Exam 1:  
Physics 2113 Spring 2016  
6:00 PM, Monday, February 3, 2016

Last Name ____________________  First Name ____________________

Clearly circle your section:

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<td>Abdelwahab Sec 1</td>
<td>Tzanov Sec 5</td>
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Answer all 7 Problems.

You may use only scientific or graphing calculators.  
No Phone!  No Tablet!

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.”

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

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. Be sure that all numerical quantities include appropriate units for full credit.

You have 60 min to complete the examination.
Problem 1 [10 pts] Multiple choice questions: *Circle the correct response.*

The figure shows three situations involving a point particle $P$ with mass $m$ and a spherical shell with a uniformly distributed mass $M$. The radii of the shells are given.

(a) [5 points] Compare the situations (a) and (b) according to the magnitude of the gravitational force on particle $P$ due to the shell. Circle one.

\[(a) > (b) \quad (a) = (b) \quad (a) < (b)\]

(b) [5 points] Compare the situations (b) and (c) according to the magnitude of the gravitational force on particle $P$ due to the shell. Circle one.

\[(b) > (c) \quad (b) = (c) \quad (b) < (c)\]
**Problem 2 [10 pts]** Multiple choice questions: *Circle the correct response.*

The figure shows three pairs of identical spheres that are to be touched together and then separated.

(a) [5 points] Rank the pairs according to the magnitude of the charge transferred during touching, greatest first

\[ 1 > 2 > 3 \quad 1 = 3 > 2 \quad 3 > 1 > 2 \]

(b) [5 points] Rank the situations according to the magnitude of the electrostatic force between the spheres (assume all pairs have the same distance between them)

\[ 3 > 1 > 2 \quad 1 = 2 = 3 \quad 2 > 1 > 3 \]
Problem 3 [10 pts] Multiple choice questions: Circle the correct response.

In the scenarios in the figure to the right, black circles represent positive charges and white circles represent negative charges. The smaller dots have charges of 1 C, but the larger dots have charges of 4 C.

(a) [5 points] In which case is the magnitude of the electric field at the origin greatest?

A. Scenario A  
B. Scenario B  
C. Scenario C  
D. Scenario D

(b) [5 points] If we place a negative charge at the origin of Scenario A, what is the direction of the force that would act on it?
Problem 4 [10 pts] Multiple choice questions: *Circle the correct response.*

A dipole is placed in a uniform electric field directed to the top of the page as shown.

(a) [5 points] Rank the situations A through F according to the magnitude of the torque on the dipole, largest to smallest.

1. \( C > A > E = B > D > F \)
2. \( A = B = C = D = E = F \)
3. \( C = F > A = D > B = E \)
4. \( B = E > D = A > C = F \)
5. \( C > A > E > F > D > B \)

(b) [5 points] Rank the situations A through F according to the magnitude of the net force on the dipole, largest to smallest.

1. \( C > A > E = B > D > F \)
2. \( A = B = C = D = E = F \)
3. \( C = F > A = D > B = E \)
4. \( B = E > D = A > C = F \)
5. \( C > A > E > F > D > B \)
Problem 5 [20 points] Show all relevant work!!!

The escape speed is defined as the minimum speed that will cause a projectile to move upward forever, theoretically coming to rest only at the infinity.

(a) [5 points] Calculate the gravitational potential energy of a spacecraft (with its mass $m = 8,000$ kg) on the surface of the Earth. Assume the potential energy is zero at infinity and the Earth is a perfect sphere with uniform mass density.

(b) [5 points] The mechanical energy is the sum of the potential energy and the kinetic energy. Using the conservation of mechanical energy ("From Earth To Infinity"), derive the expression for the escape speed for the spaceship on the surface of the earth.

(c) [5 points] Calculate the escape speed for the spaceship on the surface of the earth.

(d) [5 points] Calculate the escape speed for the spaceship on the surface of the earth, if the mass of the spaceship is 4,000 kg instead.
Problem 6 [20 points] Show all relevant work!!!

The configuration shows an array of 3 particles with charges \( q_1 = +4 \text{ C}, q_2 = -2 \text{ C} \) and \( q_3 = +3 \text{ C} \). The distance between \( q_1 \) and \( q_2 \) is \( R = 8 \text{ cm} \) and the distance between \( q_1 \) and \( q_3 \) is \( r = 12 \text{ cm} \). The angle is \( \theta_1 = 30^\circ \).

(a) [5 points] On the figure, sketch the forces due to charges \( q_2 \) and \( q_3 \) on \( q_1 \)

(b) [5 points] Calculate the \( x \) component of the net electrostatic force on \( q_1 \) due to the other charges

(c) [5 points] Calculate the \( y \) component of the net electrostatic force on \( q_1 \) due to the other charges

(d) [5 points] Calculate direction (angle that it makes with the \( x \)-axis) of the net force. Is the result consistent with your drawing?
Problem 7 [20 points] Show all relevant work!!!

A thin uniformly charged arc with radius $R$ is shown in the figure below. The total charge of the arc is $Q$. Point $O$ is the origin at the center of the arc.

Express all of your answers symbolically in terms of $R$, $Q$, and any physical constants, as needed.

(a) [5 points] Write down an expression for the linear density $\lambda$. Write down an expression for the infinitesimal charge $dq$.

(b) [5 points] Write down the magnitude of the electric field $|d\vec{E}|$ at point $O$ due to the infinitesimal charge $dq$. Write an expression for the electric field $d\vec{E}$ at point $O$ due to the infinitesimal charge $dq$ in terms of unit vectors. (Hint: Find the $x$ and $y$-components of the electric field $d\vec{E}$.)
(c) [10 points] Calculate the x and y-components ($E_x$, $E_y$) of the electric field $\vec{E}$ at the center of the arc due to the whole arc. (*Hint: You need to integrate the expressions from part b. Be careful with the limits.*)
Formula Sheet for LSU Physics 2113, First Exam, Spring '16

- Constants, definitions:
  \( g = 9.8 \text{ m/s}^2 \)
  \( R_{\text{Earth}} = 6.37 \times 10^6 \text{ m} \)
  \( M_{\text{Earth}} = 5.98 \times 10^{24} \text{ kg} \)
  \( G = 6.67 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2} \)
  \( R_{\text{Moon}} = 1.74 \times 10^6 \text{ m} \)
  \( M_{\text{Moon}} = 7.36 \times 10^{22} \text{ kg} \)
  \( \epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2} \)
  \( k = \frac{1}{4 \pi \epsilon_0} = 8.99 \times 10^9 \text{ N} \text{ m}^2 \text{ C}^{-2} \)
  \( c = 3.00 \times 10^8 \text{ m/s} \)
  \( m_p = 1.67 \times 10^{-27} \text{ kg} \)
  \( m_e = 9.11 \times 10^{-31} \text{ kg} \)
  \( 1 \text{ eV} = e(1\text{V}) = 1.60 \times 10^{-19} \text{ J} \)
  \( \sigma = \frac{Q}{A} \)
  \( \lambda = \frac{Q}{L} \)
  \( \rho = \frac{Q}{V} \)

- Kinematics (constant acceleration):
  \( v = v_o + at \)
  \( x - x_o = \frac{1}{2}(v_o + v)t \)
  \( x - x_o = v_o t + \frac{1}{2}at^2 \)
  \( v^2 = v_o^2 + 2a(x - x_o) \)

- Circular motion:
  \( F_c = ma_c = \frac{mv^2}{r} \)
  \( T = \frac{2\pi r}{v} \)
  \( v = \omega r \)

- General (work, def. of potential energy, kinetic energy):
  \( K = \frac{1}{2}mv^2 \)
  \( \vec{F}_{\text{net}} = m\vec{a} \)
  \( E_{\text{mech}} = K + U \)
  \( W = -\Delta U \) (by field)
  \( W_{\text{ext}} = \Delta U = -W \) (if objects are initially and finally at rest)

- Gravity:
  Newton’s law: \( |\vec{F}| = \frac{Gm_1m_2}{r^2} \)
  Gravitational acceleration (planet of mass \( M \)): \( a_g = \frac{GM}{r^2} \)
  Potential Energy: \( U = -\frac{Gm_1m_2}{r_{12}} \)
  Potential Energy of a System (more than 2 masses): \( U = - \left( \frac{Gm_1m_2}{r_{12}} + \frac{Gm_1m_3}{r_{13}} + \frac{Gm_2m_3}{r_{23}} + \ldots \right) \)

- Electrostatics:
  Coulomb’s law: \( |\vec{F}| = k \frac{|q_1||q_2|}{r^2} \)
  Force on a charge in an electric field: \( \vec{F} = q\vec{E} \)
  Electric field of a point charge: \( |\vec{E}| = k \frac{|q|}{r^2} \)
  Electric field of a dipole on axis, far away from dipole: \( \vec{E} = \frac{2k\vec{p}}{z^3} \)
  Electric field of an infinite line charge: \( |\vec{E}| = \frac{2k\lambda}{r} \)
  Electric field at the center of uniformly charged arc of angle \( \phi \): \( |\vec{E}| = \frac{\lambda \sin(\phi/2)}{2\pi\epsilon_0 R} \)
  Torque on a dipole in an \( \vec{E} \) field: \( \vec{\tau} = \vec{p} \times \vec{E} \)
  Potential energy of a dipole in \( \vec{E} \) field: \( U = -\vec{p} \cdot \vec{E} \)