PHYS 102 Midterm Examination #1 (version E)

June 15, 2012

Time: 50 minutes

Last Name : Key

First Name : ______________________

Student No. : ______________________

Computing ID : ______________________

Tutorial Section : ______________________

	score	Maximum
Multiple Choice		5
✓ Written # 6		5
Written # 7		5
✓ Written # 8		5
✓ Written # 9		5
Total		25

Part I (Multiple choice questions. 1 mark each.)

E

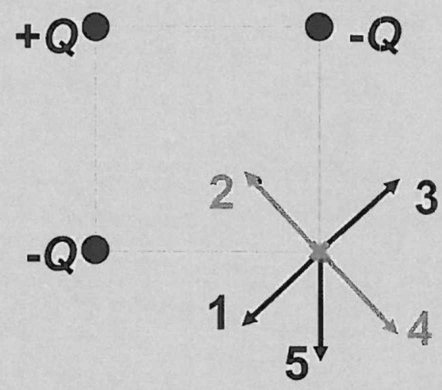
1. You are sitting a certain distance from a point charge, and you measure an electric field of E_0. If the charge is doubled and your distance from the charge is also doubled, what is the electric field strength now?

A) $2E_0$; B) $4E_0$; C) E_0 ; D) $E_0/4$; E) $E_0/2$.

B

2. What is the direction of the electric field at the position of **x**?

A) 1
B) 2
C) 3
D) 4
E) 5



C

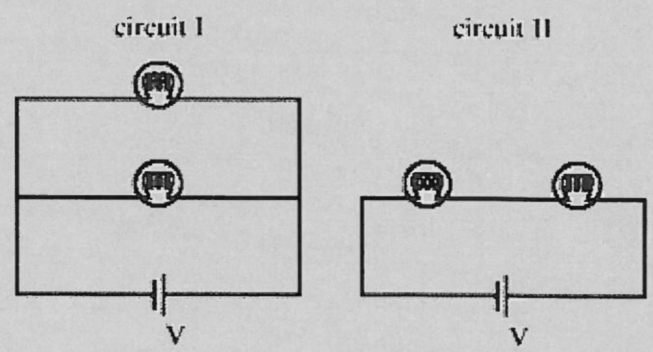
3. The total flux of magnetic field through a closed surface:

A) is always positive.
B) is always negative.
C) is always zero.
D) depends on the field.
E) depends on the closed surface.

A

4. The lightbulbs in the circuits below are identical with the same resistance *R*. Which circuit consumes more power?

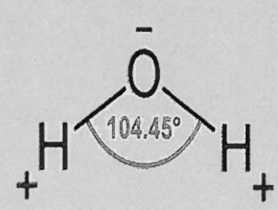
A) circuit I
B) circuit II
C) both the same
D) it depends on *R*
E) it depends on V



C

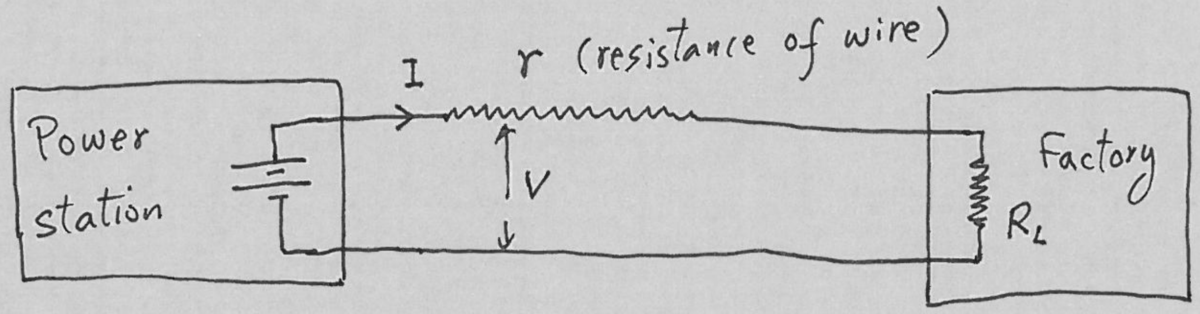
5. Does a water molecule carry an electric dipole moment?

A) No, because the molecule is electrically neutral.
B) No, because the molecule is symmetrical and the net dipole moment is zero.
C) Yes, because of the uneven distribution of electron density and the asymmetrical structure.
D) Can't tell from the structure of the molecule.
E) It depends on the environment such as the existence of an external field.



Part II (Full solution questions, 5 marks each. **SHOW ALL WORK FOR FULL MARKS!**)

6. A power station delivers 800 kW of power at 10,000 V to a factory through wires with total resistance 4.0 Ω. How much less power is wasted if the electricity is delivered at 80,000 V rather than 10,000V?



Power wasted in the wire: $P_W = rI^2$

Power delivered to the factory: $P_f = IV \quad \left(= \frac{V^2}{R_L} = R_L I^2 \right)$

when $V = 10{,}000$ V: $I = \frac{P_f}{V} = \frac{800{,}000}{10{,}000} = 80$ A

Power wasted: $P_W = rI^2 = 4 \times 80^2 = 25600$ W

when $V = 80{,}000$ V: $I = \frac{800{,}000}{80{,}000} = 10$ A.

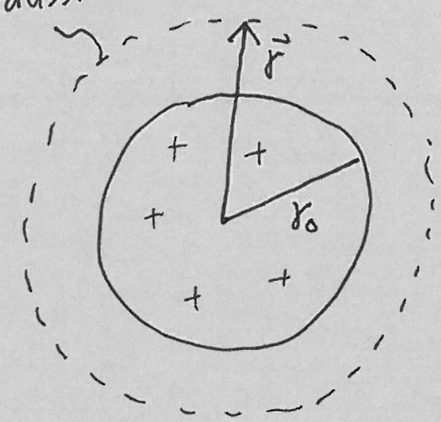
Power wasted: $P_W = 4 \times 10^2 = 400$ W.

Difference in P_W: $25600\text{ W} - 400\text{ W} = 25200$ W

$= 25.2$ kW.

∴ 25.2 kW less power is wasted when the voltage is changed from 10,000 V to 80,000 V.

7. An electric charge Q is distributed uniformly throughout a nonconducting sphere of radius r_0. For the following two cases, determine the electric field at a point whose distance from the centre of the sphere is r.
(a$_{2/5}$) outside the sphere ($r > r_0$);
(b$_{3/5}$) inside the sphere ($r < r_0$).



(a) $r > r_0$ Gauss' law:

$$\Phi = \sum_{G.S.} \vec{E}\cdot\vec{A} = \frac{Q_{encl.}}{\varepsilon_0}$$

By symmetry, $\vec{E} \parallel \vec{r}$.

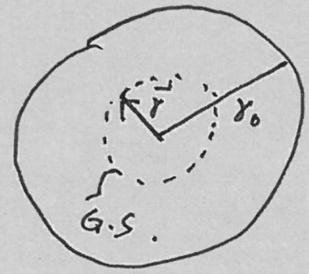
E = constant on G.S.

$$\therefore \quad E \cdot 4\pi r^2 = \frac{Q}{\varepsilon_0}$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}.$$

Direction: $\vec{E}$ is along $\vec{r}$.

(b) $r < r_0$.



$$\Phi = \sum_{G.S.} \vec{E}\cdot\vec{A} = \frac{Q_{encl.}}{\varepsilon_0}$$

$$E\,4\pi r^2 = \frac{1}{\varepsilon_0}\cdot\rho\cdot V$$

ρ – charge density
V – volume

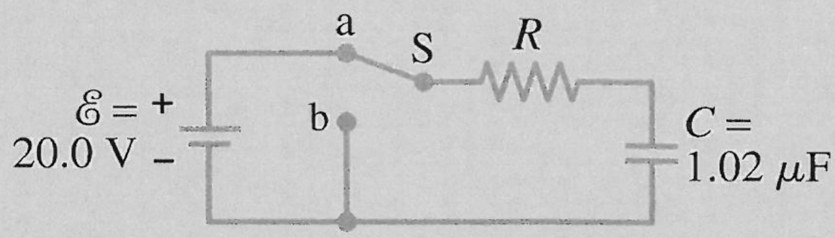
$$\rho = \frac{Q}{\frac{4}{3}\pi r_0^3}, \qquad V = \frac{4}{3}\pi r^3.$$

$$\therefore \quad E\cdot 4\pi r^2 = \frac{1}{\varepsilon_0}\cdot\frac{Q}{\frac{4}{3}\pi r_0^3}\cdot\frac{4}{3}\pi r^3 = \frac{Q}{\varepsilon_0}\frac{r^3}{r_0^3}$$

$$\therefore \quad E = \frac{Q}{4\pi\varepsilon_0}\frac{r}{r_0^3}.$$

Direction of $\vec{E}$: along $\vec{r}$.

8. In the *RC* circuit shown, the battery has fully charged the capacitor. Then at $t = 0$ the switch is thrown from position a to b. The battery emf is 20.0 V, and the capacitance C = 1.02 μF. The current I is observed to decrease to 20% of its initial value in 40 μs.
($a_{1/5}$) What is the value of Q, the charge on the capacitor, at $t = 0$?
($b_{3/5}$) What is the value of R?
($b_{1/5}$) What is the current through R after a long time (as $t \to \infty$)?



(a). At $t = 0$

$V_c = V_0 = \mathcal{E} = 20.0\,V$

$Q_0 = V_0 C = 20 \times 1.02 \times 10^{-6} = 2.04 \times 10^{-5}\,C$

(b). $I = I_0 e^{-t/\tau}$, $\tau = RC$.

when $t = 4 \times 10^{-5}\,s$, $0.2 I_0 = I_0 e^{-t/\tau}$

$0.2 = e^{-t/\tau}$ $\ln 0.2 = -t/\tau$.

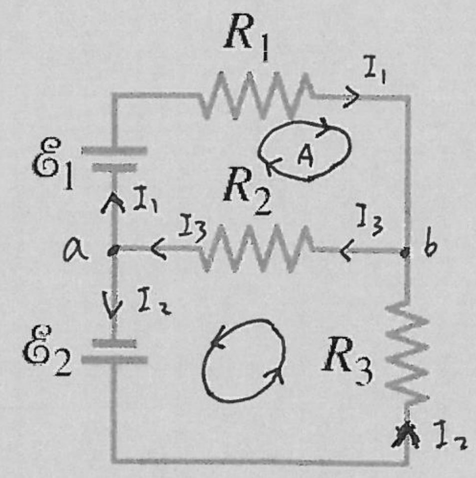
$\tau = \frac{-t}{\ln 0.2} = \frac{-4.0 \times 10^{-5}}{-1.6094} = 2.485 \times 10^{-5}\,s$.

$R = \frac{\tau}{C} = \frac{2.485 \times 10^{-5}}{1.02 \times 10^{-6}} = 24.4\,\Omega$.

(c). as $t \to \infty$,

$I \to 0$.

9. Determine the magnitudes of the currents in each resistor shown in the figure . The batteries have emfs of $\mathcal{E}_1$=7.2V and $\mathcal{E}_2$=8.1V and the resistors have values of R_1=9.0Ω, R_2=18Ω, and R_3=27Ω.



Junction a: $I_3 = I_1 + I_2$

Loop A: $\mathcal{E}_1 - R_1 I_1 - R_2 I_3 = 0$

Loop B: $\mathcal{E}_2 - R_3 I_2 - R_2 I_3 = 0$.

i.e.: $\begin{cases} I_1 + I_2 - I_3 = 0 \\ R_1 I_1 + R_2 I_3 = \mathcal{E}_1 \\ R_3 I_2 + R_2 I_3 = \mathcal{E}_2 \end{cases}$

or: $\begin{cases} I_1 + I_2 - I_3 = 0 & ① \\ 9I_1 + 18 I_3 = 7.2 & ② \\ 27 I_2 + 18 I_3 = 8.1 & ③ \end{cases}$

$\begin{cases} I_1 + I_2 - I_3 = 0 & ① \\ I_1 + 2I_3 = 0.8 & ② \\ 3I_2 + 2I_3 = 0.9 & ③ \end{cases}$

② − ①: $\begin{cases} -I_2 + 3I_3 = 0.8 & ④ \\ 3I_2 + 2I_3 = 0.9 & ③ \end{cases}$

④ × 3: $-3I_2 + 9I_3 = 2.4$.

③: $3I_2 + 2I_3 = 0.9$

\+ $11 I_3 = 3.3$.

$I_3 = 0.3$ A .

Subs into ④:

$I_2 = 3I_3 - 0.8$

$= 3 \times 0.3 - 0.8$

$= 0.1$ A .

Subs into ①:

$I_1 = I_3 - I_2$

$= 0.3 - 0.1$

$= 0.2$ A

$\therefore \begin{cases} I_1 = 0.2 \text{ A} \\ I_2 = 0.1 \text{ A} \\ I_3 = 0.3 \text{ A} \end{cases}$