increases	Decreases
(D)	Decreases	Increases
(E)	Decreases	Decreases

Questions 9-11



The figure above shows two charged spherical conductors, X and Y, which are equal in size. When each conductor is isolated and surrounded by a closed cubical surface, the total electric flux through the surfaces is $+\Phi_0$ for conductor X and $-4\Phi_0$ for conductor Y.



9. Conductor Y is brought into contact with conductor X and then separated. If the separation is small so that both conductors are inside the same closed cubical surface, as shown above, what is the total electric flux through the surface?

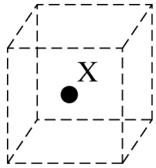
(A) $-3\Phi_0$

(B) $-\frac{5}{2}\Phi_0$

(C) $-\frac{3}{2}\Phi_0$

(D) $\frac{5}{2}\Phi_0$

(E) It cannot be determined without knowing the distance separating the two conductors and the individual charges on each.



10. After being brought into contact with conductor X, conductor Y is moved a very large distance away from conductor X. What is the total electric flux through a closed cubical surface surrounding conductor X, as shown above?

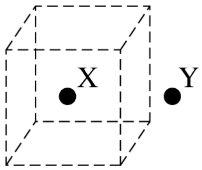
(A) $-3\Phi_0$

(B) $-\frac{3}{2}\Phi_0$

(C) $\frac{1}{2}\Phi_0$

(D) Φ_0

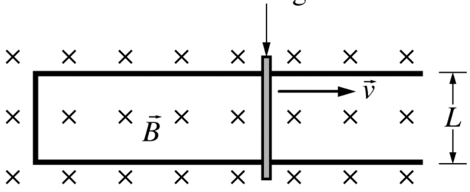
(E) $\frac{3}{2}\Phi_0$



11. Conductor Y is then moved closer to conductor X until it is just outside a closed cubical surface containing conductor X, as shown in the figure above. How would the total electric flux through the cubical surface change as conductor Y is moving?

(A) It would increase.
(B) It would decrease.
(C) It would change sign.
(D) It would remain constant, with the flux through each side of the surface also remaining constant.
(E) It would remain constant, but the flux through each side of the cubical surface would change.

Conducting Rod



Top View

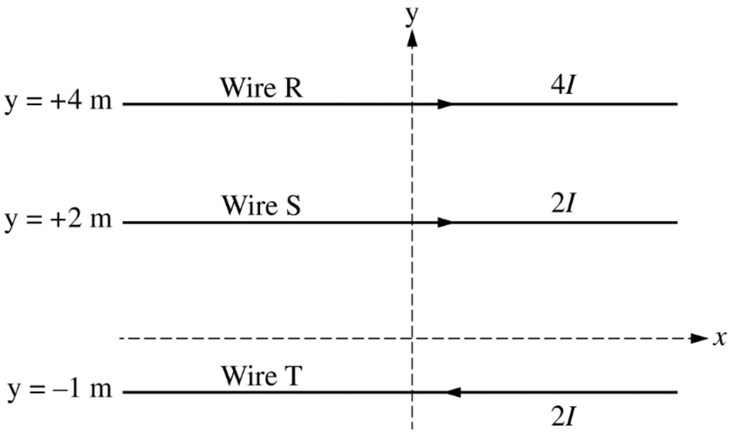
12. A conducting rod of resistance R is in electrical contact with a frictionless U-shaped rail of width L and negligible resistance. The rod is pulled to the right at a constant velocity $\vec{v}$. A magnetic field $\vec{B}$ is directed into the page, as shown in the figure above. Under these conditions, the electric power dissipated in the rod is P. If the velocity of the rod is doubled, the power dissipated in the rod is

(A) $P/4$
(B) $P/2$
(C) P
(D) $2P$
(E) $4P$

13. Which of the following will increase the magnetic field on the axis of a long solenoid?

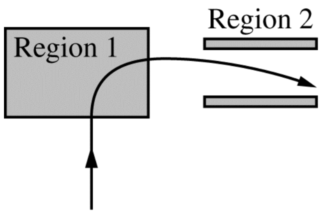
I. Increasing the current in the solenoid
II. Increasing the cross-sectional area of the solenoid
III. Inserting an iron core into the solenoid

(A) I only
(B) III only
(C) I and III only
(D) II and III only
(E) I, II, and III



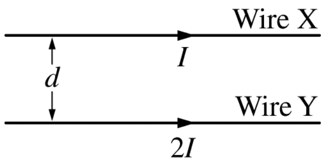
14. Three long wires, R, S, and T, are in the positions and carrying the currents indicated in the figure above. All currents are in the plane of the page and in the direction indicated. What are the magnitude and direction of the magnetic field at the origin?

	Magnitude	Direction
(A)	$\dfrac{\mu_0 I}{\pi}$	Into the page
(B)	$\dfrac{\mu_0 I}{\pi}$	Out of the page
(C)	$\dfrac{2\mu_0 I}{\pi}$	Into the page
(D)	$\dfrac{2\mu_0 I}{\pi}$	Out of the page
(E)	$\dfrac{4\mu_0 I}{\pi}$	Out of the page



15. A positively charged particle travels along the path shown in the figure above through region 1 and between two parallel plates in region 2. A magnetic field exists in region 1, and one of the plates in region 2 is at a higher potential than the other. What is the direction of the magnetic field in region 1, and which plate is at a higher potential in region 2 ?

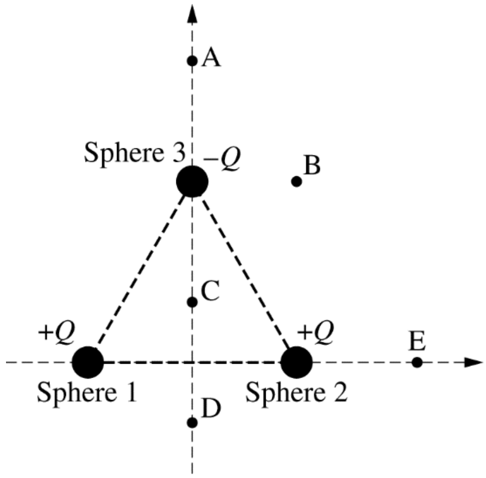
	Region 1	Plate at Higher Potential
(A)	Out of the page	Top plate
(B)	Out of the page	Bottom plate
(C)	Into the page	Top plate
(D)	Into the page	Bottom plate
(E)	To the right	Bottom plate



16. Two long, straight parallel wires X and Y are separated by a distance d and carry currents I and $2I$, as shown in the figure above. The force on wire X has magnitude F. If the current in each wire is both doubled and reversed in direction, which of the following is true of the magnitude and direction of the new force on wire X?

	Magnitude	Direction
(A)	F	Unchanged
(B)	$2F$	Reversed
(C)	$2F$	Unchanged
(D)	$4F$	Reversed
(E)	$4F$	Unchanged

Questions 17-18



Three identical spheres are equally spaced from one another. Spheres 1 and 2 have charge $+Q$, and sphere 3 has a charge of $-Q$, as shown in the figure above. Five different positions are labeled A, B, C, D, and E. Positions A, B, and C are all the same distance from sphere 3. Positions C, D, and E are all the same distance from sphere 2. All spheres and points lie in the same plane.

17. The electric potential is highest at position

    (A) A
    (B) B
    (C) C
    (D) D
    (E) E

18. At which of the five positions are the horizontal and vertical components of the electric field directed toward the left and the top of the page, respectively?

    (A) A
    (B) B
    (C) C
    (D) D
    (E) E

19. The magnetic field at a perpendicular distance r from a long, straight current-carrying wire is directly proportional to

    (A) r
    (B) r^2
    (C) $1/r$
    (D) $1/r^2$
    (E) $\ln(r)$

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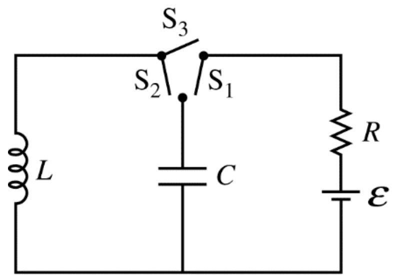
Questions 20-21



A circuit is constructed using a battery of emf $\mathcal{E}$, a resistor of resistance R, a capacitor of capacitance C, an inductor of inductance L, and three switches, as shown in the figure above. The three switches are labeled S_1, S_2, and S_3, and they can be operated independently.

20. All switches are open, and there is no stored energy in the capacitor or the inductor. Switch S_3 is closed. What is the current in the inductor after steady state has been reached?

    (A) $\dfrac{\mathcal{E}}{LR}$

    (B) $\dfrac{\mathcal{E}R}{L}$

    (C) $\dfrac{\mathcal{E}L}{R}$

    (D) $\dfrac{\mathcal{E}}{R}$

    (E) Zero

21. All switches are open, and there is no stored energy in the capacitor or the inductor. Switch S_1 is closed. After the capacitor is fully charged, switch S_1 is opened and switch S_2 is closed. Which of the following expressions represents the maximum current in the *LC* circuit?

    (A) $\dfrac{\mathcal{E}}{R}$

    (B) $\mathcal{E}\sqrt{\dfrac{C}{L}}$

    (C) $\mathcal{E}\sqrt{\dfrac{L}{C}}$

    (D) $\dfrac{\mathcal{E}C}{L}$

    (E) $\dfrac{\mathcal{E}L}{C}$

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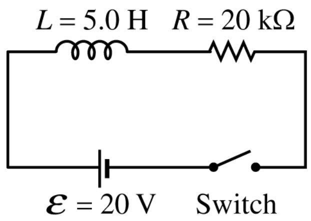
Questions 22-23



After the switch is closed in the circuit above, the current in the circuit is given by $i = I\left(1 - e^{-t/\tau}\right)$, where I and τ are constants.

22. What is the value of I ?

(A) 0
(B) 0.001 A
(C) 0.80 A
(D) 1.0 A
(E) 4.0 A

23. What is the value of τ ?

(A) 1.0×10^{-5} s
(B) 2.5×10^{-4} s
(C) 1.0 s
(D) 4.0×10^{3} s
(E) 1.0×10^{5} s

24. Two stationary point charges of unknown magnitude and sign are isolated from all other charges. If the electric field strength is zero at the midpoint of the line joining them, which of the following can be concluded about the charges?

(A) They are equal in magnitude but opposite in sign.
(B) They are equal in magnitude and have the same sign.
(C) They are not necessarily equal in magnitude but have opposite signs.
(D) They are not necessarily equal in magnitude but have the same sign.
(E) None of the above can be concluded without additional information.

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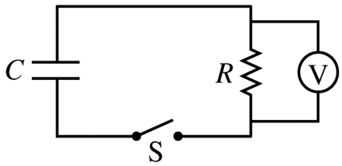
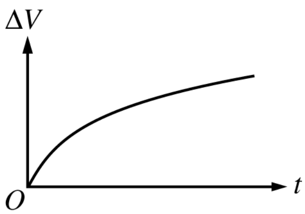
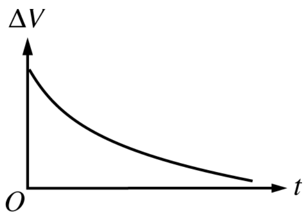
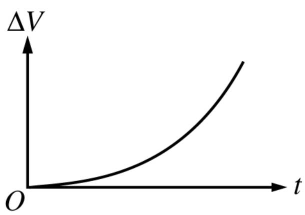
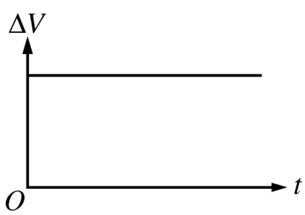


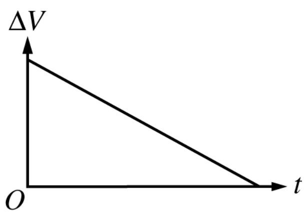
25. A charged capacitor C, resistor R, and switch S are connected in series. Voltmeter V is connected in parallel with the resistor, as shown in the figure above. At time $t = 0$, the switch is then closed. Which of the following shows the potential difference ΔV reading on the voltmeter as a function of time t after the switch is closed?

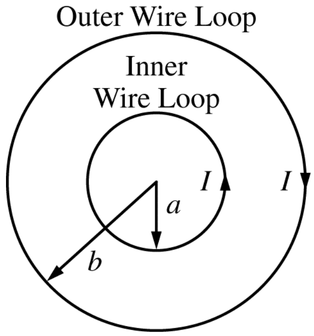
(A) 

(B) 

(C) 

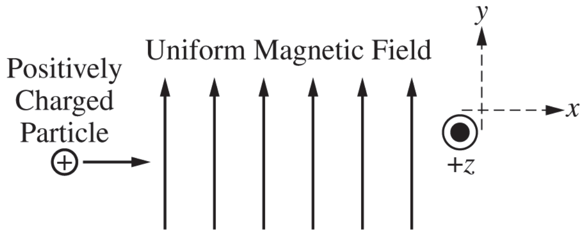
(D) 

(E) 



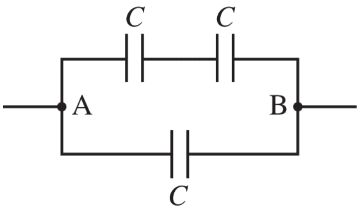
26. Two concentric circular wire loops carry equal currents I in opposite directions, as shown in the figure above. The inner loop has a radius a and carries a counterclockwise current. The outer loop has a radius b and carries a clockwise current. What is the magnitude and direction of the magnetic field at the center of the loops?

	Magnitude	Direction
(A)	$\frac{\mu_0 I}{2}\left(\frac{1}{a}-\frac{1}{b}\right)$	Out of the page
(B)	$\frac{\mu_0 I}{2}\left(\frac{1}{a}-\frac{1}{b}\right)$	Into the page
(C)	Zero	Undefined since magnitude is zero
(D)	$\frac{\mu_0 I}{2\pi}\left(\frac{1}{a}-\frac{1}{b}\right)$	Out of the page
(E)	$\frac{\mu_0 I}{2\pi}\left(\frac{1}{a}-\frac{1}{b}\right)$	Into the page



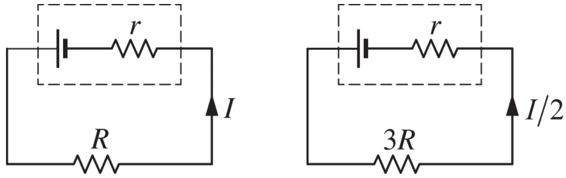
27. A positively charged particle moves in the positive x-direction in a uniform magnetic field directed in the positive y-direction. The net force on the particle could be zero if there is also an electric field present in the

(A) positive z-direction
(B) negative z-direction
(C) positive x-direction
(D) negative x-direction
(E) negative y-direction



28. Three identical capacitors with capacitance C are arranged as shown above. What is the equivalent capacitance between points A and B?

(A) $C/3$
(B) $2C/3$
(C) C
(D) $3C/2$
(E) $3C$



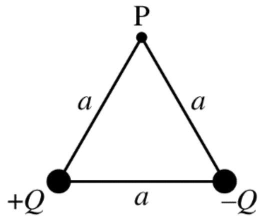
29. When a battery is connected to an external resistance R, as shown above on the left, there is a current I in the circuit. When the external resistance is changed to $3R$, the current changes to $I/2$, as shown above on the right. What is the internal resistance r of the battery?

(A) $R/4$
(B) $R/2$
(C) R
(D) $2R$
(E) $4R$

30. The advantage of using a dielectric in a capacitor is that it

(A) increases the capacitance of the capacitor
(B) increases the conductivity of the capacitor
(C) decreases the charging time of the capacitor
(D) makes the capacitor dissipate less power
(E) eliminates the electric field in the capacitor

Questions 31-33



Two small spheres have charges $+Q$ and $-Q$ and are located at the bottom corners of an equilateral triangle, as shown in the figure above. The equilateral triangle has sides of length *a*, and point P is at the top corner of the triangle.

31. The potential energy stored in the charge configuration shown is

(A) $\dfrac{Q^2}{4\pi\varepsilon_0 a}$

(B) $\dfrac{Q}{4\pi\varepsilon_0 a^2}$

(C) zero

(D) $-\dfrac{Q}{4\pi\varepsilon_0 a^2}$

(E) $-\dfrac{Q^2}{4\pi\varepsilon_0 a}$

32. The electric potential at point P due to the two spheres is

(A) zero

(B) $\dfrac{Q}{4\pi\varepsilon_0 a}$

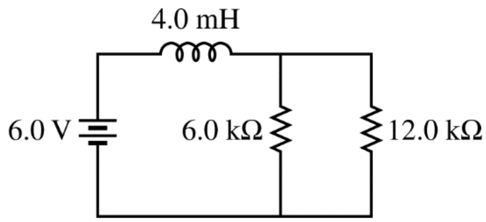
(C) $\dfrac{Q}{4\pi\varepsilon_0 a^2}$

(D) $\dfrac{2Q}{4\pi\varepsilon_0 a}$

(E) $\dfrac{2Q}{4\pi\varepsilon_0 a^2}$

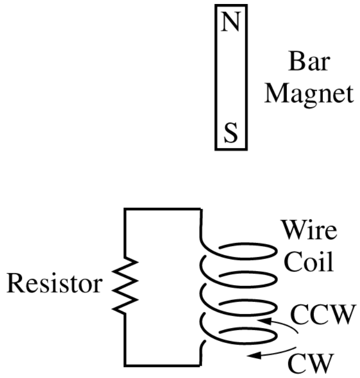
33. The direction of the electric field at point P due to the two spheres is

(A) to the left
(B) to the right
(C) toward the bottom of the page
(D) toward the top of the page
(E) undefined, because the magnitude of the electric field at point P is zero



34. An inductor and two resistors are connected to an ideal battery, as shown in the figure above. What is the time constant for the circuit?

(A) 0.22 μs
(B) 0.33 μs
(C) 0.67 μs
(D) 1.0 μs
(E) 72 μs



35. A bar magnet with its south pole pointing down is released from rest and falls through a wire coil, as shown above. A resistor is connected across the two ends of the coil. What current would be produced in the coil, as observed by a person directly above the coil?

(A) A clockwise current only
(B) A counterclockwise current only
(C) A current that is first clockwise and then counterclockwise
(D) A current that is first counterclockwise and then clockwise
(E) No current would be produced.

S T O P

END OF ELECTRICITY AND MAGNETISM SECTION I

IF YOU FINISH BEFORE TIME IS CALLED,
YOU MAY CHECK YOUR WORK ON ELECTRICITY AND MAGNETISM SECTION I ONLY.

DO NOT TURN TO ANY OTHER TEST MATERIALS.

MAKE SURE YOU HAVE DONE THE FOLLOWING.

- **PLACED YOUR AP NUMBER LABEL ON YOUR ANSWER SHEET**
- **WRITTEN AND GRIDDED YOUR AP NUMBER CORRECTLY ON YOUR ANSWER SHEET**
- **TAKEN THE AP EXAM LABEL FROM THE FRONT OF THIS BOOKLET AND PLACED IT ON YOUR ANSWER SHEET**

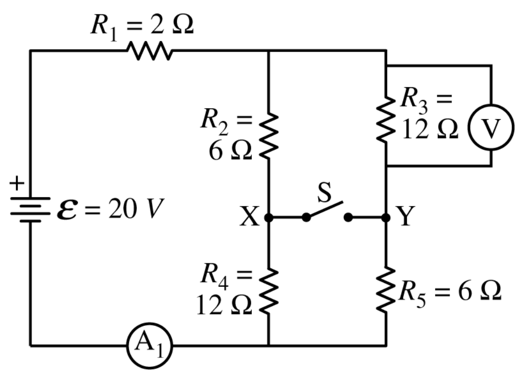
PHYSICS C: ELECTRICITY AND MAGNETISM

SECTION II

Time—45 minutes

3 Questions

Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part.



1. A circuit is created with an ideal battery and five resistors with the values shown in the figure above. An open switch is shown that can connect points X and Y. A voltmeter V and an ammeter A_1 are also shown in the figure.

   (a) The switch is in the open position.

      i. Calculate the current measured by the ammeter A_1.

      ii. Calculate the potential difference measured by the voltmeter V.

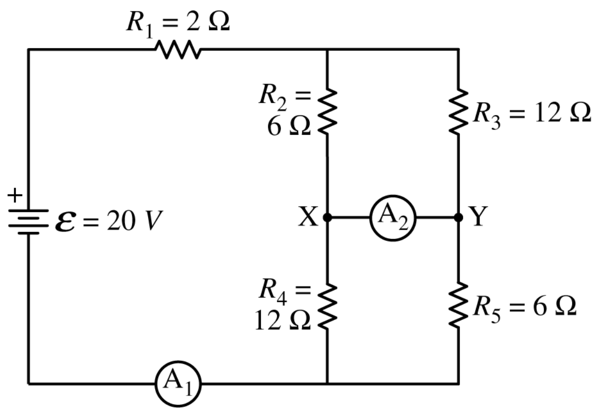
   (b) The switch is now moved to the closed position.

      i. Calculate the current measured by the ammeter A_1.

GO ON TO THE NEXT PAGE.

ii. Calculate the potential difference measured by the voltmeter V.

A student wants to determine if there is a current in the closed switch. The switch is now replaced with ammeter A_2 between points X and Y. The ammeter acts as a closed switch and can measure the current, if any, between the two points.



(c)

i. Calculate the current measured by ammeter A_2.

ii. Indicate the direction of the current, if any, through the ammeter A_2.

____ Left ____ Right ____ Undefined, because the current is zero

Question 1 continues on the next page.

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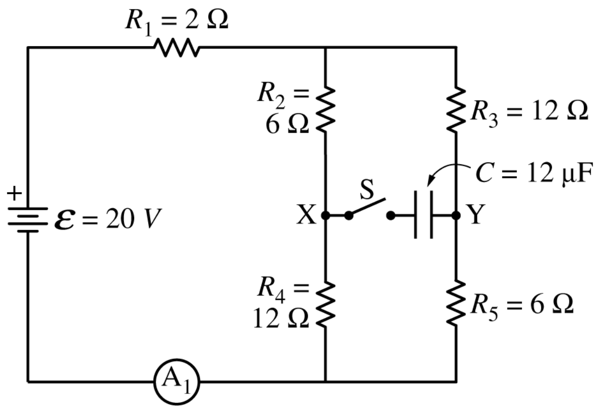


(d) The ammeter A_2 is replaced with switch S and capacitor $C = 12\ \mu F$, as shown in the figure above. Switch S is closed.

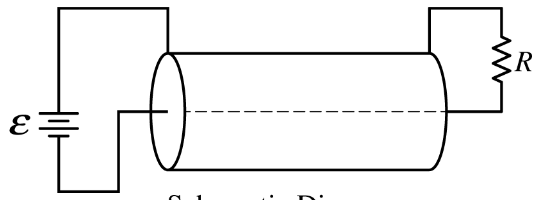
i. Calculate the charge stored on the positive plate of capacitor C a long time after switch S is closed.

ii. Which point, X or Y, is at a higher electric potential?

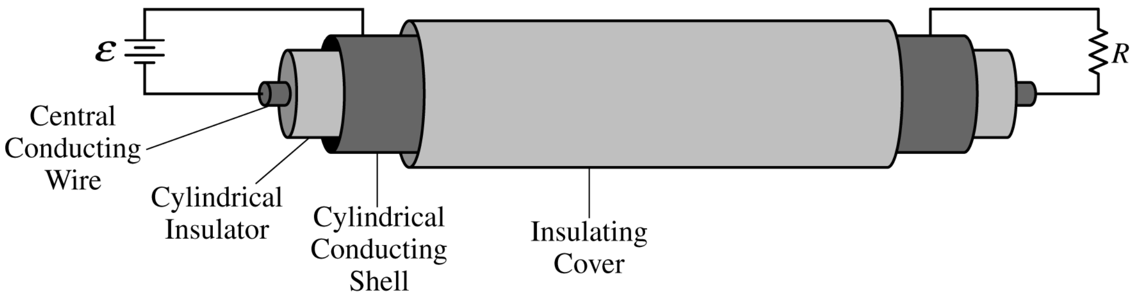
____ X ____ Y

Justify your answer.

THIS PAGE MAY BE USED FOR SCRATCH WORK.



Schematic Diagram



Circuit Figure

2. A coaxial cable is composed of a central conducting wire surrounded by a cylindrical insulator, and around that is a conducting cylindrical shell with an insulating cover. A power supply of emf $\mathcal{E}$ is used at one end to connect the two conducting regions, and a resistive load of resistance R is connected at the other end of the cable to complete the circuit, as shown in the schematic diagram and circuit figure above.

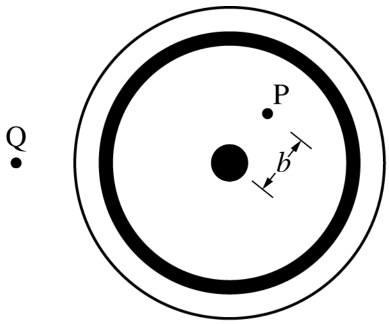


Figure 1

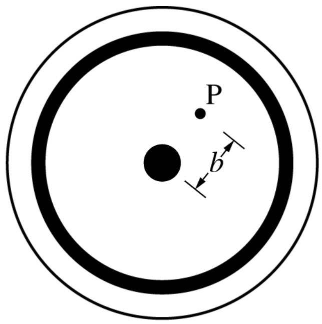


Figure 2

A cross section of the cable from the perspective of the power supply end is depicted above as if looking into the left end of the cable. Point P is inside the cylindrical insulator a distance b from the center of the cable. Point Q is outside the cable.

(a)

i. On figure 1 shown above left, draw an Amperian loop that could be used to determine the magnitude of the magnetic field at point P in the diagram. Clearly mark this loop as “Loop 1.”

ii. On figure 1, draw an Amperian loop that could be used to determine the magnitude of the magnetic field at point Q in the diagram. Clearly mark this loop as “Loop 2.”

iii. On figure 2 shown above right, draw an arrow to show the direction of the magnetic field at point P. The arrow should start on and point away from the point in the direction of the magnetic field.

(b) Using Ampere's law, derive an expression for the magnitude of the magnetic field at point P. Express your answer in terms of ε, R, b, and physical constants, as appropriate.

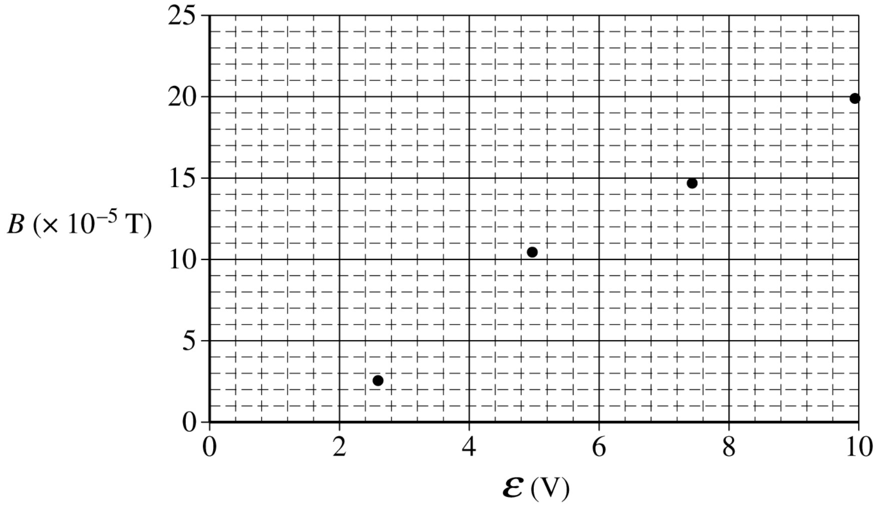
(c) Determine the magnitude of the magnetic field at point Q.

Justify your answer.

Question 2 continues on the next page.

GO ON TO THE NEXT PAGE.

Some physics students conduct an experiment with a coaxial cable in which they connect the cable to a variable power supply and measure the resulting magnetic field strength at point P inside the cylindrical insulator using a magnetic field sensor. Point P is 0.0050 m from the center of the cable. The plot of the magnetic field strength B as a function of the emf $\mathcal{E}$ of the power supply is shown below.



(d)

i. Draw the best-fit line for the data.

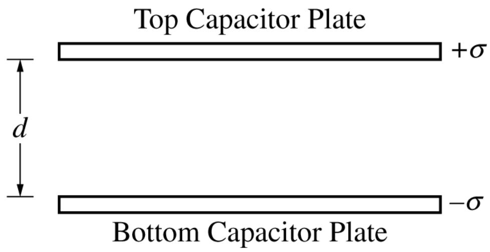
ii. Use the straight line to calculate the resistance R of the resistor used in the experiment.

(e) The lab group uses a multimeter to measure the resistance of the resistor and determines that their experimental value for R from part (d) is approximately 10% larger than that found with the multimeter. Describe a physical reason that might account for this result.

(f) The lab group notices that when the current is reversed in the cable and the experiment is again performed, the plot has a positive vertical axis intercept equal in magnitude to the negative vertical axis intercept in the plot shown before part (d).

i. Describe a physical reason for the vertical axis intercept.

ii. Describe a physical reason that the vertical axis intercept switches from negative to positive when the current in the cable is reversed.



Note: Figure not drawn to scale.

3. A parallel plate capacitor is connected to a battery, fully charged, and then isolated from the battery. The plates are given equal and opposite charge densities σ, and the separation between the plates is d, as shown in the figure above. The area of each plate has a value of A.

   (a) Derive an expression for the energy stored in the capacitor. Express your answer in terms of σ, d, A, and physical constants, as appropriate.

While the capacitor is isolated from the battery, an uncharged metal slab of thickness x and area A is inserted between the capacitor plates so that it is an equal distance from the two plates, as shown in the figure above.

(b) On the figure above, draw an arrow to indicate the direction of the electric field in the following three regions of space between the capacitor plates. If the electric field is zero in any region, indicate this by writing "$E = 0$" in that region.

   i. The region between the top plate and the metal slab

   ii. The region inside the metal slab

   iii. The region between the metal slab and the bottom plate

(c) On the lines below, rank the regions according to the magnitude of the electric field, with 1 being the largest magnitude. If any regions have the same magnitude of electric field, give them the same ranking.

____ The region between the top plate and the metal slab

____ The region inside the metal slab

____ The region between the metal slab and the bottom plate

(d) Is the capacitance of the capacitor with the metal slab greater than, less than, or equal to the capacitance of the original capacitor without the slab?

____ Greater than ____ Less than ____ Equal to

Justify your answer.

(e) When charged to the original charge density, is the energy stored in the capacitor with the metal slab greater than, less than, or equal to the original energy stored in the capacitor calculated in part (a) ?

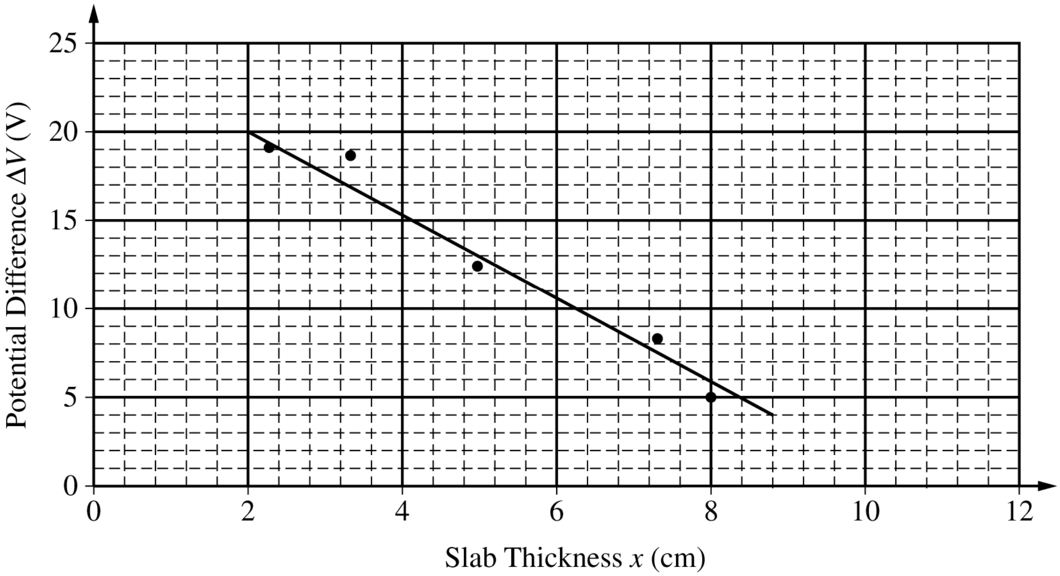
____ Greater than ____ Less than ____ Equal to

Justify your answer.

Question 3 continues on the next page.

GO ON TO THE NEXT PAGE.

Some physics students conduct an experiment in which they charge the capacitor to the same potential difference, isolate it from the battery, insert the metal slab, and measure the new potential difference across the capacitor. This experiment is repeated with slabs of different thickness. The plot of the potential difference ΔV across the capacitor as a function of the thickness x of the slab is shown below. A best-fit line for the data has been drawn.



(f) Use the best-fit line to calculate the following:

i. σ, the charge density on the plates

ii. d, the distance between the capacitor plates

THIS PAGE MAY BE USED FOR SCRATCH WORK.

STOP

END OF EXAM

THE FOLLOWING INSTRUCTIONS APPLY TO THE COVERS OF THE SECTION II BOOKLET.

- **MAKE SURE YOU HAVE COMPLETED THE IDENTIFICATION INFORMATION AS REQUESTED ON THE FRONT AND BACK COVERS OF THE SECTION II BOOKLET.**
- **CHECK TO SEE THAT YOUR AP NUMBER LABEL APPEARS IN THE BOX ON THE COVER.**
- **MAKE SURE YOU HAVE USED THE SAME SET OF AP NUMBER LABELS ON ALL AP EXAMS YOU HAVE TAKEN THIS YEAR.**