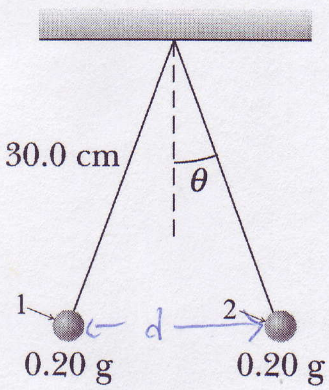
PHYSICS 102 | Midterm | Name: Jake Bobowski - Sol'ns
Feb. 15, 2013 12:30-13:20 | | Student Number:__________

Midterm (24 points)
Multiple Choice: Circle the best answer for each of the three multiple choice questions.

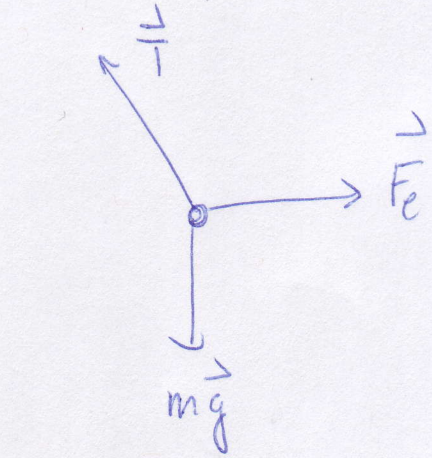
(2pts) **1.** Two identical spheres (same radius and mass) are suspended from strings of equal length as shown in the figure. Initially, both spheres carry a charge of q and the electrostatic repulsion causes the string on the right to make an angle θ with respect to the vertical dashed line.



If the charge on sphere 1 is changed to $q/2$ and the charge on sphere 2 is changed to $2q$, what happens to θ?

(a) θ increases.
(b) θ decreases.
(c) θ stays the same.
(d) More information is needed.

FBD of 2.



initially $F_e = \frac{1}{4\pi\varepsilon_0}\frac{q\cdot q}{d^2} \sim \frac{q^2}{d^2}$

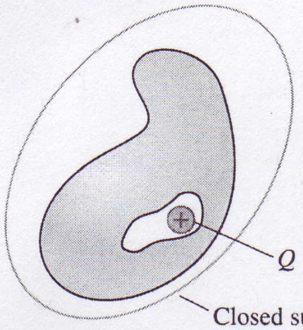
after charge changed

$F_e = \frac{1}{4\pi\varepsilon_0}\frac{\frac{q}{\cancel{2}}\cancel{2}q}{d^2} \sim \frac{q^2}{d^2}$

same.

2 pts

(2pts) **2.** The figure shows a hollow cavity within a neutral conductor. Point charge Q is inside the cavity. What is the net electric flux through the closed surface that surrounds the conductor?

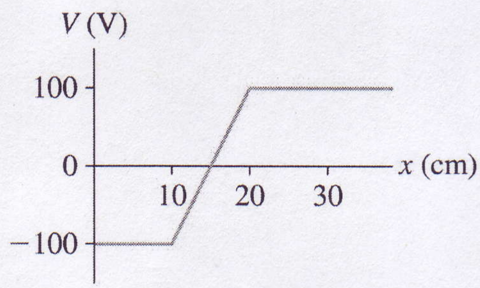


$$\Phi_e = \frac{Q_{in}}{\varepsilon_0} = \frac{Q}{\varepsilon_0}$$

$Q_{in} = Q$ since conductor is neutral.

(a) $-2Q/\varepsilon_0$ (b) $-Q/\varepsilon_0$ (c) zero (d) Q/ε_0 (e) $2Q/\varepsilon_0$

(2pts) **3.** The electric potential along the x-axis of a coordinate system is given by the plot below. What is the electric field along the x-direction at the position $x = 15$ cm?



$$E_x = -\frac{dV}{dx} = -\text{slope}.$$

(a) $-2000\ \frac{\text{V}}{\text{m}}\ \hat{\imath}$ (b) $-20\ \frac{\text{V}}{\text{m}}\ \hat{\imath}$ (c) zero (d) $+20\ \frac{\text{V}}{\text{m}}\ \hat{\imath}$ (e) $+2000\ \frac{\text{V}}{\text{m}}\ \hat{\imath}$

$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{200\ \text{V}}{10\ \text{cm}} = \frac{200\ \text{V}}{0.10\ \text{m}} = 2000\ \frac{\text{V}}{\text{m}}$$

$$\therefore E_x = -2000\ \frac{\text{V}}{\text{m}}$$

$$\vec{E} = -2000\ \frac{\text{V}}{\text{m}}\ \hat{\imath}$$

4 pts

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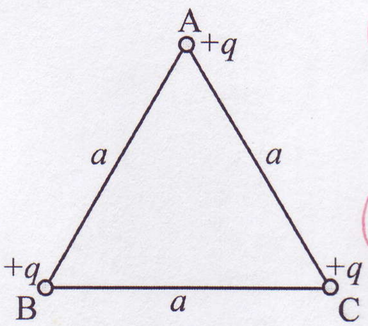
Free Response: Write out complete answers to the following questions. Show your work since it allows us to be generous with partial credit.

(6pts) **4.** Three identical charges of mass m and charge q are held in place at the corners of an equilateral triangle. The charges are then simultaneously released from rest. With what speed v_f do the charges move once they are very far apart? Find an expression for v_f in terms of q, m, a, and Coulomb's constant K.



1 $\Delta K + \Delta U = 0$. 1

$K_i = 0$

1 $K_f = 3\,\frac{1}{2} m v_f^2$

three charges.

$U_f = 0$ since charges very far apart.

$U_i = U_{AB} + U_{AC} + U_{BC}$ (three pairs of charges).

$= \frac{Kq^2}{a} + \frac{Kq^2}{a} + \frac{Kq^2}{a} = \frac{3Kq^2}{a}$

2

∴ from 1

$\frac{\cancel{3}}{2} m v_f^2 - \frac{\cancel{3}Kq^2}{a} = 0$

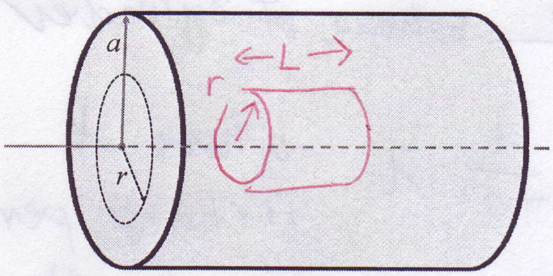
2

$\therefore\ v_f^2 = \frac{2Kq^2}{ma}$

$$\boxed{v_f = \sqrt{\frac{2Kq^2}{ma}}}$$

6 pts

(6pts) **5.** A section of a long cylinder of radius a is shown below. The cylinder has a *uniform* charge per unit volume ρ. Find an expression for the magnitude of the electric field E at point *inside* the cylinder that is a distance r from the cylinder axis.



Gauss's law

1 $\oint_{surface} \vec{E}\cdot d\vec{A} = \frac{Q_{in}}{\varepsilon_0}$

By symmetry $\vec{E}$ is radial.

Choose Gaussian surface to be cylinder concentric which charged cylinder a contained within charged cylinder. Gaussian surface has volume $\pi r^2 L = V$

$\therefore Q_{in} = \rho V = \rho \pi r^2 L$ 1

$\oint_{surface} \vec{E}\cdot d\vec{A} = \int_{curved} \vec{E}\cdot d\vec{A} + \cancelto{0}{\int_{sides} \vec{E}\cdot d\vec{A}}$ 1 since $d\vec{A} \perp \vec{E}$ for left & right side pieces.

$= \int_{curved} E\,dA = E\int_{curved} dA = E\,\underbrace{2\pi r L}_{\text{surface area of curved part of Gaussian surface.}}$ 1

$\therefore E\,2\cancel{\pi}\cancel{r}\cancel{L} = \frac{\rho\cancel{\pi} r^{\cancel{2}}\cancel{L}}{\varepsilon_0}$

$\boxed{\therefore E = \frac{\rho r}{2\varepsilon_0}}$ magnitude of $\vec{E}$ inside uniformly charged cylinder. 2

6 pts

total charge of cylinder

Note: $\rho = \dfrac{Q}{\pi a^2 L}$

volume of cylinder

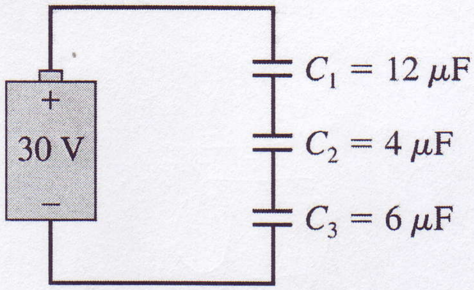
$$= \frac{1}{\pi a^2}\frac{Q}{L} = \frac{1}{\pi a^2}\lambda$$

where λ is charge per unit length.

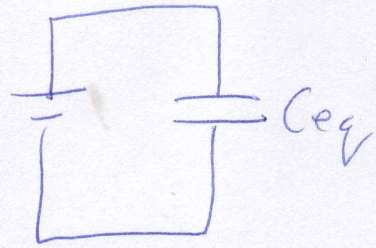
$$\therefore E = \frac{\rho r}{2\varepsilon_0} = \boxed{\frac{\lambda r}{2\pi\varepsilon_0 a^2}}$$

also acceptable.

(6[pts]) **6.** What is the charge on capacitor C_3?



$\Rightarrow$



$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$\Rightarrow C_{eq} = 2.0\,\mu F$$

2

$$C = \frac{Q}{\Delta V}$$ 1

$$\therefore Q_{eq} = C_{eq}\,\Delta V = (2.0\,\mu F)(30\,V) = 60.0\,\mu C$$ 1

$Q_1 = Q_2 = Q_3 = Q_{eq}$ for series capacitors.

$$\therefore \boxed{Q_3 = 60.0\,\mu C}$$

2