PHY2054 Spring 2014 Exam I

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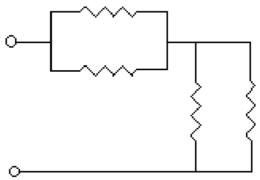
MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question. Please circle the correct answer. Each question is worth 5 points.

1) The resistors in the circuit shown in Figure below each have a resistance of $900\ \Omega$. What is the equivalent resistance of the circuit?



A) $900\ \Omega$ B) $3600\ \Omega$ C) $225\ \Omega$ D) $1800\ \Omega$

2) A 4.0 m length of metal wire is connected to a 1.5 V battery, and a current of 8.0 mA flows through it. What is the diameter of the wire? (The resistivity of metal is $2.24 \times 10^{-8}\ \Omega \cdot m$.)

A) 96 μm B) 9.0 μm C) 13 μm D) 25 μm

3) Each plate of a parallel-plate air capacitor has an area of $0.0080\ m^2$, and the separation of the plates is 0.030 mm. An electric field of 4.2×10^6 V/m is present between the plates. The potential difference across the capacitor is closest to:

A) 252 V B) 210 V C) 126 V D) 84 V E) 168 V

4) A 3.0 μC negative charge is attracted to a large, well-anchored, positive charge. How much kinetic energy does the negatively charged object gain if the potential difference through which it moves is 4 mV?

A) 1.33 kJ B) 1.33 J C) 3.0 μJ D) 12 nJ

5) A plastic rod is charged up by rubbing a wool cloth, and brought to an initially neutral metallic sphere. It is allowed to touch the sphere for a few seconds, and then is separated from the sphere by a small distance. After the rod is separated, the rod

A) feels no force due to the sphere.
B) is attracted to the sphere.
C) is repelled by the sphere.

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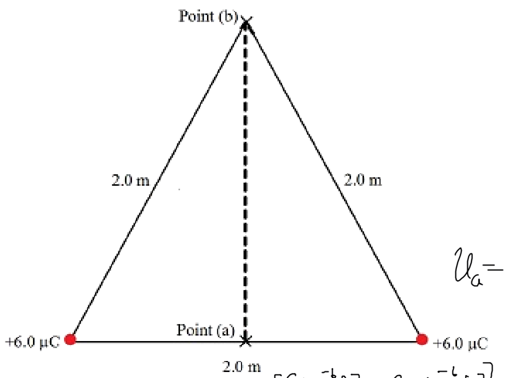
ᴚT ANS ER. Solve the problem and show your work. Make sure to include "Givens" and "Physics" for maximum s. Also, penalties are assesed for not including units in your final answer or if the number of significant figures is nsistent with given information. Circle your final answer. Each question is worth 15 points.

6) Two point charges +9.0 μC are afixed at the corners of the base of an equilateral triangle, as shown in the figure. A third charge of +3.3 μC is first placed midway between two charges at point (a) find the work done by the two charges on the third charge as it moves from point (a) to (b) ($k = 1/4\pi\varepsilon_0 = 8.99 \times 10^9\ \mathrm{N \cdot m^2/C^2}$)
For extra CREDIT find the Electric Field at point (b). (5 additional points awarded for correct answer)



Givens +1

$q_1 = +9.0\mu C$

$q_2 = +9.0\mu C$

$q_3 = +3.3\mu C$

Physics +4

$W_{ab} = U_a - U_b$ (initial, final)

$U = k\dfrac{q_i q_j}{r_{ij}}$

$U_a = k\dfrac{q_1 q_3}{r^a_{13}} + k\dfrac{q_1 q_2}{r^a_{12}}$ $\qquad U_b = k\dfrac{q_1 q_3}{r^b_{13}} + k\dfrac{q_1 q_2}{r^b_{12}}$

$r^a_{13} = r^a_{12} = 1.0[m]$ $\qquad r^b_{13} = r^b_{12} = 2.0[m]$

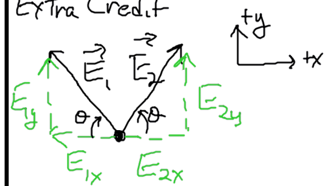
$U_a = (8.99\times10^9[\frac{Nm^2}{c^2}])(3.3\times10^{-6}[c])\left[\frac{9.0\times10^{-6}[c]}{1.0[m]} + \frac{9.0\times10^{-6}[c]}{1.0[m]}\right] = 0.534006[J]$

$U_b = (8.99\times10^9[\frac{Nm^2}{c^2}])(3.3\times10^{-6}[c])\left[\frac{9.0\times10^{-6}[c]}{2.0[m]} + \frac{9.0\times10^{-6}[c]}{2.0[m]}\right] = 0.267003\ [J]$

$W_{ab} = U_a - U_b = 0.534006 - 0.267003 = +0.267003$ $\quad \boxed{W_{ab} = 0.27[J]}$ +10

−1 if sig fig is wrong
−1 if units are not included or wrong
−2 if numerical mistake

Extra Credit



Physics

$\vec{E} = \vec{F_c}/q_{test}$

$\vec{F} = k\dfrac{q_i q_{test}}{r^2}$

The E component along the x direction cancels along the y they are x2

$|\vec{E}_{1y}| = |\vec{E}_1|\sin\theta = |\vec{E}_{2y}|$

$\theta = \cos^{-1}(\frac{1}{2}) = 60°$

$|\vec{F_1}| = |\vec{F_2}| = k\dfrac{q_1 q_{test}}{r^2} = (8.99\times10^9\ \frac{Nm^2}{c^2})(9.0\times10^{-6}c)\dfrac{q_{test}}{(2.0\ m)^2} = 2.02275\times10^4\ q_{test}\ [N]$

$\vec{E}_T = \vec{E}_{1y} + \vec{E}_{2y} = 2|\vec{E}_{1y}| = \dfrac{|\vec{F_1}|\sin\theta}{q_{test}} = 2\cdot 2.02275\times10^4 \dfrac{\cancel{q_{test}}\sin 60°}{\cancel{q_{test}}} = 1.7518\times10^4$

$\boxed{\vec{E}_b = 1.8\times10^4\ [\frac{V}{m}]\ (\hat{+y})}$

+5 if correct in addition to
−3 if direction "+ŷ" not included or incorrect

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7) An oil droplet with 4 excess electrons is held stationary in a field of 1.27×10^{4} N/C. What is the radius of the oil drop? (The density of the oil is 824 kg/m^3, $e = 1.60 \times 10^{-19}$ C.)

Givens +1

$q = 4 \times 1.6 \times 10^{-19}\,C$

$\vec{E} = 1.27 \times 10^{4}\,\frac{N}{C}$

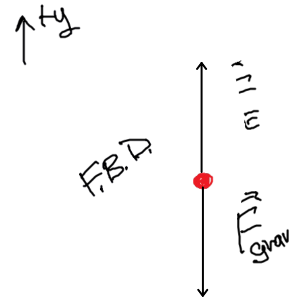
$\rho_{oil} = 824\,kg/m^3$

Physics +4

$\vec{F} = q\vec{E}$

$\vec{F} = mg(-\hat{y})$

$m_{sphere} = \frac{4\pi}{3}\rho r^3$



For drop to be stationary forces have to balance!

$$\Sigma F_y : +F_E - F_{grav} = 0$$

$$+qE - mg = 0$$

but $m = \frac{4\pi}{3} r^3 \rho$

solving for the radius r

$$qE = \frac{4\pi}{3}\rho r^3 g$$

$$\sqrt[3]{\frac{3}{4\pi}\frac{qE}{\rho g}} = r$$

$$\sqrt[3]{\frac{3}{4\pi}\frac{(4 \times 1.6 \times 10^{-19} C)(1.27 \times 10^{4} \frac{N}{C})}{(824 \frac{kg}{m^3})(9.8 \frac{M}{s^2})}} = 6.216996164 \times 10^{-7}\,[m]$$

$$\boxed{r_{drop} = 6.22 \times 10^{-7}\,[m]}$$ +10

−1 if sig fig is wrong

−1 if units are not included or wrong

−2 if numerical mistake

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9) Three point charges are placed at the following (x, y) coordinates: charge $+6.0 \times 10^{-6}$ C at (0, 0.5 m), charge $+2.0 \times 10^{-6}$ C at (0.7 m, 0), and charge -4.0×10^{-6} C at (0.7 m,0.5 m). Calculate the electrical force on a pointt particle with charge -1.6×10^{-6} C at the origin (0, 0).

Givens +1

$q_1 = +6.0\times10^{-6}[C]$ @ $(0, 0.5m)$

$q_2 = +2.0\times10^{-6}[C]$ @ $(0.7m, 0)$

$q_3 = -4.0\times10^{-6}[C]$ @ $(0.7, 0.5m)$

$Q = -1.6\times10^{-6}[C]$ @ $(0,0)$

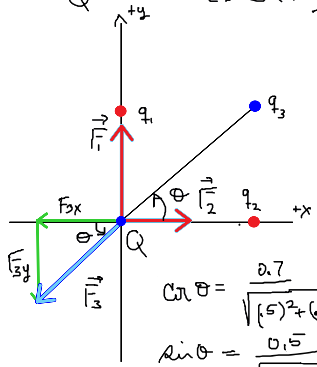

figure is not required

$$\cos\theta = \frac{0.7}{\sqrt{(.5)^2+(.7)^2}} = 0.813733$$

$$\sin\theta = \frac{0.5}{\sqrt{(.5)^2+(.7)^2}} = 0.5812381$$

Physics +4

$$\vec{F}_{Total} = \sum_{i=1}^{3} k\frac{q_i Q}{r_i^2}\hat{r}_i$$

$$\vec{F}_1 = k\frac{q_1 Q}{r_1^2}(+\hat{y})$$ the sign comes for the figure

$$= \left(8.99\times10^9 \frac{Nm^2}{C^2}\right)(6.0\times10^{-6}C)(1.6\times10^{-6}C)\frac{1}{(0.5m)^2}$$

$$= 0.345216\ N\ (+\hat{y})$$

$$\vec{F}_2 = k\frac{q_2 Q}{r_2^2}(+\hat{y})$$

$$= \left(8.99\times10^9 \frac{Nm^2}{C^2}\right)(2.0\times10^{-6}C)(1.6\times10^{-6}C)\frac{1}{(0.7m)^2}$$

$$= 0.0587102\ (+\hat{y})$$

$$\vec{F}_3 = |\vec{F}_3|\cos\theta(\hat{x}) \oplus |\vec{F}_3|\sin\theta(\hat{y})$$

$$|\vec{F}_3| = k\frac{Qq_3}{r_3^2} = \frac{\left(8.99\times10^9\frac{Nm^2}{C^2}\right)(1.6\times10^{-6}C)(4.0\times10^{-6}C)}{(0.7m)^2+(0.5m)^2}$$

$$= 0.077751\ N$$

$$\vec{F}_{Total\,Q} = (F_2 - F_{3x})(+\hat{x}) \oplus (F_1 - F_{3y})(+\hat{y})$$

$$= (0.587102 - (0.077751N)(0.813733))(-\hat{x}) \oplus (0.345216 - (0.07775)(0.5812381))(+\hat{y})$$

$$(0.523671\ N)(+\hat{x}) \oplus 0.200653(+\hat{y})$$

$$\boxed{\vec{F}_Q = 0.52[N](-\hat{x}) \oplus 0.20[N](+\hat{y})}$$ +10

−1 if sig fig is wrong
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9) Three point charges are placed at the following (x, y) coordinates: charge $+6.0 \times 10^{-6}$ C at (0, 0.5 m), charge $+2.0 \times 10^{-6}$ C at (0.7 m, 0), and charge -4.0×10^{-6} C at (0.7 m,0.5 m). Calculate the electrical force on a pointt particle with charge -1.6×10^{-6} C at the origin (0, 0).

Givens +1

$q_1 = +6.0\times10^{-6}[C]$ @ $(0, 0.5m)$

$q_2 = +2.0\times10^{-6}[C]$ @ $(0.7m, 0)$

$q_3 = -4.0\times10^{-6}[C]$ @ $(0.7, 0.5m)$

$Q = -1.6\times10^{-6}[C]$ @ $(0,0)$

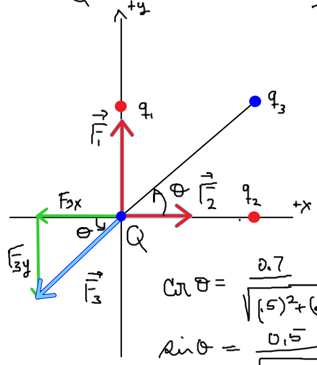

figure is not required

$$\cos\theta = \frac{0.7}{\sqrt{(.5)^2+(.7)^2}} = 0.813733$$

$$\sin\theta = \frac{0.5}{\sqrt{(.5)^2+(.7)^2}} = 0.5812381$$

Physics +4

$$\vec{F}_{Total} = \sum_{i=1}^{3} k\frac{q_i Q}{r_i^2}\hat{r}_i$$

$$\vec{F}_1 = k\frac{q_1 Q}{r_1^2}(+\hat{y})$$ the sign comes for the figure

$$= \left(8.99\times10^9 \frac{Nm^2}{C^2}\right)(6.0\times10^{-6}C)(1.6\times10^{-6}C)\frac{1}{(0.5m)^2}$$

$$= 0.345216\ N\ (+\hat{y})$$

$$\vec{F}_2 = k\frac{q_2 Q}{r_2^2}(+\hat{y})$$

$$= \left(8.99\times10^9 \frac{Nm^2}{C^2}\right)(2.0\times10^{-6}C)(1.6\times10^{-6}C)\frac{1}{(0.7m)^2}$$

$$= 0.0587102\ (+\hat{y})$$

$$\vec{F}_3 = |\vec{F}_3|\cos\theta(\hat{x}) \oplus |\vec{F}_3|\sin\theta(\hat{y})$$

$$|\vec{F}_3| = k\frac{Qq_3}{r_3^2} = \frac{\left(8.99\times10^9\frac{Nm^2}{C^2}\right)(1.6\times10^{-6}C)(4.0\times10^{-6}C)}{(0.7m)^2+(0.5m)^2}$$

$$= 0.077751\ N$$

$$\vec{F}_{Total\ Q} = (F_2 - F_{3x})(+\hat{x}) \oplus (F_1 - F_{3y})(+\hat{y})$$

$$= (0.587102 - (0.07775N)(0.813733))(-\hat{x}) \oplus (0.345216 - (0.07775)(0.5812381))(+\hat{y})$$

$$(0.523671\ N)(+\hat{x}) \oplus 0.200653(+\hat{y})$$

$$\boxed{\vec{F}_Q = 0.52[N](-\hat{x}) \oplus 0.20[N](+\hat{y})}$$ +10

−1 if sig fig is wrong
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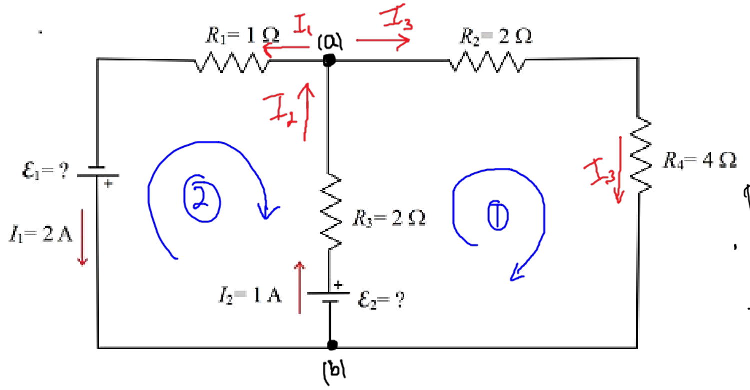
10) Consider the circuit diagram below.
   a) Find the EMF values for $\mathcal{E}_1$ and $\mathcal{E}_2$
   b) Find rhe power dissipated by the resitor R_4.



Givens +1
see figure

Physics +4

Kirchoff's Rules

$\sum_i I_i = 0$ in (+) out (-)

$\sum_{i=a}^{a} V_i = 0$

$P = I^2 R$

K. jnct rule
at point (a)

$I_2 - I_1 - I_3 = 0$

$1[A] - 2[A] = I_3$

$-1[A] = I_3$

K loop rule

loop $①_a$ $-2I_3 - 4I_3 + \mathcal{E}_2 - 2I_2 = 0 \rightarrow +2+4-2 = -\mathcal{E}_2 \rightarrow \mathcal{E}_2 = -2[V]$

loop $②_a$ $+2I_2 - \mathcal{E}_2 - \mathcal{E}_1 + I_1 = 0 \rightarrow +4+2+2 = \mathcal{E}_1 \rightarrow \mathcal{E}_1 = 8[V]$

$$\boxed{a)\ \mathcal{E}_2 = -4[V],\ \mathcal{E}_1 = 8[V]}$$ +7

To find power dissipated by R_4 use

$P_{R_4} = I_3^2 R_4 = (-1\,A)^2(4\,\Omega) = 4\,[W]$

$$\boxed{b)\ P_{R_4} = 4\,[W]}$$ +3

-1 if sig fig is wrong
-1 if units are not included or wrong
-2 if numerical mistake