CollegeBoard

AP Physics C: Electricity and Magnetism Practice Exam

From the 2012 Administration

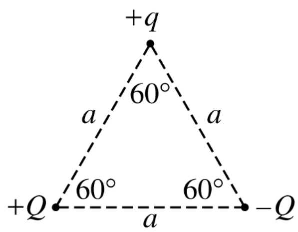
PHYSICS C: ELECTRICITY AND MAGNETISM
SECTION I
Time—45 minutes
35 Questions

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.

1. A proton moving along the positive x-axis enters an electric field that is directed along the positive y-axis. What is the direction of the electric force acting on the proton after it enters the electric field?

    (A) Along the negative z-axis
    (B) Along the positive z-axis
    (C) Along the negative y-axis
    (D) Along the positive y-axis
    (E) The direction cannot be determined since the magnitude of the electric field is not known.

Questions 2-4



Three particles having charges of $+q$, $+Q$, and $-Q$ are placed at the corners of an equilateral triangle of side a, as shown above.

2. The net force on the particle with charge $+q$ due to the other two charges is in the plane of the page and directed

    (A) vertically upward
    (B) vertically downward
    (C) horizontally to the right
    (D) horizontally to the left
    (E) toward the charge $-Q$

3. The magnitude of the force on the particle with charge $+q$ due to the other two charges is

    (A) $\dfrac{kqQ}{a}$

    (B) $\dfrac{2kqQ}{a}$

    (C) $\dfrac{2kqQ}{a^2}$

    (D) $\dfrac{2kqQ\sin 60°}{a^2}$

    (E) $\dfrac{2kqQ\cos 60°}{a^2}$

4. The potential energy of the particle with charge $+q$ due to the other two charges is

    (A) zero

    (B) $\dfrac{-2kQ}{a}$

    (C) $\dfrac{kqQ}{a}$

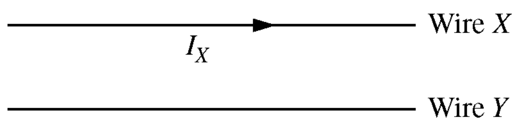
    (D) $\dfrac{2kqQ}{a}$

    (E) $\dfrac{2kqQ}{a^2}$

5. All the following statements about an isolated, solid charged conductor are correct EXCEPT:

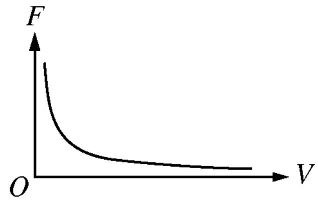
(A) All parts of the conductor are at the same potential.
(B) All excess charge resides on the outer surface.
(C) The net charge enclosed by any surface lying entirely within the conductor must equal zero.
(D) The electric field **E** just outside the conductor is directed parallel to the surface.
(E) The electric field intensity inside the conductor is zero.

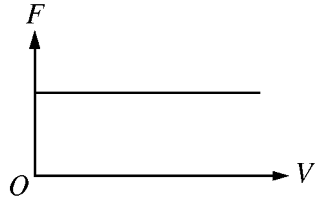
Questions 6-8



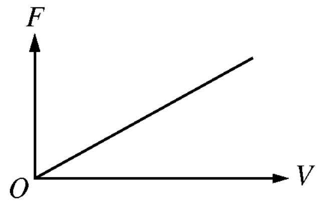
Two long, straight, parallel wires are held fixed, as shown above. A voltage is applied to wire X, creating a current I_X to the right, and the wire experiences a magnetic force of magnitude F_B toward wire Y.

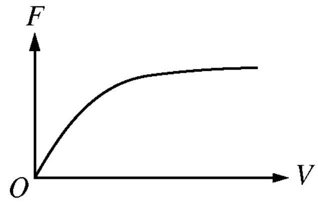
6. Assuming the resistance of wire X is constant, which of the following graphs correctly illustrates the magnitude of the magnetic force F on wire X as a function of the voltage V applied to the wire?

(A)


(B)


(C)


(D)


(E)


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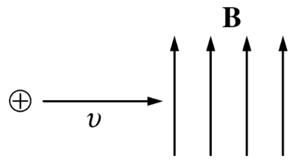
7. Which of the following could be true of wire Y ?

   I. It carries a current in the same direction as the current in wire X.
   II. It experiences a force directed away from wire X.
   III. It experiences a force of different magnitude than the force on wire X.

   (A) None
   (B) I only
   (C) II only
   (D) III only
   (E) I or II

8. If the distance between the two wires is tripled, what is the magnitude of the new magnetic force exerted on wire X ?

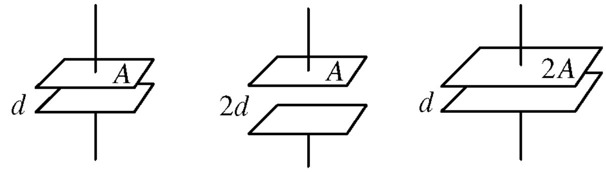
   (A) $F_B/9$
   (B) $F_B/3$
   (C) F_B
   (D) $3F_B$
   (E) $9F_B$



9. A proton moving to the right at constant speed v enters a region containing uniform magnetic and electric fields and continues to move in a straight line. The magnetic field **B** is directed toward the top of the page, as shown above. The direction of the electric field must be

   (A) into the page
   (B) out of the page
   (C) to the left
   (D) toward the top of the page
   (E) toward the bottom of the page

Questions 10-11



Capacitor I Capacitor II Capacitor III

The plate areas and separations for three capacitors are shown in the diagram above. The space between the plates in each capacitor is filled with air.

10. Suppose all three capacitors have charge $+Q$ on the top plate and charge $-Q$ on the bottom plate. Which of the following is true of the potential difference across the plates of the three capacitors?

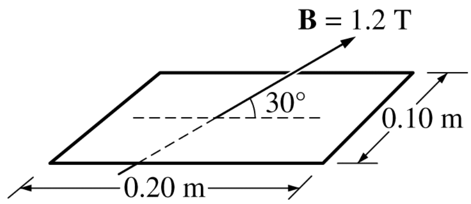
(A) It is greatest for I.
(B) It is greatest for II.
(C) It is greatest for III.
(D) It is the same for II and III and least for I.
(E) It is the same for all three capacitors.

11. Suppose all three capacitors are connected in parallel with a 9 V battery. Which of the following is true of the electric field between the plates?

(A) It is greatest for I.
(B) It is greatest for II.
(C) It is greatest for III.
(D) It is the same for I and III and least for II.
(E) It is the same for I and II and least for III.

12. The electric potential along an x-axis is given by the expression $V = ax - bx^2$, where a and b are constants. At what point on the x-axis is the electric field zero?

(A) $x = 0$
(B) $x = a/2b$
(C) $x = a/b$
(D) $x = 3a/2b$
(E) At no point



13. A uniform magnetic field **B** of magnitude 1.2 T passes through a rectangular loop of wire, which measures 0.10 m by 0.20 m. The field is oriented 30° with respect to the plane of the loop, as shown above. What is the magnetic flux through the loop?

(A) Zero
(B) $0.012\ T{\cdot}m^2$
(C) $0.02\ T{\cdot}m^2$
(D) $0.024\ T{\cdot}m^2$
(E) $0.048\ T{\cdot}m^2$

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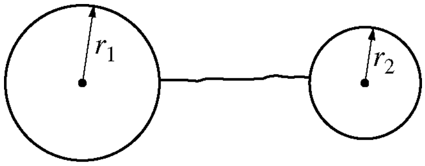


Note: Figure not drawn to scale.

14. A metal sphere with radius r_1 has a total electric charge of magnitude q. An uncharged metal sphere with radius r_2 (with $r_1 > r_2$) is then connected by a wire to the first sphere, as illustrated above. The separation of the spheres is much greater than the radius of either sphere. When equilibrium is reached, the spheres will have

(A) charges on their surfaces of equal magnitude and the same sign
(B) charges on their surfaces of equal magnitude and opposite sign
(C) equal electric fields at their surfaces
(D) equal capacitances
(E) equal electric potentials

15. A negatively charged conductor attracts a second object. The second object could be which of the following?

I. A conductor with positive net charge
II. A conductor with zero net charge
III. An insulator with zero net charge

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

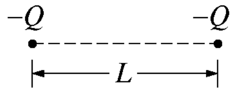
16. Three resistors having resistances of $3\ \Omega$, $6\ \Omega$, and $9\ \Omega$, respectively, are connected in parallel with a 10 V battery. True statements about the circuit include which of the following?

I. The current in the $9\ \Omega$ resistor is three times the current in the $3\ \Omega$ resistor.
II. The potential difference across each resistor is the same.
III. The power dissipated in the $9\ \Omega$ resistor is greater than the power dissipated in either of the other two resistors.

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

17. When two resistors having resistances R_1 and R_2 are connected in parallel, the equivalent resistance of the combination is $10\ \Omega$. Which of the following statements about the resistances is true?

(A) Both R_1 and R_2 are greater than $10\ \Omega$.
(B) Both R_1 and R_2 are equal to $10\ \Omega$.
(C) Both R_1 and R_2 are less than $10\ \Omega$.
(D) The sum of R_1 and R_2 is $10\ \Omega$.
(E) One of the resistances is greater than $10\ \Omega$, and the other is less than $10\ \Omega$.



18. Two particles each with a charge $-Q$ are fixed a distance L apart as shown above. Each particle experiences a net electric force F. A particle with a charge $+q$ is now fixed midway between the original two particles. As a result, the net electric force experienced by each negatively charged particle is reduced to $F/2$. The value of q is

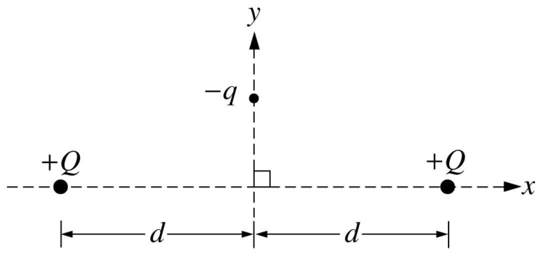
(A) Q

(B) $\frac{Q}{2}$

(C) $\frac{Q}{4}$

(D) $\frac{Q}{8}$

(E) $\frac{Q}{16}$



Top View

19. Two objects on a horizontal frictionless surface each have charge $+Q$ and each are fixed in place on the x axis at the same distance d from the origin as shown in the figure above. A particle of charge $-q$ constrained to move along the y axis is released from rest. After release, the particle will

(A) stay where it is
(B) exhibit oscillatory motion
(C) move in the direction of increasing y
(D) move in the direction of decreasing y and stop at the origin
(E) move in the direction of decreasing y and keep going to negative infinity

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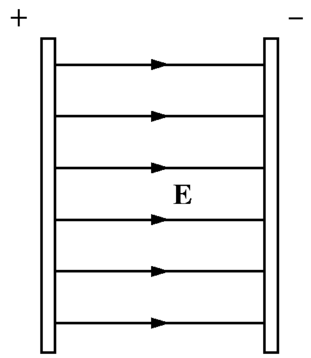


20. A uniform electric field **E** exists between the two large, oppositely charged plates shown above. If the distance between the plates is increased without changing the charges on the plates, which of the following statements can be justified?

(A) The electric field strength decreases.
(B) The electric field strength increases.
(C) The potential difference between the plates decreases.
(D) The potential difference between the plates increases.
(E) There will be no change in either the electric field strength or the potential difference.

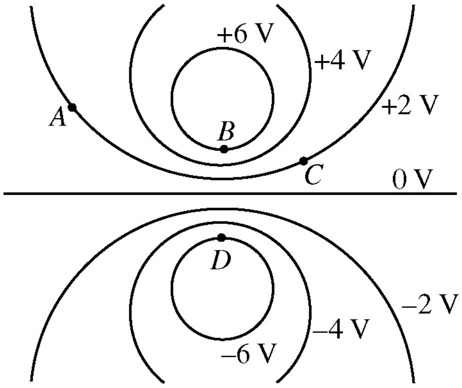
21. When two identical resistors are connected in series to a battery, the total power dissipated is P. When the same two resistors are connected in parallel to the same battery, the total power dissipated is

(A) $\frac{1}{4}P$
(B) $\frac{1}{2}P$
(C) P
(D) $2P$
(E) $4P$

22. A positively charged particle in a uniform magnetic field is moving in a circular path of radius r perpendicular to the field. How much work does the magnetic force F do on the charge for half a revolution?

(A) $\pi r^2 F$
(B) $2\pi rF$
(C) πrF
(D) $2rF$
(E) Zero

Questions 23-25



The diagram above shows a cross section of equipotential lines produced by a charge distribution. Points *A*, *B*, *C*, and *D* lie in the plane of the page.

23. For which two points can a negatively charged particle be moved from rest at one point to rest at the other with no work being done by the electric field?

(A) *A* and *B*
(B) *A* and *C*
(C) *A* and *D*
(D) *B* and *C*
(E) *B* and *D*

24. A positively charged particle is moved by an external force from rest at one point to rest at another. For which of the following motions would net positive work be required by the external force?

(A) From *A* to *D*
(B) From *B* to *A*
(C) From *C* to *A*
(D) From *C* to *D*
(E) From *D* to *B*

25. The electric potential shown in the diagram could be created by which of the following?

(A) A ring of positive charge
(B) A large sheet of positive charge
(C) Two negative point charges
(D) Two long lines of charge: one positive and one negative
(E) A long line of positive charge and a negative point charge

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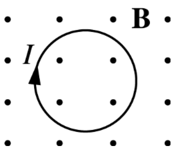
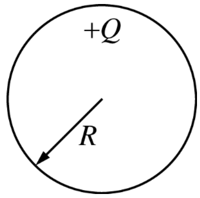
26. A magnetic field perpendicular to the plane of a wire loop is uniform in space but changes with time t in the region of the loop. If the induced emf in the loop increases linearly with time t, then the magnitude of the magnetic field must be proportional to

(A) t^3
(B) t^2
(C) t
(D) t^0 (i.e., constant)
(E) $t^{1/2}$



27. A loop of wire carrying a steady current I is initially at rest perpendicular to a uniform magnetic field of magnitude B, as shown above. The loop is then rotated about a diameter at a constant rate. The torque on the loop is maximum when the loop has rotated, with respect to its initial position, through an angle of

(A) 30°
(B) 45°
(C) 90°
(D) 180°
(E) 360°



28. The solid conducting sphere of radius R shown above has a charge $+Q$ distributed uniformly on its surface. The potential at the center of the solid sphere is

(A) $+\frac{1}{4\pi\epsilon_0}\frac{Q}{R}$

(B) $-\frac{1}{4\pi\epsilon_0}\frac{Q}{R}$

(C) $-\frac{1}{4\pi\epsilon_0}\frac{Q}{R^2}$

(D) zero

(E) undefined

Questions 29-31

A circuit consists of a resistor R, an inductor L, and an open switch S connected in series with a battery. The switch is then closed at time $t = 0$.

29. If the current in the circuit is I at time t, what energy is stored in the circuit in addition to that stored in the battery?

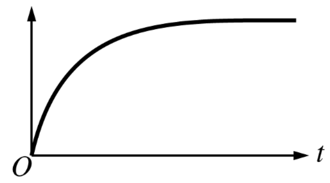
(A) LI

(B) I^2R

(C) $\frac{1}{2}LI^2$

(D) $LI + I^2R$

(E) $\frac{1}{2}LI^2 + I^2R$



30. Which of the following quantities could be represented as a function of time by the graph shown above?

I. The potential difference across the resistor
II. The potential difference across the inductor
III. The current in the circuit

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

31. The change in current when the switch is closed is determined by the inductive time constant τ. If the inductance is doubled and the resistance is halved, the new inductive time constant τ' equals

(A) $\frac{1}{4}\tau$

(B) $\frac{1}{2}\tau$

(C) τ

(D) 2τ

(E) 4τ

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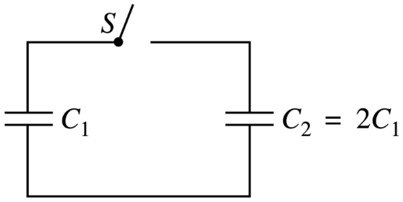
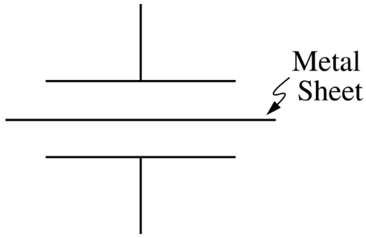


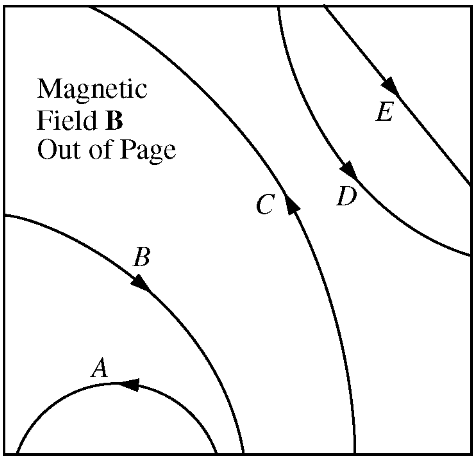
32. A capacitor of capacitance C_1 is charged and then connected to another initially uncharged capacitor of capacitance $C_2 = 2C_1$, as shown above, with the switch S in the open position. When S is closed and the system comes to equilibrium, which of the following is true of the charges on the capacitors and the potential differences across them?

	Charge	Potential Difference
(A)	$Q_1 = \frac{1}{2}Q_2$	$V_1 = \frac{1}{2}V_2$
(B)	$Q_1 = \frac{1}{2}Q_2$	$V_1 = V_2$
(C)	$Q_1 = Q_2$	$V_1 = V_2$
(D)	$Q_1 = Q_2$	$V_1 = \frac{1}{2}V_2$
(E)	$Q_1 = 2Q_2$	$V_1 = V_2$



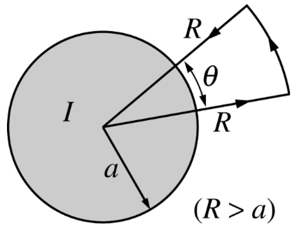
33. An air-gap capacitor originally has capacitance C. If a thin sheet of metal is placed halfway between the plates of the capacitor without touching either plate, as shown above, the effective capacitance is

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



34. The figure above shows the paths of five particles as they pass through the region inside the box that contains a uniform magnetic field **B** directed out of the page. Which particle has a positive charge?

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



35. A long, straight wire of radius a carries a current I out of the page, which is uniformly distributed over the cross section of the wire. The value of $\oint \mathbf{B} \cdot d\ell$, the line integral of the magnetic field **B** around the wedge-shaped path, equals which of the following?

(A) $\dfrac{\mu_0 \theta I}{2\pi}$

(B) $\dfrac{\mu_0 \theta I}{2\pi^2 a^2}$

(C) $\dfrac{\mu_0 \theta I}{2\pi^2 R^2}$

(D) $\dfrac{\mu_0 I}{\pi a^2}$

(E) $\dfrac{\mu_0 I}{\pi R^2}$

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**

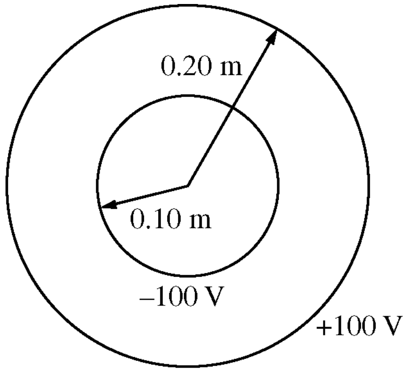
PHYSICS C: ELECTRICITY AND MAGNETISM

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.



E&M. 1.

Two thin, concentric, conducting spherical shells, insulated from each other, have radii of 0.10 m and 0.20 m, as shown above. The inner shell is set at an electric potential of -100 V, and the outer shell is set at an electric potential of +100 V, with each potential defined relative to the conventional reference point. Let Q_i and Q_o represent the net charge on the inner and outer shells, respectively, and let r be the radial distance from the center of the shells. Express all algebraic answers in terms of Q_i, Q_o, r, and fundamental constants, as appropriate.

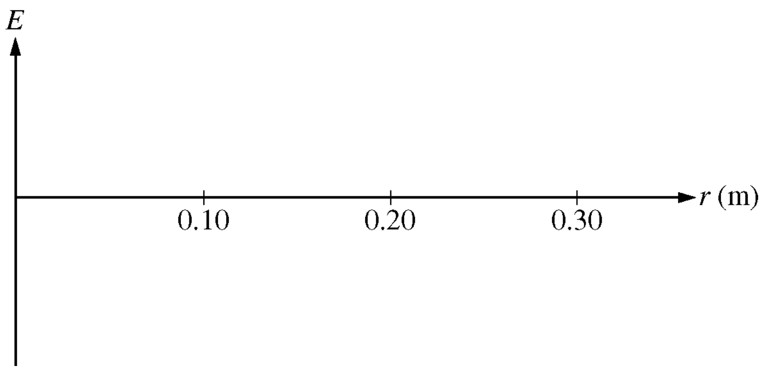
(a) Using Gauss's Law, derive an algebraic expression for the electric field $E(r)$ for $0.10 \text{ m} < r < 0.20 \text{ m}$.

(b) Determine an algebraic expression for the electric field $E(r)$ for $r > 0.20 \text{ m}$.

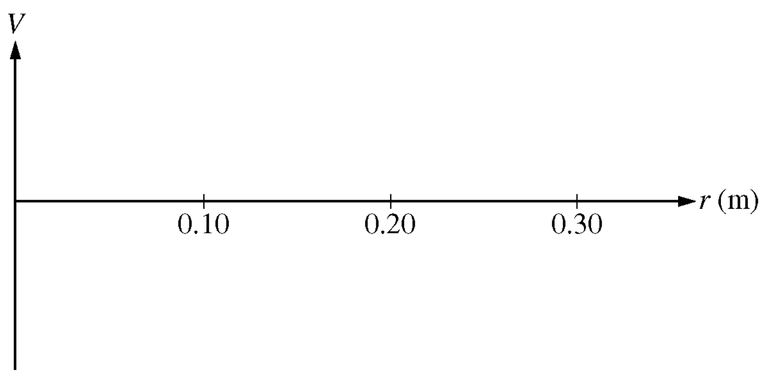
(c) Determine an algebraic expression for the electric potential $V(r)$ for $r > 0.20$ m .

(d) Using the numerical information given, calculate the value of the total charge Q_T on the two spherical shells $(Q_T = Q_i + Q_o)$.

(e) On the axes below, sketch the electric field E as a function of r . Let the positive direction be radially outward.



(f) On the axes below, sketch the electric potential V as a function of r .



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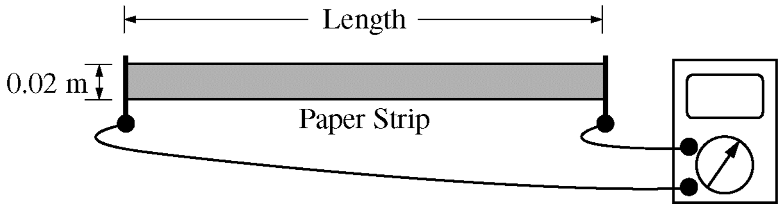
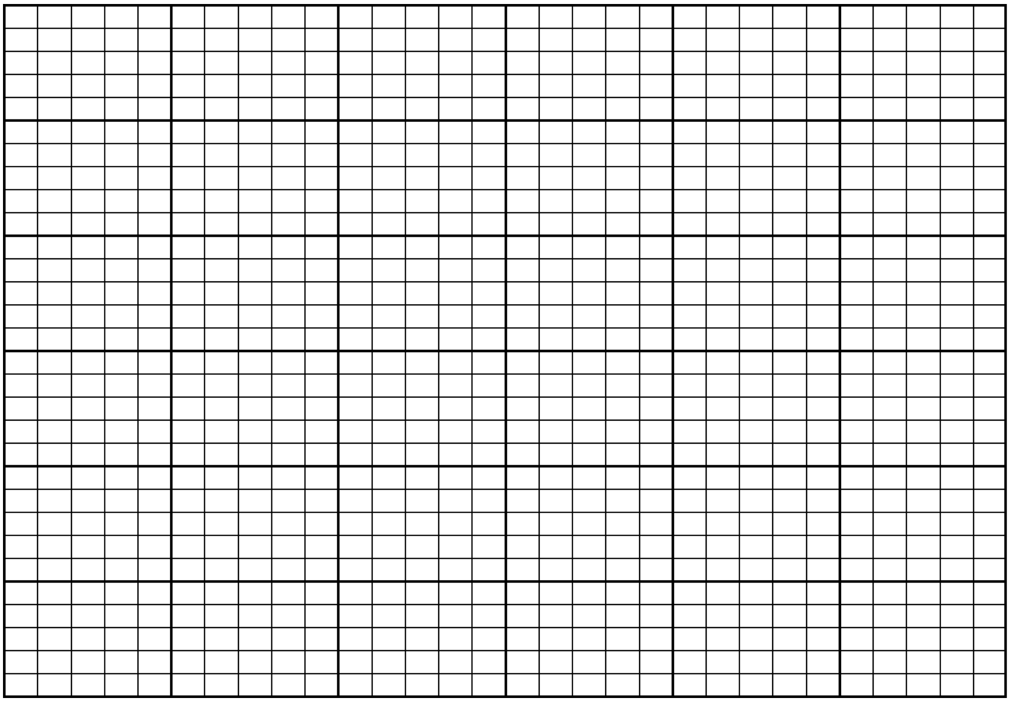


E&M. 2.

A physics student wishes to measure the resistivity of slightly conductive paper that has a thickness of 1.0×10^{-4} m . The student cuts a sheet of the conductive paper into strips of width 0.02 m and varying lengths, making five resistors labeled R1 to R5. Using an ohmmeter, the student measures the resistance of each strip, as shown above. The data are recorded below.

Resistor	R1	R2	R3	R4	R5
Length (m)	0.020	0.040	0.060	0.080	0.100
Resistance (Ω)	80,000	180,000	260,000	370,000	440,000

(a) Use the grid below to plot a linear graph of the data points from which the resistivity of the paper can be determined. Include labels and scales for both axes. Draw the straight line that best represents the data.



(b) Using the graph, calculate the resistivity of the paper.

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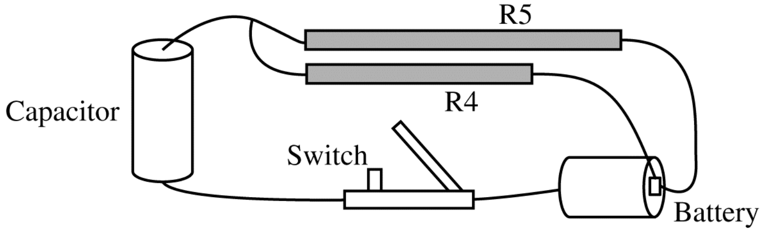
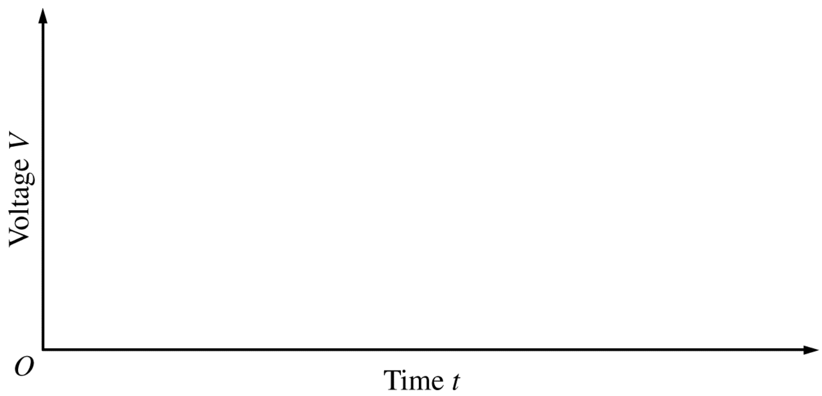


The student uses resistors R4 and R5 to build a circuit using wire, a 1.5 V battery, an uncharged 10 μF capacitor, and an open switch, as shown above.

(c) Calculate the time constant of the circuit.

(d) At time $t = 0$, the student closes the switch. On the axes below, sketch the magnitude of the voltage V_c across the capacitor and the magnitudes of the voltages V_{R4} and V_{R5} across each resistor as functions of time t. Clearly label each curve according to the circuit element it represents. On the axes, explicitly label any intercepts, asymptotes, maxima, or minima with values or expressions, as appropriate.



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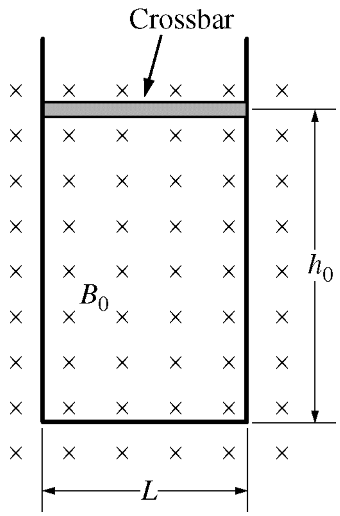

E&M. 3.

A closed loop is made of a U-shaped metal wire of negligible resistance and a movable metal crossbar of resistance R. The crossbar has mass m and length L. It is initially located a distance h_0 from the other end of the loop. The loop is placed vertically in a uniform horizontal magnetic field of magnitude B_0 in the direction shown in the figure above. Express all algebraic answers to the questions below in terms of B_0, L, m, h_0, R, and fundamental constants, as appropriate.

(a) Determine the magnitude of the magnetic flux through the loop when the crossbar is in the position shown.

The crossbar is released from rest and slides with negligible friction down the U-shaped wire without losing electrical contact.

(b) On the figure below, indicate the direction of the current in the crossbar as it falls.

Justify your answer.

GO ON TO THE NEXT PAGE.

(c) Calculate the magnitude of the current in the crossbar as it falls as a function of the crossbar's speed v .

(d) Derive, but do NOT solve, the differential equation that could be used to determine the speed v of the crossbar as a function of time t.

(e) Determine the terminal speed v_T of the crossbar.

(f) If the resistance R of the crossbar is increased, does the terminal speed increase, decrease, or remain the same?

____ Increases   ____ Decreases   ____ Remains the same

Give a physical justification for your answer in terms of the forces on the crossbar.

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(ES) ON THE COVER(S).**
- **MAKE SURE YOU HAVE USED THE SAME SET OF AP NUMBER LABELS ON ALL AP EXAMS YOU HAVE TAKEN THIS YEAR.**