Test 1 Practice Problems - Physics 2113 - Fall 2016

September 21, 2016

Last Name: Solution First name: Key

Sec. 1 MWF 8:30-9:20 Sec. 2 MWF 10:30-11:20 Sec. 3 MWF 12:30-1:20

Sec. 4 MWF 1:30-2:20 Sec. 5 MWF 2:30-3:20

Sec. 6 TuTh 12:00-1:20 Sec. 7 TuTh 1:30-2:50

Be sure to write your name and circle your section.

This "practice exam" is slightly longer than the real exam. The actual exam will have 5 questions and 3 problems.

Please read the questions carefully.

You may use scientific or graphing calculators.

You may detach and use the formula sheet provided at the back of this test. No other reference materials are allowed.

You are strictly forbidden from having access to any electronic communications device during a test. This includes cell phones, pagers, smartphones and tablet or notebook computers. You may not use calculator software on such a device during the test. Any student found with such a device will be assumed to be using it to cheat, and will be reported to the Dean of Students for disciplinary action. Any student who observes another student using such a device during the test should notify the instructor or proctor immediately.

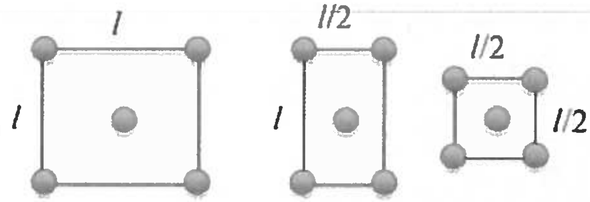
Please use clear, complete sentences if explanations are asked for.

Some questions are multiple choice. You should work these problems starting with the basic equation listed on the formula sheet and write down the steps. Although the work will not be graded, this will help you make the correct choice and be able to determine if your thinking is correct. ***Be sure to mark your final answer clearly.***

On problems that are not multiple choice, you ***must show all of your work***. No credit will be given for an answer without explanation or work. These will be graded in full, and you are expected to show all relevant steps that lead to your answer.

YOU GET 60 min (1 hr)

Question 1: The figure shows five equal masses in different configurations. (a) Rank them, largest first, according to the magnitude of the net gravitational force acting on the central mass.



(a) (b) (c)

- ● $a = b = c$
- ○ $b > a > c$
- ○ $a > b > c$
- ○ $c > a > b$
- ○ $a > c > b$
- ○ $c > b > a$

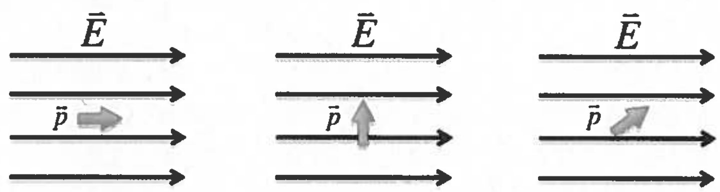
.(b) Rank them, largest first, according to the gravitational potential energy (***not*** magnitude) of the system.

- ○ $a = b = c$
- ○ $b > a > c$
- ● $a > b > c$
- ○ $c > a > b$
- ○ $a > c > b$
- ○ $c > b > a$

Question 2: A metal sphere has no net charge and is connected to ground. A positively charged conducting rod is then brought close to a metal sphere but does not touch it. While the charged rod is close by, the ground is disconnected from the metal sphere. Which of the following statements are correct. Select all the correct answers.

- ○ The metal sphere is positively charged now.
- ● The metal sphere is negatively charged now.
- ○ The metal sphere has no net charge now.
- ● The sphere and the conductor attract each other.
- ○ The sphere and the conductor repel each other.
- ○ The sphere and the conductor feel no net force.

Question 3: The figure shows electric dipoles (of same magnitude) with 3 different orientations in a uniform electric field. Rank the 3 scenarios by the potential energy of the dipole.

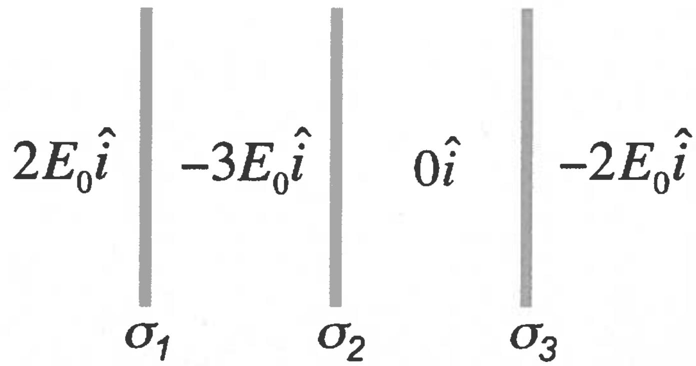


(1) (2) (3)

- ○ $U_1 > U_2 > U_3$
- ○ $U_1 > U_3 > U_2$
- ○ $U_2 > U_1 > U_3$
- ● $U_2 > U_3 > U_1$
- ○ $U_3 > U_1 > U_2$
- ○ $U_3 > U_2 > U_1$

Question 4: Three thin, parallel sheets of charge carry uniform surface charge densities σ_1, σ_2, and σ_3. The uniform electric field in the 4 regions near the sheets is shown in the figure. Rank the 3 sheets by the *magnitude* of the surface charge density.

- ● $|\sigma_1| > |\sigma_2| > |\sigma_3|$
- ○ $|\sigma_1| > |\sigma_3| > |\sigma_2|$
- ○ $|\sigma_2| > |\sigma_1| > |\sigma_3|$
- ○ $|\sigma_2| > |\sigma_3| > |\sigma_1|$
- ○ $|\sigma_3| > |\sigma_1| > |\sigma_2|$
- ○ $|\sigma_3| > |\sigma_2| > |\sigma_1|$



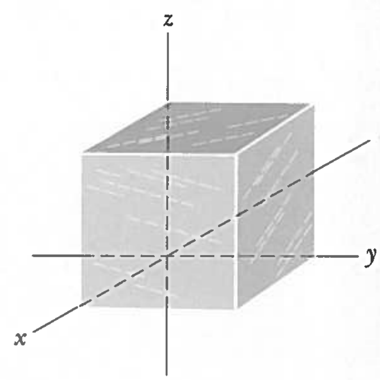
Question 5: The cube has edge length 1.40 m with one corner at the origin as shown in a uniform electric field. Rank the electric fluxes (largest first) through face on the x =1.40 m plane (front face) for the following electric fields:

a) $\vec{E}_a = (3\hat{i})N/C$

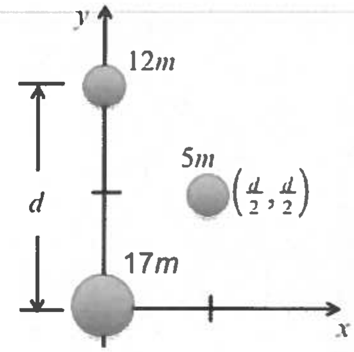
b) $\vec{E}_b = (-4\hat{i})N/C$

c) $\vec{E}_c = (2\hat{i} + 3\hat{k})(N/C)$

- ○ $a > b > c$
- ● $a > c > b$
- ○ $b > a > c$
- ○ $b > c > a$
- ○ $c > a > b$
- ○ $c > b > a$



Problem: Three particles of mass 5*m*, 12 *m* and 17 *m* are arranged as shown in the figure. (Both *d* and *m* are constants).



(a) (12 points) Find the force on the 5*m* mass. Your answer should be in unit vector notation.

$$\bar{F}_T = \bar{F}_{12} + \bar{F}_{17}$$

$$\bar{F}_T = G\frac{(12m)(5m)}{\frac{1}{2}d^2}\left[-\frac{1}{\sqrt{2}}\hat{\imath} + \frac{1}{\sqrt{2}}\hat{\jmath}\right]$$

$$+ G\frac{(17m)(5m)}{\frac{1}{2}d^2}\left[-\frac{1}{\sqrt{2}}\hat{\imath} - \frac{1}{\sqrt{2}}\hat{\jmath}\right]$$

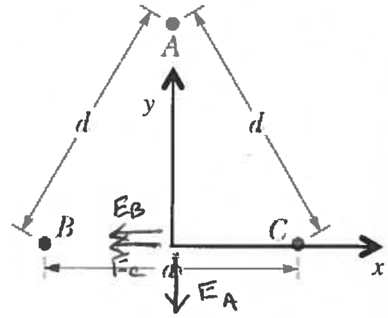
$$\bar{F} = \frac{10Gm^2}{\sqrt{2}d^2}\left[-29\hat{\imath} - 5\hat{\jmath}\right]$$

(b) (13 points) Find the total gravitational potential energy of the 3 particle system in terms of *m, d* and fundamental constants.

$$U = -\frac{Gm^2}{d}\left(\frac{12\cdot5}{\sqrt{\frac{1}{2}}} + \frac{17\cdot5}{\sqrt{\frac{1}{2}}} + \frac{12\cdot17}{1}\right)$$

$$U = -G\frac{m^2}{d}\left(204 + 145\sqrt{2}\right)$$

Problem: Three charges form an equilateral triangle with side length *d* =*0.20 m*, with charge *A* = +2*q*, charge *B* = -*q* and charge *C* = +*q*. Charges *B* and *C* lie along the *x* axis, while charge *A* lies along the *y* axis.



(a) (11 points) Find the net force on charge C. Write your answer in unit vector notation in terms of *d, q* and fundamental constants.

$$\bar{F} = \bar{F}_{CB} + \bar{F}_{CA}$$

$$\bar{F} = -\frac{1}{4\pi\varepsilon_0}\frac{q^2}{d^2}\hat{\imath} + \frac{2q^2}{d^2}\left[\cos(-60^\circ)\,\hat{\imath} + \sin(-60^\circ)\,\hat{\jmath}\right]$$

$$\bar{F} = -\frac{1}{4\pi\varepsilon_0}\frac{2q^2}{d^2}\frac{\sqrt{3}}{2}\hat{\jmath}$$

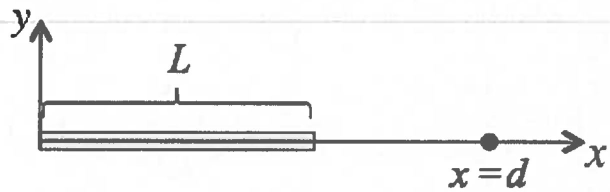
(b) (3 points) Sketch the electric field at the origin created by ***each*** of the 3 particles.

(c) (11 points) Find the net electric field at the origin caused by all 3 particles in terms of *a*. Write your answer in unit vector notation.

$$\bar{E} = -\frac{1}{4\pi\varepsilon_0}\frac{q}{\left(\frac{d}{2}\right)^2}\hat{\imath} - \frac{1}{4\pi\varepsilon_0}\frac{q}{\left(\frac{d}{2}\right)^2}\hat{\imath} - \frac{1}{4\pi\varepsilon_0}\frac{2q}{\frac{3}{4}d^2}\hat{\jmath}$$

$$\bar{E} = -\frac{1}{4\pi\varepsilon_0}\frac{8q}{a^2}\hat{\imath} - \frac{1}{4\pi\varepsilon_0}\frac{8}{3}\frac{q}{a^2}\hat{\jmath}$$

Problem: A thin rod with a length $L = 0.10\ m$ lies along the positive x-axis with one end at the origin. The rod is given a ***uniform*** charge distribution with linear charge density $\lambda = -3.0 \times 10^{-9}\ C/m$.



(a) (7 points) What is the total charge on the rod?

$$Q = \lambda L = -3 \times 10^{-10} C$$

(b) (18 points) Find the electric field at a point $x = d = 0.150\ m$ along the x-axis. Express your answer in unit vector notation.

$$d\bar{E} = \frac{1}{4\pi\varepsilon_0} \frac{\lambda\, dx}{(d-x)^2}\ \hat{\imath}$$

{ note λ is negative, so E points in $-\hat{\imath}$ direction

$$\bar{E} = \frac{1}{4\pi\varepsilon_0} \int_0^L (d-x)^{-2}\, dx\ \hat{\imath}$$

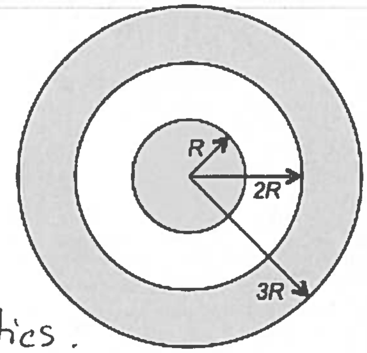
Substitute $u = d-x \rightarrow du = -dx$

$$\bar{E} = \frac{-\lambda}{4\pi\varepsilon_0} \int u^{2}\, du = \frac{\lambda}{4\pi\varepsilon_0} \frac{1}{u} = \frac{\lambda}{4\pi\varepsilon_0} \frac{1}{(d-x)} \Big|_0^L\ \hat{\imath}$$

$$\bar{E} = \frac{\lambda}{4\pi\varepsilon_0} \left[\frac{1}{d-L} - \frac{1}{d} \right] \hat{\imath}$$

Plug in # $\quad \bar{E} = -360 \frac{N}{C}\ \hat{\imath}$

Problem: A certain long coaxial cable consists of a solid inner ***cylindrical*** conductor of radius R and a second cylindrical conductor with inner radius of $2R$ and outer radius $3R$. There is vacuum between the two conductors. The cable has a total length of L. The inner conductor is given a net total charge $+q$, while the outer conductor is also given a net charge $+q$. In all parts of this question, your answers should be in terms of r, L, R, q and ε_0.



(a) (5 points) What is the field in the region where $r < R$? You must derive or justify your answer.

$\bar{E} = \phi$, No field in conductor with statics.

All charges on surface $\rightarrow q_{enc} = \phi$.

(b) (6 points) Use Gauss's Law to find the electric field in the regions where $R < r < 2R$.

$\varepsilon_0 \oint \bar{E}\cdot d\bar{A} = q_{enc}$ Use cylindrical Gaussian surface

$\varepsilon_0 \oint_{sides} \bar{E}\cdot d\bar{A} + \varepsilon_0 \oint_{ends} \bar{E}\cdot dA = q_{enc}$

$\left.\begin{array}{l} E \perp A \text{ on ends} \\ E \parallel A \text{ on sides} \end{array}\right\}$ cylindrical $\rightarrow$ E points out $\hat{r}$

$\varepsilon_0 E \int_{sides} dA = \varepsilon_0 E(2\pi r \ell) = q_{enc} \rightarrow E = \frac{1}{2\pi\varepsilon_0 r}\frac{q_{enc}}{\ell}$ uniform $\frac{q_{enc}}{\ell} = \frac{q}{L}$

$E = \frac{1}{2\pi\varepsilon_0 r}\frac{q}{L}\hat{r}$

(c) (7 points) Use Gauss's Law to find the electric field in the regions where $2R < r < 3R$.

$-q$ arranged on inner surface of shell, such that $q_{enc} = 0$ on Gaussian surface

No field in conductor $E = 0 \rightarrow q_{enc} = 0$

(d) (6 points) Use Gauss's Law to find the electric field in the regions where $3R < r$.

Same argument as (b)

$E = \frac{1}{2\pi\varepsilon_0 r}\frac{q_{enc}}{\ell}$ $\qquad q_{enc} = \frac{2q}{L}\ell$

$E = \frac{1}{2\pi\varepsilon_0 r}\frac{2q}{L}$

$E = \frac{q}{\pi\varepsilon_0 L r}\hat{r}$ out