Test 1 - Physics 2113 - Fall 2016

September 21, 2016

Last Name: Key First name: ________________

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.

Answer all 3 problems (25 points each) and 5 questions (6 points each).

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.

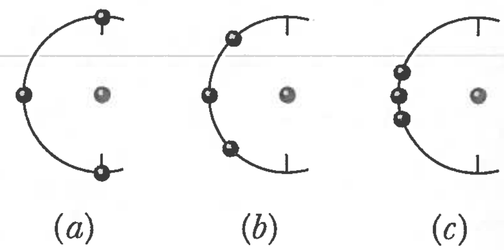
Please use clear, complete sentences if explanations are asked for.

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 four equal masses in different configurations. Rank them, largest first, according to the magnitude of the net gravitational force acting on the central mass.



○ $a = b = c$ ○ $b > a > c$

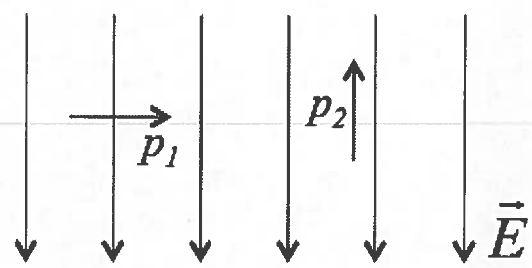
○ $a > b > c$ ○ $c > a > b$

○ $a > c > b$ ● $c > b > a$

Question 2: A negatively charged metal sphere is brought close to a second similar metal sphere that initially has no net charge and is electrically isolated. The two spheres touch for a brief period of time and are then separated. Which statements regarding the force (F) between the spheres before and after touching is correct. Indicate ***both*** correct answers

Before touching	After touching
○ *F* is repulsive	● *F* is repulsive
○ $F = 0$	○ $F = 0$
● *F* is attractive	○ *F* is attractive

Question 3: The figure shows two electric dipoles (of same magnitude) with 2 different orientations in a uniform electric field. Which of the following statements regarding the ***magnitude*** of the net torque *(τ)* and net force *(F)* on the two dipoles are correct? Indicate ***both*** correct answers.

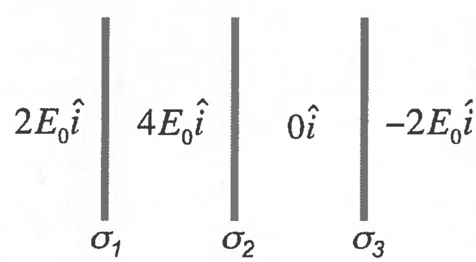


○ $F_1 > F_2$ ● $\tau_1 > \tau_2$

○ $F_2 > F_1$ ○ $\tau_2 > \tau_1$

● $F_1 = F_2 = 0$ ○ $\tau_1 = \tau_2 = 0$

Question 4: Three thin, parallel sheets of charge carry uniform surface charge densities σ_1, σ_2, and σ_3. The plot shows the electric field in the 4 regions near the 3 sheets. Which sheets have a ***negative*** surface charge density? Select ***all*** correct answers ***if*** there is more than one.



○ σ_1

● σ_2

● σ_3

○ None of the sheets

Question 5: A constant and uniform electric field of $\vec{E} = (3\hat{i} + 4\hat{j})\,N/C$ exists everywhere in space. Rank the fluxes through the following three surface areas, largest first:

a) $\vec{A}_a = (3\hat{i} - 2\hat{j})\,m^2$

b) $\vec{A}_b = (2\hat{i})\,m^2$

c) $\vec{A}_c = (\hat{i} - 2\hat{k})\,m^2$

○ $a > b > c$

○ $a > c > b$

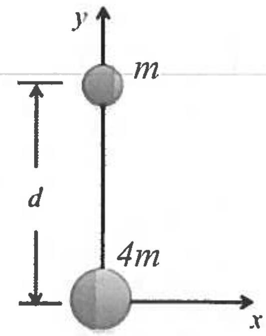
○ $b > a > c$

● $b > c > a$

○ $c > a > b$

○ $c > b > a$

Problem 1: A particle of mass m is located on the y axis at $y = d$. A second particle with 4 times the mass ($4m$) is located at the origin. (Both d and m are constants).



(a) (12 points) Find the position relative to the origin where a third particle could be placed and be in equilibrium (i.e., the net force acting on the new 3rd particle is zero).

Position must be on y-axis (on a line through the other two particles) else there would be a net force in the $\pm\hat{x}$ direction.

$$\bar{F}_3 = -G\frac{4mm_3}{y^2}\hat{y} + G\frac{mm_3}{(d-y)^2}\hat{y} = 0$$

$$\frac{4}{y^2} = \frac{1}{(d-y)^2} \rightarrow 2(d-y) = y$$

$$y = \frac{2}{3}d$$

position $(0, \frac{2}{3}d)$

or $\bar{r} = \frac{2}{3}d\,\hat{y}$

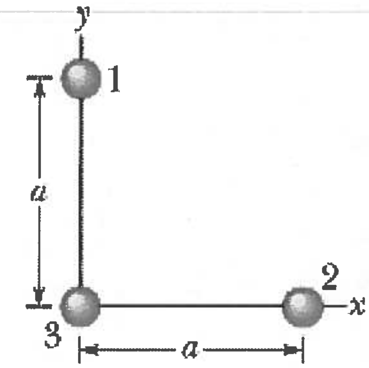
(b) (13 points) If the 3rd particle has mass $2m$ and is placed at the equilibrium position you found in part a, find the total gravitational potential energy of the 3 particle system in terms of m, d and fundamental constants.

$$U_g = -G\left(\frac{4m^2}{d} + \frac{8m^2}{\frac{2}{3}d} + \frac{2m^2}{\frac{1}{3}d}\right)$$

$$U_g = -22G\frac{m^2}{d}$$

Problem 2: Three charges are arranged at 3 corners of a square as shown. Particle 1 has charge +1.0 mC and is located on the y axis at $y = a = 3.0\ m$. Particle 2 has charge +2.0 mC and is located on the x axis at $x = a = 3.0\ m$. Particle 3 has charge -2.0 mC and is located at the origin. (Note $1mC = 10^{-3}C$)

(a) (11 points) Find the net force on Particle 3 caused by the other 2 particles. Write your answer in unit vector notation.



$$\bar{F}_{31} = \frac{1}{4\pi\epsilon_0} \frac{(2\times10^{-3}C)(1\times10^{-3}C)}{(3m)^2}\hat{j}$$

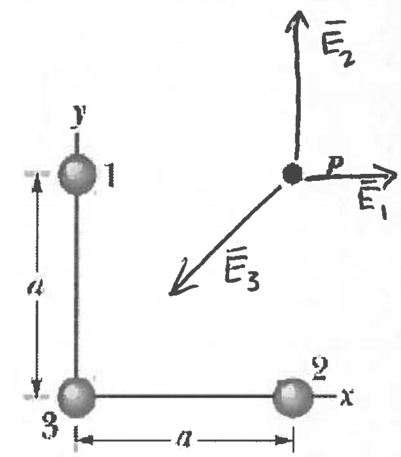
$$\bar{F}_{31} = 2000\ N\ \hat{j}$$

$$\bar{F}_{32} = \frac{1}{4\pi\epsilon_0} \frac{(2\times10^{-3}C)(2\times10^{-3}C)}{(3m)^2}\hat{i}$$

$$\bar{F}_{32} = 4000 N\ \hat{i}$$

$$\bar{F}_{3net} = \bar{F}_{31} + \bar{F}_{32} = 4000\ N\hat{i} + 2000\ N\hat{j}$$

(b) (3 points) Given the same arrangement, ***sketch*** the electric field at Point ***P*** (at the empty corner of the square) created by ***each*** of the 3 particles.



(c) (11 points) Find the net electric field at point ***P*** (at the empty corner of the square) caused by all 3 particles. Write your answer in unit vector notation.

$$\bar{E}_1 = \frac{1}{4\pi\epsilon_0} \frac{(1\times10^{-3}C)}{(3m)^2}\hat{i} = 10^6 \frac{N}{C}\hat{i}$$

$$\bar{E}_2 = \frac{1}{4\pi\epsilon_0} \frac{(2\times10^{-3}C)}{(3m)^2}\hat{j} = 2\times10^6 \frac{N}{C}\hat{j}$$

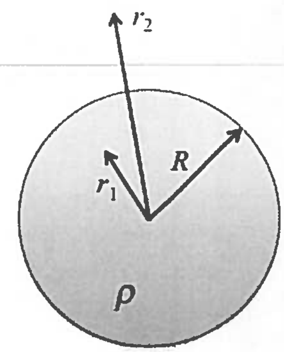
$$\bar{E}_3 = \frac{1}{4\pi\epsilon_0} \frac{(2\times10^{-3}C)}{(3\sqrt{2}m)^2}(\cos 225^\circ\hat{i} + \sin 225^\circ\hat{j})$$

$$\bar{E}_3 = 10^6 \frac{N}{C}\left(-\frac{1}{\sqrt{2}}\hat{i} - \frac{1}{\sqrt{2}}\hat{j}\right)$$

$$\bar{E}_{net} = \sum_i \bar{E}_i = 10^6 \frac{N}{C}\hat{i} + (2\times10^6)\frac{N}{C}\hat{j} + 10^6\frac{N}{C}\left(-\frac{1}{\sqrt{2}}\hat{i} - \frac{1}{\sqrt{2}}\hat{j}\right)$$

$$= 2.9\times10^5 \frac{N}{C}\hat{i} + 1.3\times10^6 \frac{N}{C}\hat{j}$$

Problem 3: A solid non-conducting sphere of radius R=*0.10 m* has ***a non-uniform*** volume charge density that varies as $\rho = ar$, where a is a constant with $a = 4.0\text{x}10^{-9} C/m^4$ and r is the distance from the center of the sphere.



(a) (8 points) What is the total charge Q of the sphere?

$$Q = \int_0^R \rho \, dV = \int_0^R \rho (4\pi r^2) dr$$

$$Q = \int_0^R 4\pi a r^3 dr = \pi a r^4 \Big|_0^R = \pi a R^4$$

$$Q = 4\pi \times 10^{-13} C = 1.3 \times 10^{-12} C$$

(b) (8 points) Use your answer from part a to find an expression for the magnitude of the electric field for points with $r = r_2 > R$. What direction does the electric field point? *Explain or justify your reasoning.*

Spherical symmetry → Shell theorem. Electric Field behaves as a point charge at center with same total charge as that enclosed. For $r > R \rightarrow q_{enc} = Q$

$$\bar{E} = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2} \hat{r} \text{ (out)} = \frac{4\pi \times 10^{-13} C}{4\pi \epsilon_0} \frac{1}{r^2} \hat{r}$$

$$\bar{E} = 0.011 \frac{1}{r^2} \left(\frac{Nm^2}{C}\right) \hat{r}$$

(c) (9 points) Find an expression for the electric field for points with $r = r_1 < R$.

Shell Theorem applies again, but must only count the charge that is enclosed

$$\bar{E} = \frac{1}{4\pi\epsilon_0} \frac{q_{enc}}{r^2} \hat{r}$$

$$q_{enc} = \int_0^r 4\pi a r^3 dr = \pi a r^4$$

$$\bar{E} = \frac{a}{4\epsilon_0} r^2 = 113 \frac{N}{Cm^2} r^2 \hat{r}$$