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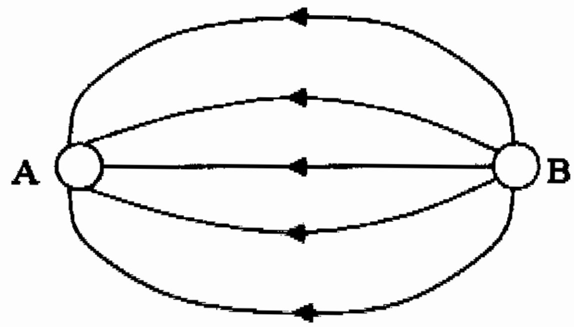
PART A

FOR EACH OF THE FOLLOWING QUESTIONS IN PART A, ENTER THE MOST APPROPRIATE RESPONSE ON THE OMR SHEET.

A1. The diagram shows the pattern of electric field lines near two objects A and B. What can be concluded about the charges on A and B?

A



$\vec{E}$ points away from a +ve charge and toward a -ve charge

(A) A has a negative charge and B has a positive charge.
(B) A has a positive charge and B has a negative charge.
(C) A has a negative charge and B has a negative charge.
(D) A has a positive charge and B has a positive charge.
(E) Nothing can be concluded since it is possible that either A or B has no charge.

A2. Electric potential energy per unit charge is called

B

(A) power. (B) potential. (C) electric field. (D) electron volt. (E) energy.

A3. If the electric potential at a distance of r_1 from an isolated point charge q is V_1, what is the electric potential at a distance of two-thirds of r_1, in terms of V_1?

C

(A) $2\,V_1$ (B) $\frac{2V_1}{3}$ (C) $\frac{3V_1}{2}$ (D) $\frac{9V_1}{4}$ (E) $\frac{4V_1}{9}$

$V_1 = \frac{kq}{r_1}$, $V_2 = \frac{kq}{(\frac{2}{3}r_1)}$, $V_2 = \frac{3}{2}\left(\frac{kq}{r_1}\right)$, $V_2 = \frac{3}{2}V_1$

A4. Two copper wires are the same length but wire 2 has a radius that is twice that of wire 1 (i.e. $r_2 = 2\,r_1$). Which one of the following statements is correct concerning the relationship between the resistances, R_1 and R_2, of the two wires?

A

(A) $R_2 = \frac{1}{4}R_1$ (B) $R_2 = \frac{1}{2}R_1$ (C) $R_2 = \sqrt{2}\,R_1$ (D) $R_2 = 2\,R_1$ (E) $R_2 = 4\,R_1$

$R = \frac{\rho L}{A} = \frac{\rho L}{\pi r^2} \Rightarrow R \propto \frac{1}{r^2}$ $r_2 = 2r_1$ so $R_2 = \frac{1}{(2)^2}R_1 = \frac{1}{4}R_1$

A5. Which one of the following statements regarding alternating current circuits is ***FALSE***?

D

(A) The voltage fluctuates sinusoidally with time. T
(B) The frequency of fluctuation in Canada is 60 Hz. T
(C) The rms voltage is less than the peak voltage. T
(D) The power dissipated by resistors in an ac circuit is zero. F
(E) The current flowing through an ac circuit reverses direction periodically. T

continued on page 3...

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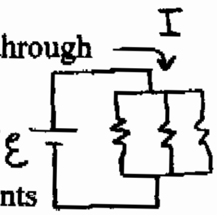
A6. Three resistors are connected in ***PARALLEL*** across an ideal voltage source. Each resistor has a resistance value that is different than those of the other two. Which one of the following statements is ***TRUE***?

D

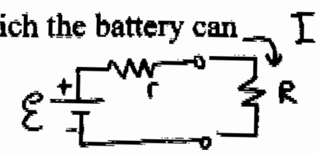
(A) The equivalent resistance of the three resistors is larger than any of the individual resistance values. F
(B) The total current drawn from the voltage source is the same as the current flowing through any of the individual resistors. F
(C) The sum of the voltage drops across the individual resistors is equal to the potential difference created by the voltage source. F
(D) The current through the resistor with the highest resistance is smaller than the currents through the other resistors. T $(I = \mathcal{E}/R)$
(E) The voltage drop across the resistor with the highest resistance is larger than the individual voltage drops across the other resistors. F



A7. Which one of the following statements is ***FALSE***?

E

(A) The emf of a battery is the maximum possible potential difference which the battery can supply. T
(B) The terminal voltage across a battery is often less than the emf. T
(C) An ideal battery has zero internal resistance. T
(D) In an external circuit connected to a battery, conventional charge carriers move from the positive terminal of the battery to the negative terminal. T
(E) In an external circuit connected to a battery, electrons move from the positive terminal of the battery to the negative terminal. F



A8. Which one of the following types of waves is ***NOT*** part of the electromagnetic spectrum?

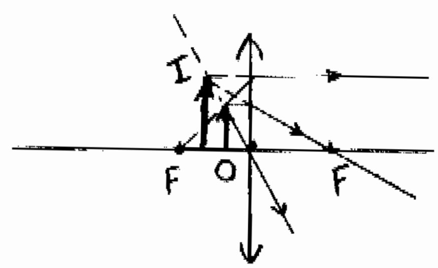
D

(A) radio (B) infrared (C) ultraviolet (D) sound (E) x-rays

A9. An object is located at a distance from a converging lens that is less than the focal length of that lens. Which one of the following statements is correct?

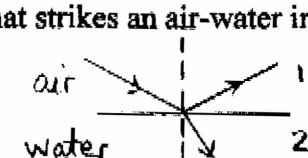
A

(A) The image is upright, enlarged, and virtual.
(B) The image is inverted, reduced, and real.
(C) The image is inverted, enlarged, and virtual.
(D) The image is inverted, enlarged, and real.
(E) No image is formed.



A10. Consider a ray of light, initially travelling in air, that strikes an air-water interface. Which one of the following statements is correct?

D



(A) All of the light passes into the water.
(B) All of the light reflects back into the air.
(C) Some of the light reflects back into the air and some refracts into the water. The angle of refraction is greater than the angle of incidence.
(D) Some of the light reflects back into the air and some refracts into the water. The angle of refraction is less than the angle of incidence. $n_2 > n_1$ so $\theta_2 < \theta_1$
(E) The answer depends on whether or not the angle of incidence is greater than the critical angle for an air-water interface.

continued on page 4...

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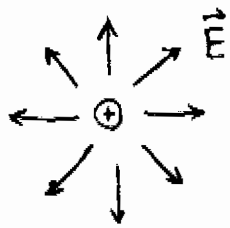
PART B

FOR EACH OF THE FOLLOWING PROBLEMS, WORK OUT THE SOLUTION IN THE SPACE PROVIDED AND ENTER YOUR ANSWERS ON PAGE 6.

ONLY THE ANSWERS WILL BE MARKED. THE SOLUTIONS WILL NOT BE MARKED.

B1. Calculate the magnitude of the electric field at a distance of 3.50 cm from a charge of +20.0 μC.

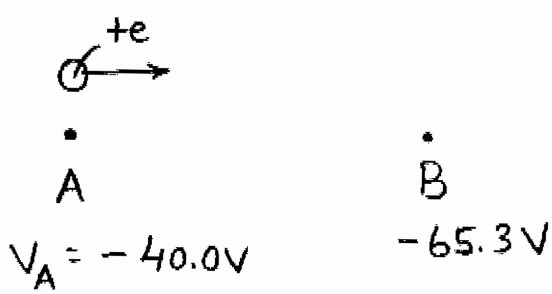


$$E = \frac{k|q|}{r^2}$$

$$E = \frac{\left(8.99 \times 10^9\ N \cdot m^2/C^2\right)\left|+20.0 \times 10^{-6} C\right|}{\left(3.50 \times 10^{-2} m\right)^2}$$

$$E = 1.47 \times 10^8\ N/C$$

B2. Calculate the change in the kinetic energy of a proton as it moves from a location where the potential is –40.0 V to a location where the potential is –65.3 V. Express your answer in electron-volts.



Energy is conserved:

$$E_A = E_B$$

$$KE_A + EPE_A = KE_B + EPE_B$$

$$\Delta KE_{AB} = KE_B - KE_A = EPE_A - EPE_B$$

$$\Delta KE_{AB} = q(V_A - V_B)$$

$$\Delta KE_{AB} = +e\left(-40.0V - (-65.3V)\right)$$

$$\Delta KE_{AB} = 25.3\ eV$$

continued on page 5...

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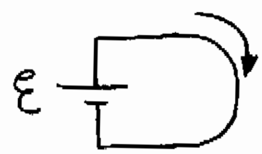
B3. A wire carries an electric current of 19.7 A. Calculate the number of electrons that pass a given point in the wire in one second.



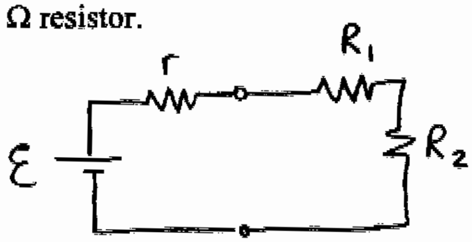
$I = 19.7\text{A}$

$$I = \frac{q}{t} = \frac{ne}{t}$$

$$n = \frac{It}{e}$$

$$n = \frac{(19.7\text{A})(1\text{ s})}{1.60 \times 10^{-19}\text{C}} = 1.23 \times 10^{20}$$

B4. Two resistors, with resistances of 5.35 Ω and 9.46 Ω, are connected in series with a battery with an emf of 9.21 V and an internal resistance of 0.392 Ω. Calculate the power dissipated in the 9.46 Ω resistor.



$\mathcal{E} = 9.21\text{V}$

$r = 0.392\,\Omega$

$R_1 = 5.35\,\Omega$

$R_2 = 9.46\,\Omega$

$$I = \frac{\mathcal{E}}{R_{tot}} = \frac{\mathcal{E}}{r + R_1 + R_2}$$

$$P_2 = I^2 R_2 = \left(\frac{\mathcal{E}}{r + R_1 + R_2}\right)^2 \cdot R_2$$

$$P_2 = 3.47\text{W}$$

continued on page 6...

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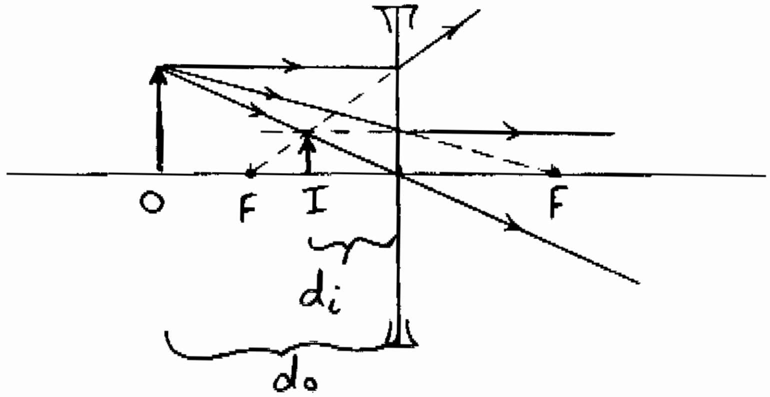
B5. Calculate the distance at which an object must be placed from a diverging lens ($f = -22.5$ cm) in order to produce an image at a distance of 16.6 cm from the lens.



$$d_o = \left(\frac{1}{f} - \frac{1}{d_i}\right)^{-1} = \left(\frac{1}{-22.5\,\text{cm}} - \frac{1}{-16.6\,\text{cm}}\right)^{-1}$$

$$d_o = +63.3\,\text{cm}$$

ANSWERS FOR PART B

ENTER THE ANSWERS FOR THE PART B PROBLEMS IN THE BOXES BELOW.

THE ANSWERS MUST CONTAIN THREE SIGNIFICANT FIGURES AND THE UNITS MUST BE GIVEN.

ONLY THE ANSWERS WILL BE MARKED. THE SOLUTIONS WILL NOT BE MARKED.

B1	1.47×10^8 N/C
B2	25.3 eV
B3	1.23×10^{20}
B4	3.47 W
B5	63.3 cm

continued on page 7...

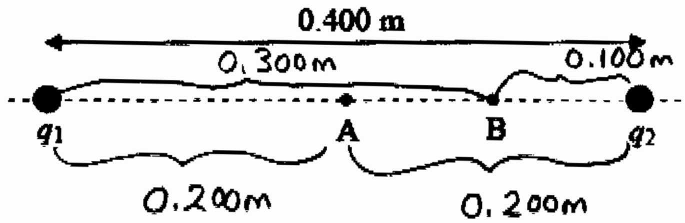
PART C

IN EACH OF THE FOLLOWING QUESTIONS, GIVE THE COMPLETE SOLUTION AND ENTER THE FINAL ANSWER IN THE BOX PROVIDED.

THE ANSWERS MUST CONTAIN THREE SIGNIFICANT FIGURES AND THE UNITS MUST BE GIVEN.

NO CREDIT WILL BE GIVEN FOR ANSWERS ONLY. EQUATIONS NOT PROVIDED ON THE FORMULA SHEET MUST BE DERIVED.

C1. Two charges, $q_1 = +3.00\ \mu C$ and $q_2 = -2.00\ \mu C$, are fixed a distance of 0.400 m apart as shown.



(a) Calculate the electric potential at the point A midway between q_1 and q_2, and at the point B midway between A and q_2.

$$V = \frac{kq}{r}$$

$$V_A = \frac{kq_1}{r_{1A}} + \frac{kq_2}{r_{2A}} \ ; \ V_B = \frac{kq_1}{r_{1B}} + \frac{kq_2}{r_{2B}}$$

$V_A =$ $4.50 \times 10^4\ V$

$V_B =$ $-8.99 \times 10^4\ V$

$$V_A = (8.99 \times 10^9\ N{\cdot}m^2/C^2)\left(\frac{+3.00 \times 10^{-6} C}{0.200 m} + \frac{(-2.00 \times 10^{-6} C)}{0.200 m}\right) = 4.50 \times 10^4\ V$$

$$V_B = (8.99 \times 10^9\ N{\cdot}m^2/C^2)\left(\frac{+3.00 \times 10^{-6} C}{0.300 m} + \frac{(-2.00 \times 10^{-6} C)}{0.100 m}\right) = -8.99 \times 10^4\ V$$

(b) A small object with mass 1.00 μg (= 1.00×10^{-9} kg) and charge $q = +1.00\ \mu C$ is released from rest at point A. Calculate the speed of the object when it reaches point B. (If you did not get answers for part (a) use the values $V_A = 3.00 \times 10^3$ V and $V_B = 1.00 \times 10^3$ V.)

Energy is conserved:

$1.64 \times 10^4\ m/s$

$$E_B = E_A$$

$$KE_B + EPE_B = KE_A + EPE_A \ ; \quad EPE = qV \quad (KE_A = 0)$$

$$\tfrac{1}{2} m v_B^2 = qV_A - qV_B$$

$$v_B = \sqrt{\frac{2q}{m}(V_A - V_B)} = \left[\frac{2(1.00 \times 10^{-6} C)(4.50 \times 10^4 V - (-8.99 \times 10^4 V))}{1.00 \times 10^{-9} kg}\right]^{1/2}$$

$$v_B = 1.64 \times 10^4\ m/s$$

continued on page 8...

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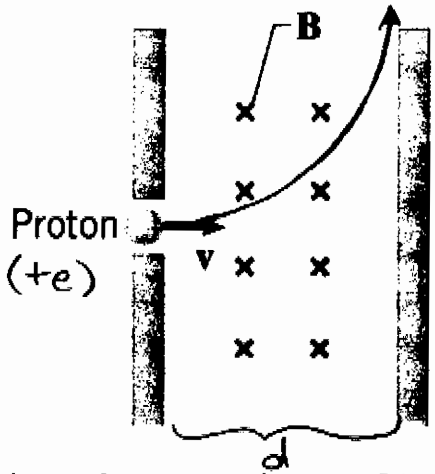
C2. A proton with a speed $v = 2.80 \times 10^6$ m/s is shot into a region between two plates where there is a magnetic field B of magnitude 0.320 T, as shown in the diagram.



from RHR,
$\vec{F}$ is initially toward top of page, motion is circular.

(a) On the diagram provided above, sketch the trajectory of the proton in the magnetic field.

(b) Calculate the separation of the two plates, if the proton *just* avoids colliding with the opposite plate.

If the proton is to just avoid hitting the opposite plate, then the plate separation must be just greater than the radius of the proton's trajectory.

$$d > 9.13 \text{ cm}$$

From Newton II for uniform circular motion:

$$\sum \vec{F} = m\vec{a}_c$$

$$qvB \sin\theta = \frac{mv^2}{r} \; ; \quad \theta = 90.0°$$

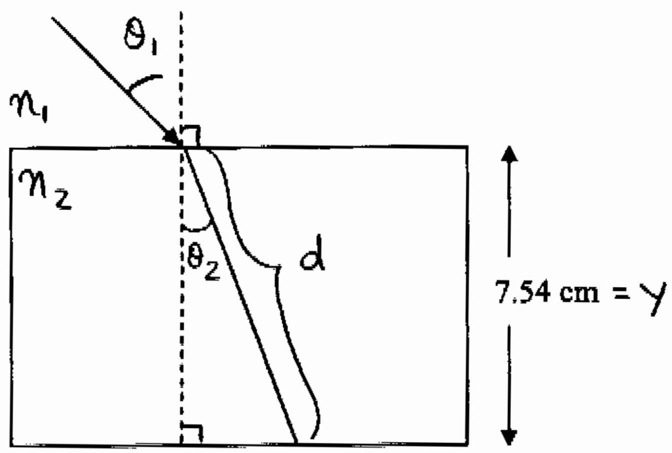
$$qvB = \frac{mv^2}{r} \Rightarrow r = \frac{mv}{qB}$$

$$r = \frac{(1.67 \times 10^{-27} \text{ kg})(2.80 \times 10^6 \text{ m/s})}{(1.60 \times 10^{-19} \text{ C})(0.320 \text{ T})} = 9.13 \times 10^{-2} \text{ m}$$

$$= 9.13 \text{ cm}$$

continued on page 9...

C3. A beam of light strikes a glass block at an angle of incidence of 35.6°, as shown in the diagram. The index of refraction of the glass is 1.63. Calculate the time required for the light to travel from its point of entry to its point of exit from the glass block.



t = time in block

d = distance

v = speed in block

$$v = \frac{d}{t} \Rightarrow t = \frac{d}{v}$$

can determine v from $n = \frac{c}{v}$: $v = \frac{c}{n_2}$

$$t = \frac{d}{v} = \frac{d}{c/n_2} = \frac{n_2 d}{c}$$

$$\boxed{4.39 \times 10^{-10}\,\text{s}}$$

From Snell's Law, $n_1 \sin\theta_1 = n_2 \sin\theta_2$

$$\theta_2 = \sin^{-1}\left(\frac{n_1 \sin\theta_1}{n_2}\right) = \sin^{-1}\left(\frac{1.00 \sin 35.6°}{1.63}\right) = 20.9°$$

From the diagram, $\cos\theta_2 = \frac{y}{d} \Rightarrow d = \frac{y}{\cos\theta_2}$

$$\therefore \quad t = \frac{n_2\left(\frac{y}{\cos\theta_2}\right)}{c} = \frac{1.63\left(\frac{7.54 \times 10^{-2}\,\text{m}}{\cos 20.9°}\right)}{3.00 \times 10^{8}\,\text{m/s}}$$

$$t = 4.39 \times 10^{-10}\,\text{s}$$

END OF EXAMINATION