Last Name: First Name:

Physics 102 Spring 2007: Final Exam, May 4, 2007
Free Response and Instructions

- Print your LAST and FIRST name on the front of your blue book, on this question sheet, the multiple-choice question sheet and the multiple-choice answer sheet.
- TIME ALLOWED 3 HOURS
- The test consists of three free-response questions and 25 multiple-choice questions.
- The test is graded on a scale of 180 points; the free-response questions account for 105 points (35 points each), and the multiple-choice questions account for 75 points (3 points each).
- Answer the three free-response questions in your blue book. Answer the multiple-choice questions by marking a dark X in the appropriate column and row in the table on the multiple-choice answer sheet.
- Consult no books or notes of any kind. You may use a hand-held calculator in non-graphing, non-programmed mode.
- Do NOT take test materials outside of the class at any time. Return this question sheet along with your blue book and multiple-choice question sheet.
- Write and sign the Pledge on the front of your blue book.

Show your work for the free-response problems, including neat and clearly labeled figures, in your blue book. Answers without explanation (even correct answers) will not be given credit.

---

35 I. A shell of conducting material has inner radius a and outer radius b. The shell carries a total charge $+Q$. The coordinate r measures the distance from the center of the shell.

6 (a) Determine the electric field $\vec{E}$ everywhere in space. Sketch $\vec{E}(r)$ vs. r.

6 (b) Determine the electrostatic potential V everywhere in space. Sketch $V(r)$ vs. r.

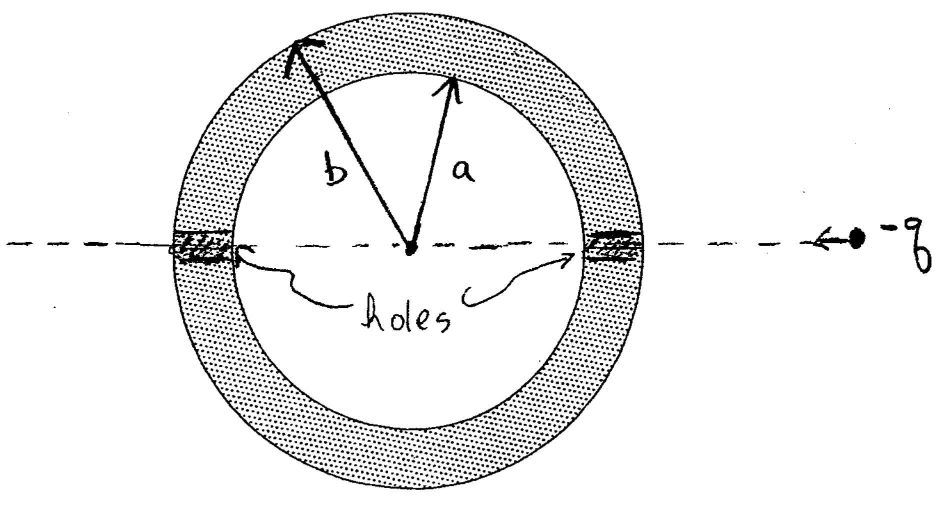
8 (c) Determine the electrostatic energy density u_E everywhere in space. Integrate u_E over all space to determine the total energy stored in the electric field.

Now suppose two small holes are drilled through the shell along a diameter. The holes are small enough that the electric field is not changed significantly. A small negative charge $-q$ is released from rest a distance $2b$ from the center of the conducting shell. The charge $-q$ passes through one hole, through the center of the shell, and exits through the hole on the other side.

8 (d) Determine the speed at which the charge $-q$ is traveling when it reaches the surface $r = b$.

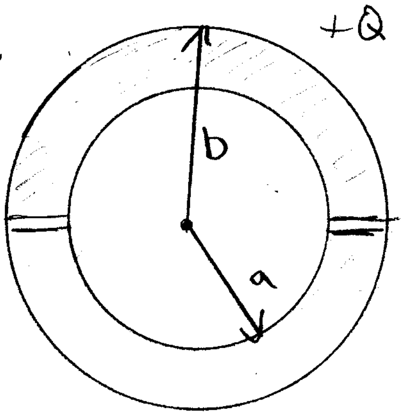
3 (e) What acceleration does the charge $-q$ experience in the region $r < b$? What is its speed when it exits the shell on the other side?

4 (f) Describe qualitatively the subsequent motion of the charge after it exits the shell on the opposite side.



Physics 102
Spring 2007 Final

I. $+Q$



(a) The charge will be distributed uniformly over the outer surface of the shell.

For $r > b$, $\oint \vec{E} \cdot d\vec{A} = 4\pi r^2 E_r = \frac{Q}{\varepsilon_0}$

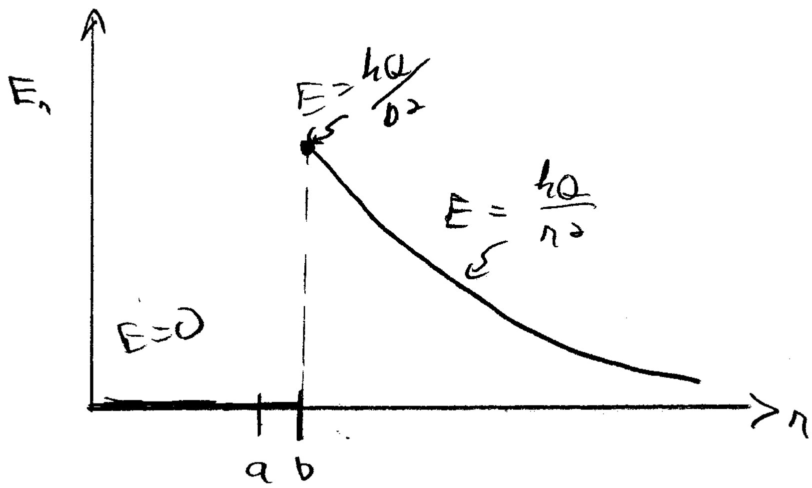
$$r > b \quad \vec{E} = \frac{Q}{4\pi\varepsilon_0 r^2}\hat{r} = \frac{kQ}{r^2}\hat{r}$$

$$\text{for } a < r < b \quad \vec{E} = 0$$

since we are inside a conductor.

For $r < a$, $\oint \vec{E} \cdot d\vec{A} = \frac{Q_{encl}}{\varepsilon_0} = 0$ since no charge is enclosed

$$r < a \quad \vec{E} = 0$$



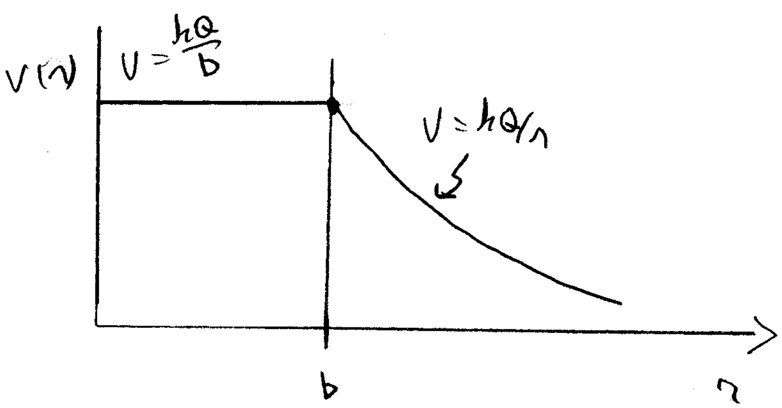
(b) $\Delta V = -\int \vec{E}\cdot d\vec{l}$ Take $V(r \to \infty) = 0$.

from ∞ to $r > b$,

$$V(r) = -\int_{\infty}^{r} \frac{kQ}{r'^2}\, dr' = \frac{kQ}{r'}\Big|_{\infty}^{r} = \frac{kQ}{r} - 0$$

$$\boxed{V(r) = \frac{kQ}{r} \qquad r > b}$$

for $r < b$, $\Delta V = 0$ since $\vec{E} = 0$. So for $r < b$, V is constant at $\boxed{V(r<b) = \frac{kQ}{b}}$



(C) $u_E = \frac{1}{2}\epsilon_0 E^2$

for $r>b$, $u_E = \frac{Q^2}{16\pi^2\epsilon_0^2} \cdot \frac{\epsilon_0}{2r^4} = \frac{Q^2}{32\pi^2\epsilon_0 r^4}$

$r>b$ $\quad u_E = \frac{Q^2}{32\pi^2\epsilon_0 r^4}$

for $r<b$, $u_E = 0$ since $\vec{E} = 0$

$U_{TOT} = \int u_E \, dV = \frac{Q^2}{32\pi^2\epsilon_0}\int_{r=b}^{\infty} \frac{4\pi r^2 \, dr}{r^4}$

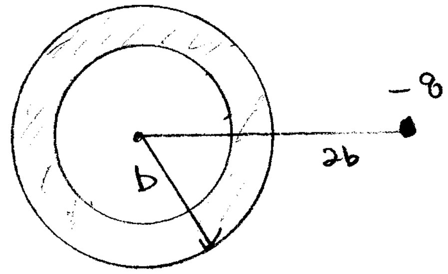
$dV = 4\pi r^2 dr$

$U_{TOT} = \frac{Q^2}{8\pi\epsilon_0}\int_b^{\infty} \frac{dr}{r^2} = \frac{-Q^2}{8\pi\epsilon_0}\left(\frac{1}{r}\right)_b^{\infty}$

$U_{TOT} = \frac{-Q^2}{8\pi\epsilon_0}\left[0 - \frac{1}{b}\right]$

$U_{TOT} = \frac{Q^2}{8\pi\epsilon_0 b}$

(d)



The easiest way to do this problem is to use energy conservation:

$$E_i = E_f$$

$$PE_i + KE_i^{\,0} = PE_f + KE_f$$

$$KE_f = PE_i - PE_f \qquad PE_i = \frac{kQ(-q)}{2b} \qquad PE_f = \frac{kQ(-q)}{b}$$

$$KE_f = -kQq\left[\frac{1}{2b} - \frac{2}{2b}\right] = -kQq\left(-\frac{1}{2b}\right)$$

$$KE_f = \frac{kQq}{2b} = \frac{1}{2}mv^2$$

$$\boxed{v = \sqrt{\frac{kQq}{mb}}}$$

Velocity when $-q$ reaches $r=b$.

(e) In the region $r<b$, $-q$ experiences zero acceleration, since $E=0$!

Since $a=0$, its speed when it exits the shell on the other side will be the same, $v = \sqrt{\frac{kQq}{mb}}$

(f) Once $-q$ exits the shell on the other side, it begins to slow down. Its KE is converted back to PE, it comes to rest at $r=2b$ on the other side. It then starts back toward the right & oscillates between $\pm 2b$.

Alternative calculation of v_b:

$$F\ \text{on}\ (-q) = -\frac{kQq}{r^2} = ma$$

$$a = \frac{-kQq}{mr^2}$$ But this is a non-constant acceleration & must be integrated!

$$a = \frac{dv}{dt} = \frac{dv}{dr}\frac{dr}{dt} = v\frac{dv}{dr} = -\frac{kQq}{mr^2}$$

$$\int_0^{v_b} v\,dv = \int_{2b}^{b} -\frac{kQq}{mr^2}\,dr$$

$$\frac{v^2}{2} = +\frac{kQq}{m}\left(+\frac{1}{r}\right)\Bigg|_{2b}^{b} = \frac{kQq}{m}\Big(\underbrace{\frac{1}{b}-\frac{1}{2b}}_{=\frac{1}{2b}}\Big)$$

$$\frac{v^2}{\cancel{2}} = \frac{kQq}{\cancel{2}mb} \qquad v_b = \sqrt{\frac{kQq}{mb}} \quad \text{as before!}$$

Phy102 Final
Grading criteria I.

I 35pts

(a) 6 pts

E for $r < b$	2	Partial credit: Gauss law 2
E for $r > b$	2	
Sketch	2	

(b) 6 pts

V for $r < b$	2	
V for $r > b$	2	$\Delta V = -\int \vec{E}\cdot d\vec{l}$ — 2 pts
Sketch	2	

(c) 8 pts

u_E for $r < b$	2
u_E for $r > b$	3
Integral for total U	3

(d) 8 pts

Use potential energy	2
Calculate ΔV	2
Equate $\Delta PE = \Delta KE$	2
Solve for v	2

(e) 3 pts

zero acceleration	2
speed same	1

(f) 3 pts

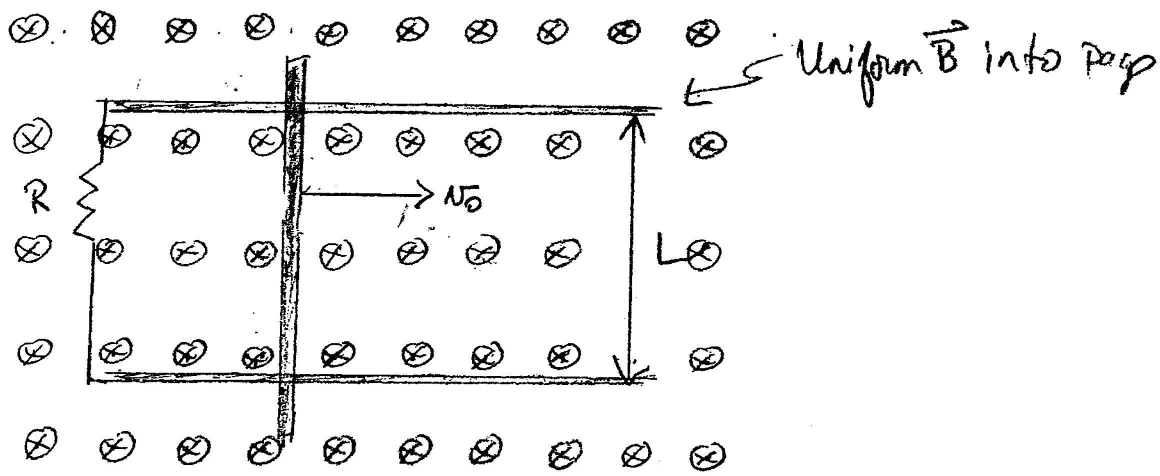
II. The figure below shows a pair of parallel conducting rails of negligible resistance, a distance L apart. A uniform magnetic field $\vec{B}$ is directed into the page. A resistance R is connected across the rails, and a conducting bar of negligible resistance is being pulled across the rails with constant velocity v_o to the right. Friction between the moving bar and rails is negligible.

8 (a) Determine the direction and magnitude of the current in the resistor.

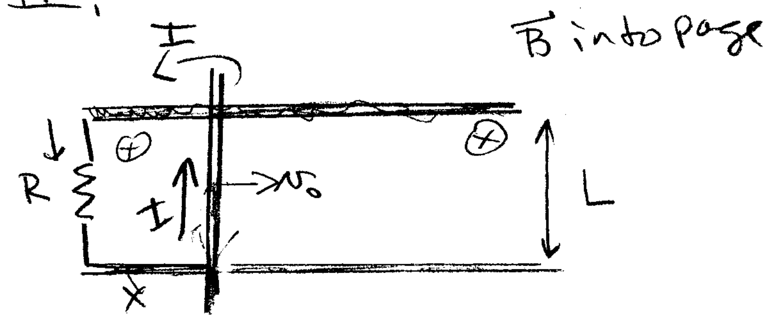
9 (b) Determine the constant external force which must be applied to the bar to keep it moving with constant velocity v_o to the right.

9 (c) Determine the rate at which work must be done by the external force to maintain a constant velocity v_o.

9 (d) Compare the rate at which the external agent does work to the power dissipated in the resistor.



II.



(a) The changing flux in the loop will induce an emf which will drive a current.

$$\mathcal{E} = -\frac{d\Phi_B}{dt} \qquad \Phi_B = LxB \qquad \frac{d\Phi_B}{dt} = LBv_0$$

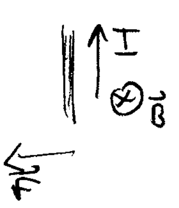
The direction of the induced current will be such as to oppose the change of flux. The flux is increasing downward, so I will be in the direction that would produce an upward flux, I is in the counterclockwise direction. The current through R is down

$$\mathcal{E} = IR = LBv_0$$

$$\boxed{I = \frac{LBv_0}{R}} \quad \text{ccw}$$

(b) Once the current is established, $\vec{B}$ exerts a force on the rod.

$$\vec{F} = I\vec{L}\times\vec{B}$$



$\vec{F}$ is to the left, opposing the motion

$$\vec{F}_B = \frac{L^2B^2v_0}{R}(-\hat{\imath})$$ force on rod by $\vec{B}$

To keep the bar moving at constant velocity, an external force must be applied to cancel $\vec{F}_B$.

$$\vec{F}_{ext} = \frac{B^2 L^2 v_0}{R}\,\hat{\imath}$$

(c) $\text{work} = \int \vec{F} \cdot d\vec{l} = F_{ext} \cdot \Delta x$

$$\frac{dw}{dt} = F_{ext}\frac{dx}{dt} = F_{ext}\, v_0$$

$$\frac{dw}{dt} = \frac{B^2 L^2 v_0^2}{R}$$

(d) $P = I^2 R = \frac{L^2 B^2 v_0^2}{R^2} \cdot R = \frac{L^2 B^2 v_0^2}{R}$

$\text{Power (in } R) = \frac{L^2 B^2 v_0^2}{R}$ $\Rightarrow$ same as $\frac{dw}{dt}$ done by external force!

Grading Criteria II.

II. 35 pts

(a) 8 pts

Faraday's law 2

Correct emf 2

correct current 2

correct direction 2

(b) 9 pts

$F = I\vec{l} \times B$ 2pts

correct magnitude of force 3

correct magnitude & direction of external force 4

(c) 9 pts

$W = \int \vec{F} \cdot dl$ 3 pts

$\frac{dW}{dt} = F \cdot v$ 3 pts

Correct $\frac{dW}{dt}$ 3

(d) 9 pts

$P = I^2 R$ 2 pts

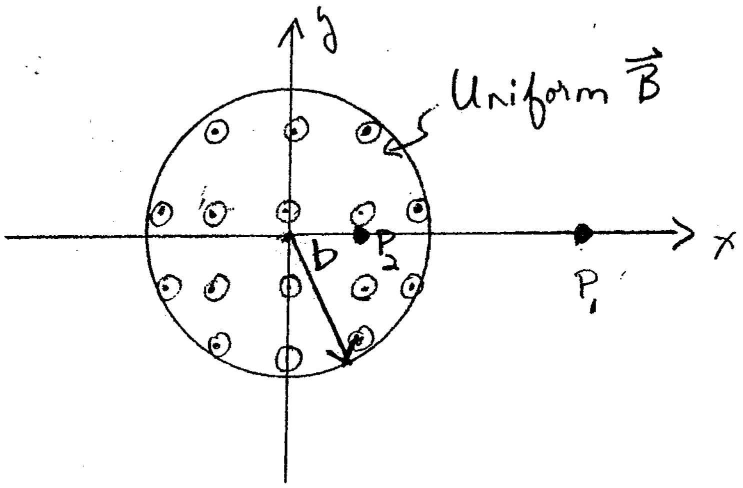
Correct $I^2 R$ 3 pts

Compare to (c) 4 pts

III. A cylindrical region of space has a uniform magnetic field $\vec{B}$ pointing up out of the page as shown in the figure below. The coordinate r measures the distance from the axis of the cylindrical region. For purposes of this problem, we will neglect fringe field effects, so that we can assume the field drops abruptly to zero at $r = b$. Although the field is uniform in space, its magnitude is increasing at a constant rate $\frac{d|\vec{B}|}{dt} = \alpha$.

10 (a) Determine the electric field $\vec{E}$ everywhere in space due to the changing magnetic field. Be sure to indicate both the direction and magnitude of the field. Plot the magnitude of the field $|\vec{E}(r)|$ vs. r.

5 (b) If an electron is released from rest at the point P_1 ($x = 2b, y = 0$) what acceleration if any does it experience immediately after it is released? If an electron is released from rest at the point P_2 ($x = \frac{b}{2}, y = 0$) what acceleration if any does it experience immediately after it is released?

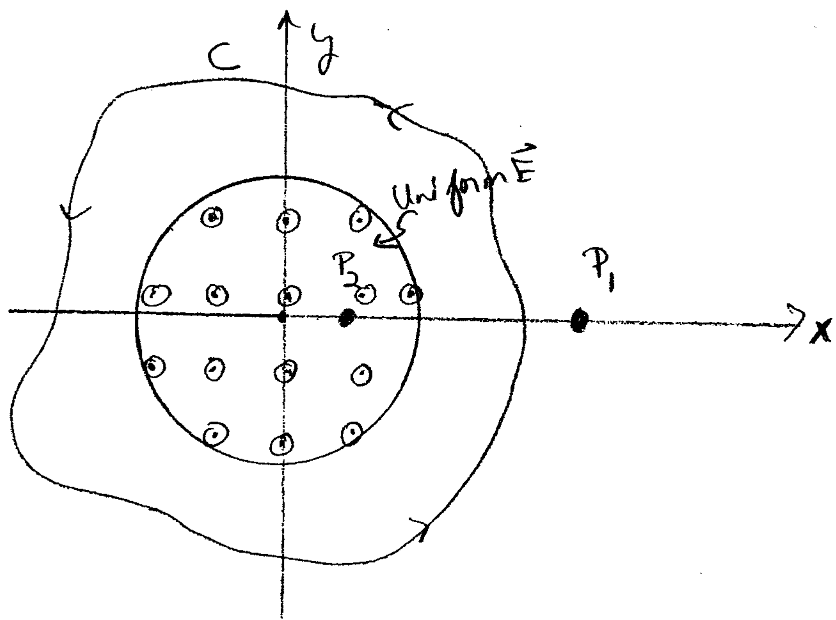


Now consider a similar situation, except that instead of a uniform magnetic field in the cylindrical region of space we now have a uniform electric field. As before, the magnitude of the electric field is increasing with time at a constant rate $\frac{d|\vec{E}|}{dt} = \alpha$.

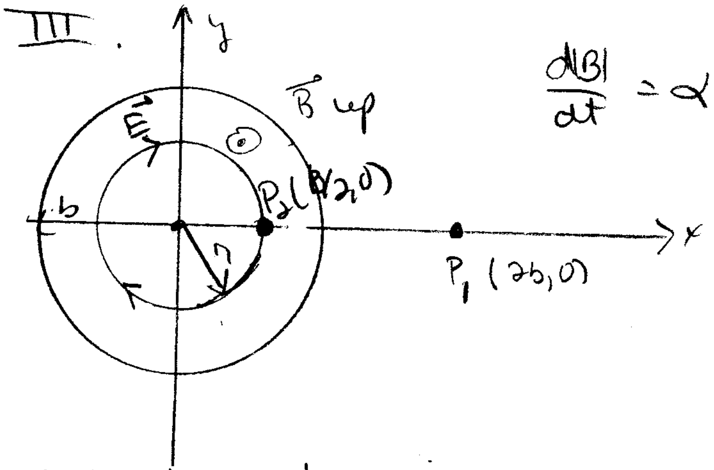
10 (c) Determine the magnetic field $\vec{B}$ everywhere in space due to the changing electric field. Be sure to indicate both the direction and magnitude of the magnetic field. Plot the magnitude of the field $|\vec{B}(r)|$ vs. r.

5 (d) Determine the displacement current I_D that passes through the region enclosed by the contour C shown in the figure below.

5 (e) If an electron is released from rest at the point P_1 ($x = 2b, y = 0$), what acceleration if any does it experience immediately after it is released? If an electron is released from rest at the point P_2 ($x = \frac{b}{2}, y = 0$), what acceleration if any does it experience immediately after it is released?



III.



$\frac{d|B|}{dt} = \alpha$ B is increasing

(a) from Faradays law,

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d\phi_B}{dt}$$

from cylindrical symmetry, $\vec{E}$ is constant along a countour at constant r. The direction of $\vec{E}$ is given by Lenz' Law, since Φ_B is increasing upwards, $\vec{E}$ forms closed loops in the clockwise sense.

for $r < b$, $\phi_B = \pi r^2 B$

$$\frac{d\phi_B}{dt} = \pi r^2 \frac{dB}{dt} = \pi r^2 \alpha$$

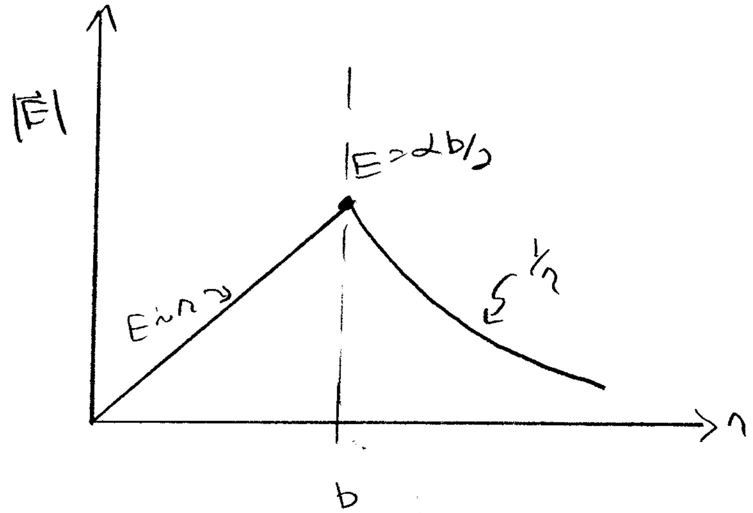
$$\oint \vec{E} \cdot d\vec{l} = 2\pi r|\vec{E}| = \pi r^2 \alpha$$

$$|E| = \frac{\alpha r}{2}$$ – direction is cw loops. $r < b$

for $r > B$, $\phi_B = \pi b^2 B$ $\frac{d\phi_B}{dt} = \pi b^2 \alpha$

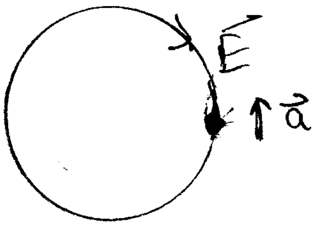
$$2\pi r|\vec{E}| = \pi b^2 \alpha$$

$$|\vec{E}| = \frac{b^2 \alpha}{2r}$$ – cw loops $r > b$



(b) An electron is released from rest at $x = 2b, y = 0$.

$\vec{F} = -e\vec{E}$ acceleration is upward.



$$|E|(r = 2b) = \frac{b^2\alpha}{4b} = \frac{b\alpha}{4}$$

$$\vec{F} = \frac{eb\alpha}{4}\hat{j} = ma$$

$$\boxed{\vec{a} = \frac{eb\alpha}{4m_e}\hat{j}}$$ at P_1

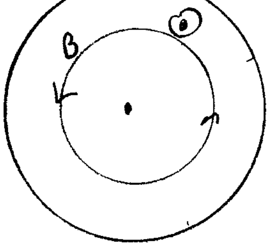
At $P_2(b/2, 0)$ $$|\vec{E}|(b/2) = \frac{\alpha(b/2)}{2} = \frac{b\alpha}{4}$$

$$\vec{F} = -q\vec{E} = \frac{eb\alpha}{4}\hat{j} = m\vec{a}$$

$$\boxed{\vec{a} = \frac{eb\alpha}{4m}\hat{j}}$$ at P_2

Note that since the electron is released from rest, it is not accelerated by the $\vec{B}$ field.

(c) Now we have a changing electric field $\frac{dE}{dt} = \alpha$



from the extended form of Ampere's Law:

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I^{\nearrow 0} + \mu_0 \varepsilon_0 \frac{d\phi_E}{dt}$$

By symmetry $\vec{B}$ forms concentric loops. The direction is counter-clockwise.

for $r < b$ $\quad \phi_E = \pi r^2 E$

$$\frac{d\phi_E}{dt} = \pi r^2 \frac{dE}{dt} = \pi r^2 \alpha$$

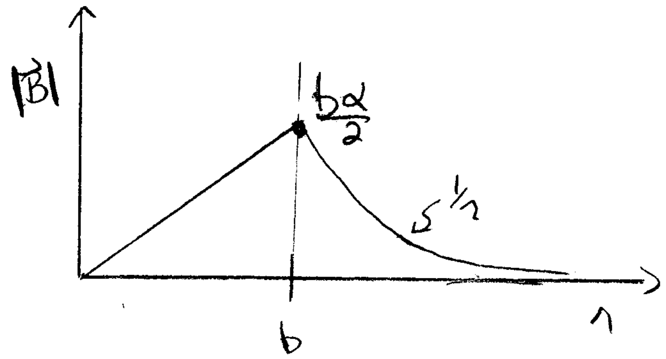
$$\oint \vec{B} \cdot d\vec{l} = 2\pi r B = \mu_0 \varepsilon_0 \pi r^2 \alpha$$

$$|\vec{B}| = \frac{\mu_0 \varepsilon_0 \alpha r}{2}$$ direction is ccw loops for $r < b$

for $r > b$, $\quad \phi_E = \pi b^2 E \qquad \frac{d\phi_E}{dt} = \pi b^2 \alpha$

$$\oint \vec{B} \cdot d\vec{l} = 2\pi r B = \mu_0 \varepsilon_0 \pi b^2 \alpha$$

$$|\vec{B}| = \frac{\mu_0 \varepsilon_0 \alpha b^2}{2r}$$ — ccw loops for $r > b$



(d) $I_D = \epsilon_0 \frac{d\Phi_E}{dt} = \epsilon_0 \pi b^2 \frac{dE}{dt}$

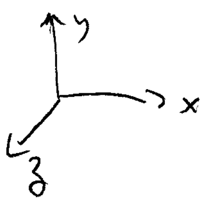
$$I_D = \epsilon_0 \pi b^2 \alpha$$

(e) If an electron is released from (P_1) $x = 2b, y = 0$, it is out of the region of $\vec{E}$, and since it is released from rest, it is not accelerated by $\vec{B}$!

At P_1, $\vec{a} = 0$

At P_2 ($x = b/2, y = 0$), $\vec{a}$ due to $\vec{B}$ is still zero since the electron is released from rest. But $\vec{E} \neq 0$ there & the electron will be accelerated in the direction $\perp$ the page.

$$\vec{F}_{one} = -e\vec{E} = -eE(t)\hat{k} = m_e\vec{a}$$



$$\vec{a} = \frac{-eE(t)}{m_e}\hat{k}$$

acceleration is into the page

Grading Criteria III

III. 35 pts

(a) 10 pts

Symmetry of problem & $\vec{E}$ in loops	2	
Faraday's law	2	
E for $r < b$	2	−1 for wrong direction
E for $r > b$	2	
Sketch	2	

(b) 5 pts

Acceleration at P_1 due to E	2
Accel. at P_2 due to E	2
No accel. due to B	1

(c) 10 pts

Symmetry & $\vec{B}$ in loops	2	
Extended Ampere's law	2	
B for $r < b$	2	−1 for wrong direction
B for $r > b$	2	
Sketch	2	

(d) 5 pts

Definition of displacement current	2
Correct value	3

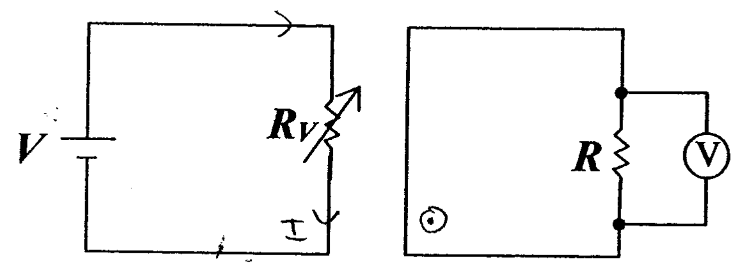
(e) 5 pts

Acceleration at $P_1 = 0$	2
Acceleration at P_2 due to E	2
No accel. from $\vec{B}$ since at rest	1

Last Name: First Name:

Physics 102 Spring 2007: Final Exam —Multiple-Choice Questions

1. The circuit on the left in the figure below contains a battery of potential V and a variable resistor R_V. The circuit on the right in the figure below contains an ideal voltmeter connected in parallel across a resistor R. While the resistance of the variable resistor in the left circuit is *increased* linearly with respect to time , the voltmeter measures



   (A) a non-zero and constant voltage.
   (B) a non-zero and increasing voltage.
   (C) a non-zero and decreasing voltage.
   (D) a zero voltage.

2. The frequency of an LC oscillator (a fully charged capacitor placed in series with an inductor) is ω_0. The plates of the parallel plate capacitor are pulled apart to twice the original distance, and a dielectric ($\kappa > 1$) is completely inserted into the capacitor. What is the new frequency of oscillation for the circuit?

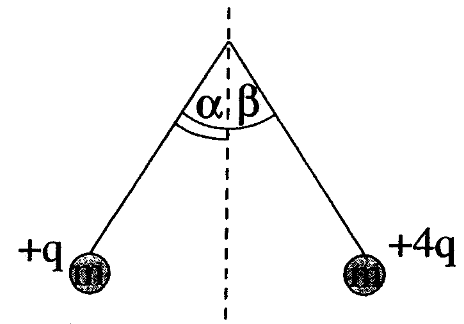
   (A) $\frac{2}{\kappa}\omega_0$.
   (B) $\sqrt{\frac{2}{\kappa}}\,\omega_0$.
   (C) $\sqrt{\frac{\kappa}{2}}\,\omega_0$.
   (D) $\frac{\kappa}{2}\omega_0$.

3. Consider a solenoid with radius R and length L ($R \ll L$). The magnetic field at the center of the solenoid is B_0. A second solenoid is constructed that has twice the radius, twice the length, and carries twice the current as the original solenoid, but has the same number of turns per meter. The magnetic field at the center of the second solenoid is

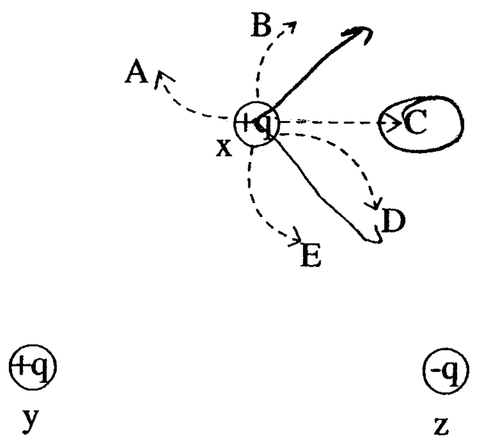
   (A) $B_0/4$.
   (B) $B_0/2$.
   (C) B_0.
   (D) $2B_0$.
   (E) $4B_0$.

4. Two balls of equal mass m are hung from silk threads of equal length. If the sphere on the right has a charge $4q$ and the sphere on the left has charge q, then how are the angles α and β related.

   (A) $\alpha = \frac{1}{4}\beta$.
   (B) $\alpha = \frac{1}{2}\beta$.
   (C) $\alpha = \beta$.
   (D) $\alpha = 2\beta$.
   (E) $\alpha = 4\beta$.

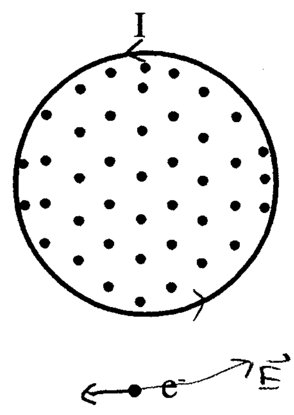


5. Three small spheres x, y, and z carry charges of equal magnitudes and with signs shown below. They are placed on the vertices of an isosceles triangle with the distance between x and y equal to the distance between x and z. Spheres y and z are held in place but sphere x is free to move on a frictionless surface. Which path labeled A through E will sphere x take upon release?

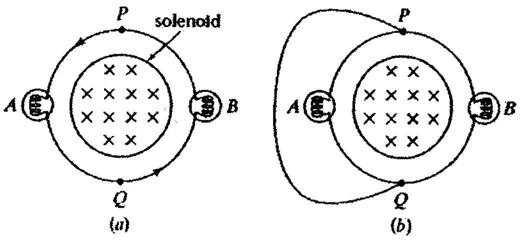


6. The current through an infinitely long solenoid is decreased linearly as a function of time. The figure below represents a cross section of the solenoid with the direction of the arrow indicating the current and the dots indicating the direction of the magnetic field. An electron is placed *initially at rest* outside the solenoid. The force the electron experiences at the instant it is released is best represented by which of the following arrows

   (A) ←
   (B) ↘
   (C) ↖
   (D) →
   (E) 0

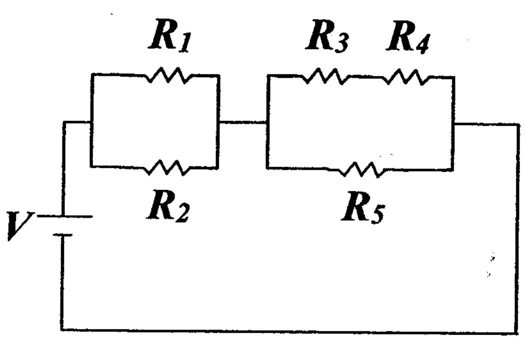


7. In figure (a) below, a solenoid produces a magnetic field whose strength increases into the plane of the page. An induced EMF is established in a conducting loop surrounding the solenoid, and this EMF lights bulbs A and B. In figure (b), points P and Q are shorted (that is a wire with negligible resistance is connected across points P and Q). After the short is inserted,



(A) bulb A turns off and bulb B gets brighter.
(B) bulb B turns off and bulb A gets brighter.
(C) bulb A turns off and bulb B gets dimmer.
(D) bulb B turns off and bulb A gets dimmer.
(E) both bulbs go out.

8. A battery and five resistors of ***equal resistance*** are arranged as shown in the figure below. Which resistor dissipates the most power?



(A) R_1.
(B) R_2.
(C) R_3.
(D) R_5.
(E) The power dissipated by each resistor is the same for all resistors.

9. Consider a very long wire carrying a steady current I going into the page as indicated in the figure below. Three oriented loops are also shown in the figure below. Which statement(s) is (are) correct?

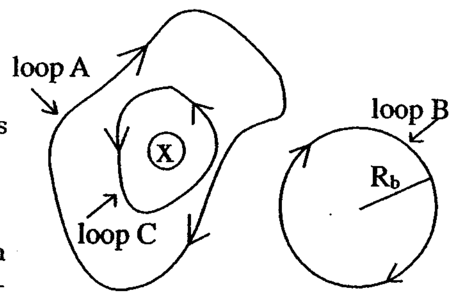
   I. $\oint_A \vec{\mathbf{B}} \cdot d\vec{l} = \mu_0 I$.

   II. $\oint_A \vec{\mathbf{B}} \cdot d\vec{l} = -\mu_0 I$.

   III. The magnetic field at every point around loop B is $\frac{\mu_0 I}{2\pi R_b}$.

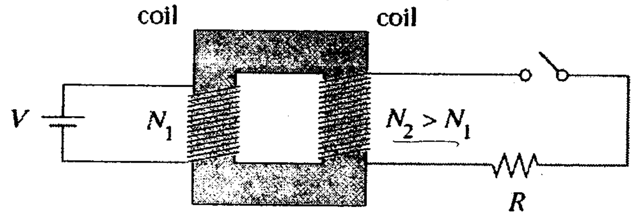
   IV. $\oint_A \vec{\mathbf{B}} \cdot d\vec{l} > \oint_B \vec{\mathbf{B}} \cdot d\vec{l} > \oint_C \vec{\mathbf{B}} \cdot d\vec{l}$.

   V. An external agent would do negative work when moving a positive charge around loop B in the direction of loop B.



   (A) Only I and IV are correct.
   (B) Only II and IV are correct.
   (C) Only III and V are correct.
   (D) Only I, IV, and V are correct.
   (E) Only II, IV and V are correct.

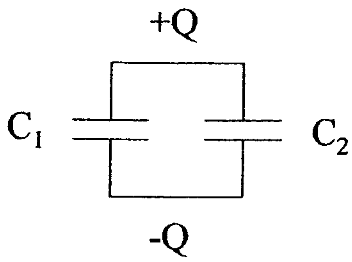
10. When the switch is closed, the potential difference across R is



   (A) $V\, N_2 / N_1$.
   (B) $V\, N_1 / N_2$.
   (C) V.
   (D) 0.
   (E) insufficient information.

11. Consider the arrangement of two capacitors connected by wires depicted below. A charge of $+Q$ is ripped from the bottom wire and added to the top. For the case $C_1 > C_2$, compare the charge on each capacitor's top plate (Q_1 and Q_2) and the voltage difference (V_1 and V_2) across each capacitor. Which of the statement(s) below is (are) true?

I. $Q_1 > Q_2$.
II. $Q_1 = Q_2$.
III. $Q_1 < Q_2$.
IV. $V_1 > V_2$.
V. $V_1 = V_2$.
VI. $V_1 < V_2$.

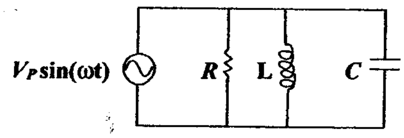


$C = Q/V$ $Q_1 = C_1 V$ $Q_2 = C_2 V$ $Q_1 > Q_2$

(A) Only I and VI are correct.
(B) Only II and VI are correct.
(C) Only I and IV are correct.
(D) Only III and VI are correct.
(E) Only I and V are correct

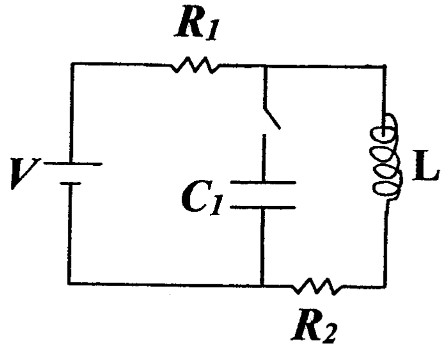
12. Consider the circuit below. A resistor R, inductor L, and capacitor C are connected in *parallel* across an alternating voltage source. Which statement(s) is (are) correct?

I. The instantaneous current through each element must add up to the instantaneous current provided by the driving source.
II. The instantaneous voltages across each element must add up to the instantaneous voltage of the driving source.
III. The voltage across C is 90° out of phase with the voltage across R.
IV. The voltage across C is 180° out of phase with the voltage across L.
V. All energy is dissipated by the resistor.



(A) Only I and V are correct.
(B) Only II and V are correct.
(C) Only I, III, and V are correct.
(D) Only I, IV, and V are correct.
(E) Only II, IV, and V are correct.

Refer to the circuit below for Questions 13 - 15. The circuit has been established for a very long time. At time $t = 0$, the switch is closed



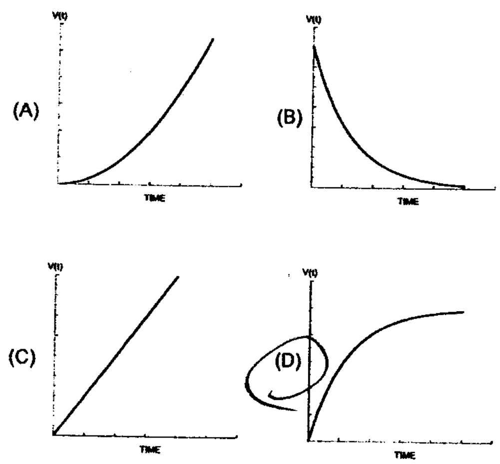
13. The current, I_0, through resistor R_2 at the instant $t = 0$ is

    (A) 0.
    (B) $I_0 = V/R_1$.
    (C) $I_0 = V/R_2$.
    (D) $I_0 = V/(R_1 + R_2)$.

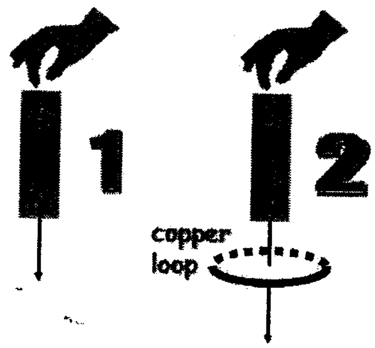
14. After the switch has been closed for a very long time, the charge on the capacitor is

    (A) $Q = 0$.
    (B) $Q = VC_1$.
    (C) $Q = VC_1\,(R_2/R_1)$.
    (D) $Q = VC_1\,(\frac{R_1}{R_1+R_2})$.
    (E) $Q = VC_1\,(\frac{R_2}{R_1+R_2})$.

15. Which of the following graphs best represents the behavior of the potential difference across the capacitor as a function of time?



Refer to the figure below for questions 16 and 17. Two identical magnets are dropped at the same time from the same height above the ground. The first magnet (Case 1) is dropped in a region of space that contains no conducting loops. The second magnet (Case 2) is dropped and allowed to pass through the center of a small copper ring. The diameter of the copper ring is larger than the width of the bar magnet so that the bar magnet does not hit the copper ring.



16. How does the kinetic energy of the magnet in Case 1 compare to the kinetic energy of the magnet in Case 2 right before the magnets hit the ground?

(A) KE (Case 1) > KE (Case 2).
(B) KE (Case 1) = KE (Case 2).
(C) KE (Case 1) < KE (Case 2).
(D) More information is needed.

17. Which magnet strikes the ground first?

(A) The magnet in Case 1.
(B) The magnet in Case 2.
(C) Both magnets will hit the ground at the same time.

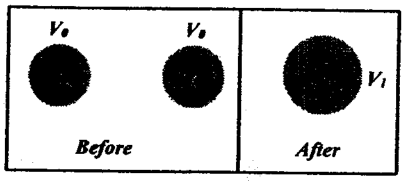
18. The leads of a sinusoidal AC-generator with angular frequency ω and peak voltage V_p are connected across a resistor with resistance R. What is the average power $< P >$ dissipated by the resistor?

(A) $< P >= 0$.
(B) $< P >= V^2/(\sqrt{2}\,R)$.
(C) $< P >= V^2/(2\,R)$.
(D) $< P >= V^2/(R)$.
(E) $< P >= 2\,V^2/(R)$.

$I = \frac{V}{R}$

$I^2 R \quad \frac{V^2}{R}$

For questions 19 - 20 refer to the figure below. Two isolated, identical spherical drops of mercury (a good electrical conductor) each carry a net charge of $+q_0$ and an electric potential V_0 at the surface with respect to infinity. The two drops are pushed together to form a single drop of mercury with charge q_1 and electric potential V_1 at its surface as illustrated in the figure below.



19. Which of the following statement(s) is (are) true?

    I. $V_1 = V_0$.

    II. $V_1 = 2\,V_0$.

    III. $q_1 = q_0$.

    IV. $q_1 = 2\,q_0$.

    (A) Only III is correct.

    (B) Only IV is correct.

    (C) Only I and III is correct.

    (D) Only I and IV is correct.

    (E) Only II and IV are correct.

20. What can be stated about the amount of work the *electric field* does on the system of the two mercury drops?

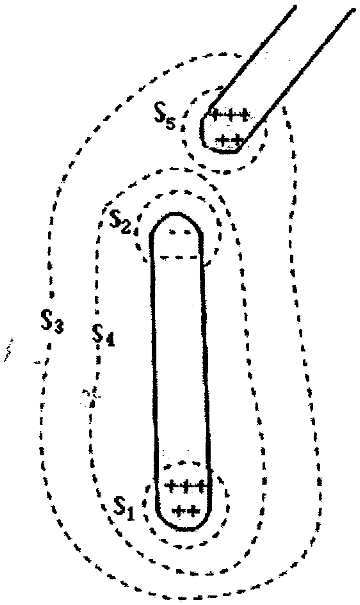
    (A) The work done by the electric field is positive.

    (B) The work done by the electric field is zero.

    (C) The work done by the electric field is negative.

    (D) Information about the displacement of the drops is needed to answer the question.

21. The charge on an originally neutral isolated conductor is separated by induction from a positively charged rod brought near the conductor. Rank the electric flux (Φ_E) through the gaussian surfaces labeled S_1 through S_5 in the figure below from greatest to least. NOTE: The electric flux through surface S_1 is denoted as $\Phi(S_1)$.



$\phi_1 = \frac{Q}{\varepsilon_0}$ $\phi_3 = \frac{Q}{\varepsilon_0}$

$\phi_2 = \frac{-Q}{\varepsilon_0}$ $\phi_4 = 0$

$\phi_5 = \frac{Q}{\varepsilon_0}$

$\phi_1 = \phi_3 = \phi_5 > \phi_4 > \phi_2$

(A) $\Phi(S_3) > \Phi(S_4) > \Phi(S_1) = \Phi(S_5) > \Phi(S_2)$.
(B) $\Phi(S_2) > \Phi(S_5) > \Phi(S_4) = \Phi(S_3) > \Phi(S_1)$.
(C) $\Phi(S_1) = \Phi(S_5) > \Phi(S_4) = \Phi(S_3) > \Phi(S_2)$.
(D) $\Phi(S_1) = \Phi(S_3) = \Phi(S_5) > \Phi(S_4) > \Phi(S_2)$
(E) $\Phi(S_1) = \Phi(S_3) = \Phi(S_5) > \Phi(S_2) > \Phi(S_4)$

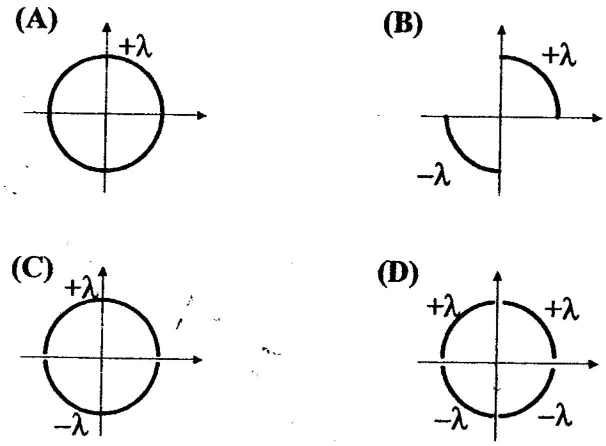
22. A new electronic device requires an AC - Voltage of 6V in order to operate. You wish to make an transformer that will connect into the 120 V house wiring. What must the ratio of the primary to the secondary turns be in the *ideal* transformer?

(A) 0.0025
(B) 0.05
(C) 20
(D) 400

$\frac{V_1}{N_1} = \frac{V_2}{N_2}$

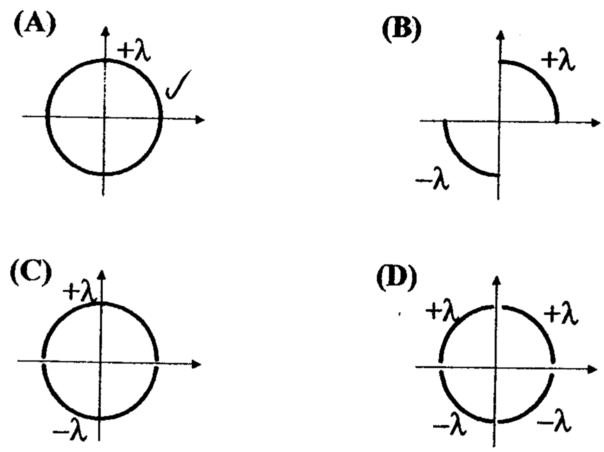
$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{120}{6} = 20$

23. Which charge distribution shown below will yield a **non-zero electric field,** and a **non-zero potential** at the origin of the coordinate system if the potential is defined to be zero infinitely far away from the origin? NOTE: All semi- and quarter-circles have the same radius as the complete circle in (A) and are all centered about the origin of the coordinate system.



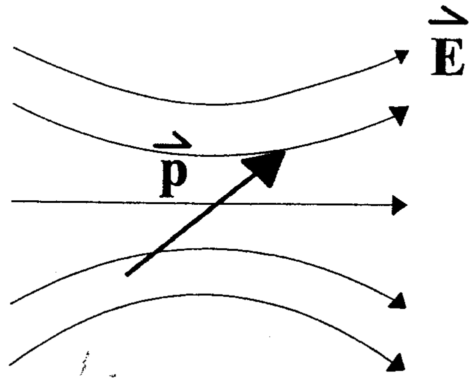
(A) A.
(B) B.
(C) C.
(D) D.
(E) None of the listed charge distributions meet the criteria.

24. Which charge distribution shown below will yield a **zero electric field,** and a **non-zero potential** at the origin of the coordinate system if the potential is defined to be zero infinitely far away from the origin? NOTE: All semi- and quarter-circles have the same radius as the complete circle in (A) and are all centered about the origin of the coordinate system.



(A) A.
(B) B.
(C) C.
(D) D.
(E) None of the listed charge distributions meet the criteria.

25. An electric dipole $\vec{p}$ is placed in an external electric field $\vec{E}$ as shown in the figure below. What statement is correct about the subsequent behavior of the electric dipole?



(A) The electric dipole experiences a net force but no net torque.

(B) The electric dipole experiences a net torque but no net force.

(C) The electric dipole experiences both a net torque and a net force.

(D) The electric dipole experiences no net torque and no net force.