Exam 1: Physics 2113 SPRING 2015

8:00PM MON 09 FEB 2015

Name (Last, First): KEY

Section #________________

Instructor's name:________________________________

Answer all 3 problems & all 4 questions.

Be sure to write your name. Please read the questions carefully.

You may use only scientific or graphing calculators. *In particular you may not use the calculator app on your phone or tablet!*

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

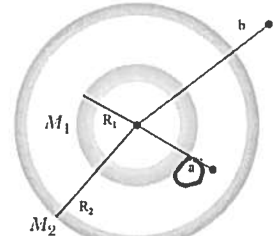
You may not answer or use cell phones during the exam. Please note that the official departmental policy for exams is as follows: "During your test, the only electronic device you may have with you at your seat is a scientific or graphing calculator. You may not have your cell phone, tablet, smartphone, smart watch, PDA, pager, digital camera, computer, or any other device capable of taking pictures or video, sending text messages, or accessing the Internet. This means not just on your person, but close enough to you that you could reach it during the test. Any student found with such a device during a test will be assumed to be violating the LSU Honor Code and will be referred to the Dean of Students for Judicial Affairs." The simplest remedy is to bring nothing to this test but the calculator, and leave your backpack or purse at home. *If you have brought your cell phone or tablet with you, please leave it at the front of the room under the watchful eye of your instructor.*

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

On problems that are not multiple-choice, be sure to show all of your work, since 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.
Please use complete sentences where explanations are asked for. For numerical answers that require units you must give the correct units for full credit.

YOU GET 60 min (1 hr)

1. (Question) [10 points] Two concentric spherical shells with uniformly distributed masses M_1 and M_2 and radii R_1 and R_2 are situated as shown in the figure.



(a) [5 points] Find the net gravitational force on a mass m located at a radial distance a from the center of the shells. *Circle one.*

• only M_1 attracts m! as if all the mass (M_1) is in the center

(i) $F = G\dfrac{M_1 m}{R_1^2}$ (ii) $F = G\dfrac{(M_1 - M_2)m}{R_1^2}$ (iii) $F = G\dfrac{M_1 m}{a^2}$

(iv) $F = G\dfrac{(M_1 - M_2)m}{a^2}$ (v) $F = 0$

(b) [5 points] Find the net gravitational force on a mass m located at a radial distance b from the center of the shells. *Circle one.*

both M_1 and M_2 attract m (as if $M_1 + M_2$ is in the center)

(i) $F = G\dfrac{(M_1 + M_2)m}{R_2^2}$ (ii) $F = G\dfrac{(M_1 - M_2)m}{R_2^2}$ (iii) $F = G\dfrac{(M_1 + M_2)m}{b^2}$

(iv) $F = G\dfrac{(M_1 - M_2)m}{b^2}$ (v) $F = 0$

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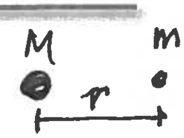
2. (Question) [6 points] You move a ball of mass m away from a sphere of mass M.



(a) [3 points] Does the gravitational potential energy of the system of ball and sphere *(circle one):*

$\Delta U > 0$ if $r_f > r_i$ $\Delta U = GMm\left(\frac{1}{r_i} - \frac{1}{r_f}\right)$

Increase? Decrease? Remain the same?

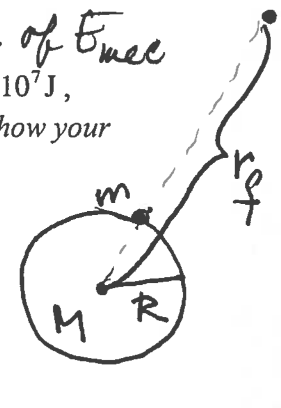
(b) [3 points] Is positive work, negative work, or zero work done *by you* when you move the sphere, which starts off at rest and ends up at rest? *Circle one:*

Positive work Negative work Zero Work

$W_{ext} = +\Delta U$ if $\Delta K = 0 \Rightarrow W_{ext} > 0$ (positive)

3. (Problem) [16 points] Zero, a hypothetical planet, has a mass of $3.0 \times 10^{23}\,\text{kg}$, a radius of $5.0 \times 10^{6}\,\text{m}$, and no atmosphere. A 10 kg space probe is to be launched vertically from Zero's surface.

· radial motion $\Rightarrow$ cons. of E_{mec}



(a) [8 points] If the probe is launched with an initial kinetic energy of $5.0 \times 10^{7}\,\text{J}$, calculate its kinetic energy when it is $6.0 \times 10^{6}\,\text{m}$ from the center of Zero. *Show your work!*

$r_i = R = 5 \times 10^6\,\text{m}$
$r_f = 6 \times 10^6\,\text{m}$
$M = 3 \times 10^{23}\,\text{kg}$
$K_i = 5 \times 10^7\,\text{J}$
$K_f = ?$

· use conservation of mech. energy!

$$(K+U)_i = (K+U)_f$$

$$K_i - G\frac{mM}{r_i} = K_f - G\frac{mM}{r_f}$$

$$K_f = K_i - GmM\left(\frac{1}{R} - \frac{1}{r_f}\right) = 5\times10^7\,\text{J} - \left(6.67\times10^{-11}\,\tfrac{\text{Nm}^2}{\text{kg}^2}\right)(10\,\text{kg})(3\times10^{23}\,\text{kg})\left(\frac{1}{5\times10^6\,\text{m}} - \frac{1}{6\times10^6\,\text{m}}\right) = 4.33\times10^7\,\text{J}$$

(b) [8 points] If instead the probe is to achieve a maximum distance of $8.0 \times 10^{6}\,\text{m}$ from the center of Zero, calculate the kinetic energy it must be launched with from *the surface* of Zero. *Show your work!*

$r_f = 8\times10^6\,\text{m} = \text{max}$
$\Rightarrow K_f = 0$
$K_i = ?$
$r_i = R = 5\times10^6\,\text{m}$

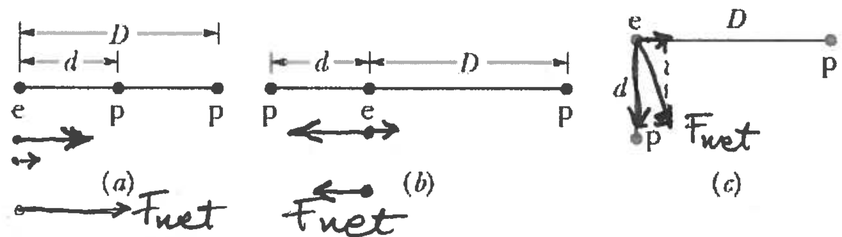
$$(K+U)_i = (K+U)_f$$

$$K_i - G\frac{mM}{R} = \cancel{K_f}^{\,0} - G\frac{mM}{r_f}$$

$$K_i = GmM\left(\frac{1}{R} - \frac{1}{r_f}\right) = \left(6.67\times10^{-11}\,\tfrac{\text{Nm}^2}{\text{kg}^2}\right)(10\,\text{kg})(3\times10^{23}\,\text{kg})\left(\frac{1}{5\times10^6\,\text{m}} - \frac{1}{8\times10^6\,\text{m}}\right)$$

$$K_i = 1.50\times10^7\,\text{J}$$

4. (Question) [10 points] The figure here shows three arrangements of an electron *e* and two protons *p*. The distance $D = 2d$.



(i) **[5 points]** Rank the arrangements according to the *magnitude* of the net electrostatic force *on the electron due to the two protons*, largest first. Circle one.

$$F_e^{(a)} = F_e^{(b)} = F_e^{(c)}$$

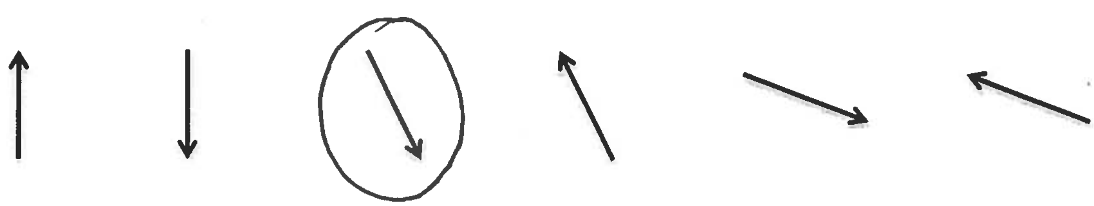
$$F_e^{(a)} > F_e^{(b)} > F_e^{(c)}$$

$$F_e^{(a)} > F_e^{(c)} > F_e^{(b)}$$

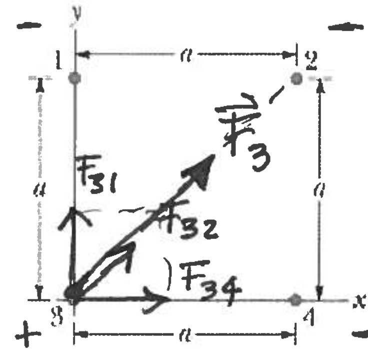
$$F_e^{(a)} = F_e^{(b)} > F_e^{(c)}$$

$$F_e^{(a)} = F_e^{(c)} > F_e^{(b)}$$

(ii) **[5 points]** In situation *c*, what is the *direction* of the net electrostatic force *on the electron due to the two protons* (circle one):



5. **(Problem) [24 points]** In the figure, the particles have charges $q_1 = -1.0$ C, $q_2 = -1.0$ C, $q_3 = +1.0$ C, $q_4 = -1.0$ C, and distance a = 4.0 cm in a square.



$a = 4\,cm = 0.04\,m$

(a) [4 points] On the figure draw $\vec{F}_{3,net}$, the *net* electrostatic force *vector* on particle 3 due to all the other charges.

$|q_1| = |q_2| = |q_3| = |q_4| = q$

(b) [7 points] Compute the *magnitude* of the *x component* $F^x_{3,net}$ of the *net* electrostatic force on particle 3 due to all the other charges.

$\vec{F}_3 = \vec{F}_{31} + \vec{F}_{32} + \vec{F}_{34}$

$$F_{3x} = F_{34} + F_{32}\cos 45^\circ = k\frac{q^2}{a^2} + k\frac{q^2}{2a^2}\cos 45^\circ$$

$$F_{3x} = k\frac{q^2}{a^2}\left(1 + \frac{\cos 45^\circ}{2}\right) = (8.99\times10^9)\frac{1^2}{(0.04)^2}\left(1 + \frac{\cos 45^\circ}{2}\right)$$

$$F_{3x} = 7.60\times10^{12}\,N$$

(c) [7 points] Compute *magnitude* of the y component $F^y_{3,net}$ of the net electrostatic force on particle 3 due to all the other charges.

$$F_{3y} = F_{31} + F_3 \sin 45^\circ = k\frac{q^2}{a^2}\left(1 + \frac{\sin 45^\circ}{2}\right) = 7.60\times10^{12}\,N$$

• the same value as in (a) !! (the same charges, the same distances)

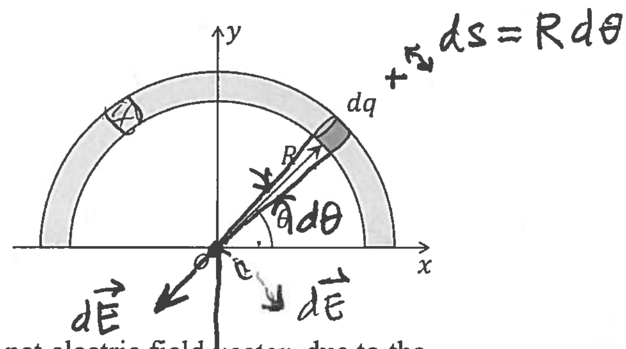
(d) [6 points] Compute *magnitude* $F_{3,net}$ of the *total net electrostatic force* on particle 3 due to all the other charges.

$$|\vec{F}_3| = \sqrt{F_{3x}^2 + F_{3y}^2} = F_{3x}\sqrt{2} = (7.60\times10^{+12}\,N)\sqrt{2} = 10.75\times10^{+12}\,N$$

$F_{3x} = F_{3y}$

$$|\vec{F}_3| = 1.08\times10^{+13}\,N$$

6. **(Problem) [24 points]** A thin plastic rod forms half of a circle of radius R and is arranged with its center of curvature at the origin O and the center of the rod on the y-axis, as shown. A *positive* charge with constant linear density λ is uniformly distributed along the rod. A short segment of the rod at random angle θ and containing infinitesimal charge dq is highlighted in the figure.



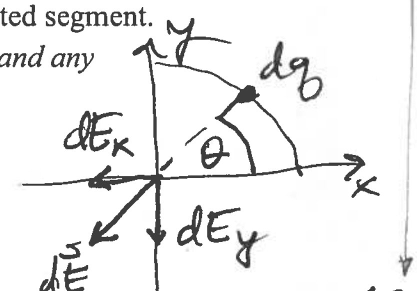
(a) [5 points] On the figure *draw the direction* of the net electric field vector, due to the rod, at the point of the origin O. vector in $-\hat{j}$ dir. $\vec{E}_{net}$

(b) [6 points] Derive an expression for the total charge Q on the rod. What is the charge dq in the highlighted segment? *Express your answers in terms of* R, λ, θ, *and any numerical constants, as needed. Show your work.*

$\lambda = \frac{q}{L} = \frac{q}{\pi R} \Rightarrow \underline{q = \pi R \lambda}$, $\quad dq = \lambda R\,d\theta$ (see below)

L = length of the arc = half of the circle

(c) [8 points] Derive expressions for dE_x and dE_y the components of the infinitesimal electric field dE at the origin O produced by the charge dq in the highlighted segment. Do not integrate anything yet. *Express your answers in terms of* R, λ, θ, *and any numerical constants, as needed. Show your work.*



$dq = \lambda\,ds = \lambda R\,d\theta$

$|d\vec{E}| = k\frac{dq}{r^2} = k\frac{\lambda R\,d\theta}{R^2} = \frac{k\lambda}{R}\,d\theta$

$r = R$

$dE_x = -\frac{k\lambda}{R}\,d\theta\cos\theta, \quad dE_y = -\frac{k\lambda}{R}\,d\theta\sin\theta$

(d) [5 points] Use your answers from part (b) to determine E, the magnitude of the net electric field at the origin O. *Express your answers in terms of* R, λ, *and any numerical constants, as needed. Show your work.* Hint: *Does your answer agree with that in the formula sheet?*

- while integrating: E_x components will cancel due to symmetry $\int_0^{180^\circ} = 2\int_0^{90^\circ}$

$$|\vec{E}| = 2\int_0^{90^\circ} dE_y = \frac{2k\lambda}{R}\int_0^{90^\circ}\sin\theta\,d\theta = \frac{2k\lambda}{R}\left(-\cos\theta\right)\Big|_{\theta=0}^{\theta=90^\circ}$$

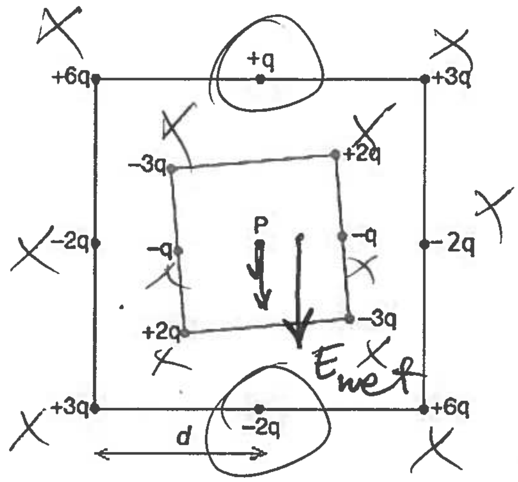
$$= \frac{2k\lambda}{R}(1)$$

$$|\vec{E}| = \frac{2k\lambda}{R} = \frac{\lambda}{2\pi\varepsilon_0 R}$$

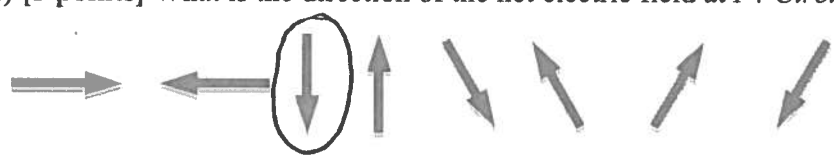
Using el.-field of an arc of opening ϕ: $\phi = 180^\circ$

$|\vec{E}| = \frac{\lambda}{2\pi\varepsilon_0 R}$ ... the same as on the left

7. (Question) [10 points] The figure to the right shows two square arrays of charged particles. The squares, which are centered on point *P*, are misaligned. The particles are separated by either *d* or *d/2* along the perimeters of the squares.



(a) [5 points] What is the direction of the net electric field at *P*? *Circle one.*



(b) [5 points] What is the magnitude of the net electric field at *P*? Cir*cle one.*

(i) $\frac{1}{2\pi\varepsilon_0}\frac{q}{d^2}$

(ii) $\frac{1}{4\pi\varepsilon_0}\frac{q}{d^2}$

(iii) $\frac{1}{8\pi\varepsilon_0}\frac{q}{d^2}$

(iv) $\frac{5}{4\pi\varepsilon_0}\frac{q}{d^2}$

(v) $\frac{3}{4\pi\varepsilon_0}\frac{q}{d^2}$

$$|\vec{E}_{net}| = k\frac{|q|}{d^2} + 2k\frac{|q|}{d^2}$$
$$= 3k\frac{|q|}{d^2} = \frac{3}{4\pi\varepsilon_0}\frac{|q|}{d^2}$$