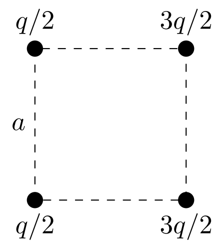
Make sure to fill out the grading sheet completely including your name, exam flavor and UIN. You are allowed to write and work on this exam copy, but your answers must be bubbled in on the grading sheet to receive credit. Your bubbled responses are the only responses that will be considered for the grade.

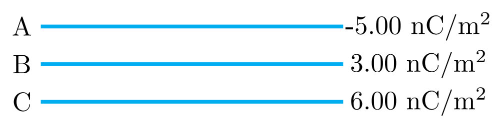
# Physics 207 Exam 1 – Flavor 1

**Problem 1 (6 points)** Four positive point charges (shown in the figure below) are placed at each corner of a square whose side is $a$. What is the net electric field produced by these four positive charges in the center of the square?
The major concepts used to solve this problem include: Vector Addition, Electric Field due to a Point Charge

(a) $+\frac{2\sqrt{2}kq}{a^2}\hat{\imath}$ [4 points]
(b) $-\frac{2\sqrt{2}kq}{a^2}\hat{\imath}$ [6 points]
(c) $+\frac{2\sqrt{2}kq}{a^2}\hat{\jmath}$
(d) $-\frac{2\sqrt{2}kq}{a^2}\hat{\jmath}$
(e) $+\frac{3\sqrt{2}kq}{a^2}\hat{\imath}$
(f) $-\frac{3\sqrt{2}kq}{a^2}\hat{\imath}$ [2 points]
(g) $+\frac{3\sqrt{2}kq}{a^2}\hat{\jmath}$
(h) $-\frac{3\sqrt{2}kq}{a^2}\hat{\jmath}$




**Problem 2 (6 points)** Find the magnitude of the electric force produced by three horizontal ($4.00\times4.00$ m$^2$) parallel sheets A, B, and C (from top to bottom) with the surface charge densities -5.00 nC/m$^2$, 3.00 nC/m$^2$, and 6.00 nC/m$^2$ accordingly on a negative charge -2.00 $\mu$C (not shown on a figure) situated 3.00 mm above the middle of sheet A. Assume that the spacing between the sheets is small compared to their size.
The major concepts used to solve this problem include: Vector Addition, Electric Field due to a Sheet (from Gauss's Law)
(a) 0.452 mN [6 points]
(b) 0.313 mN
(c) 0.225 mN [4 points]
(d) 0.184 mN
(e) 0.112 mN
(f) 0.0809 mN



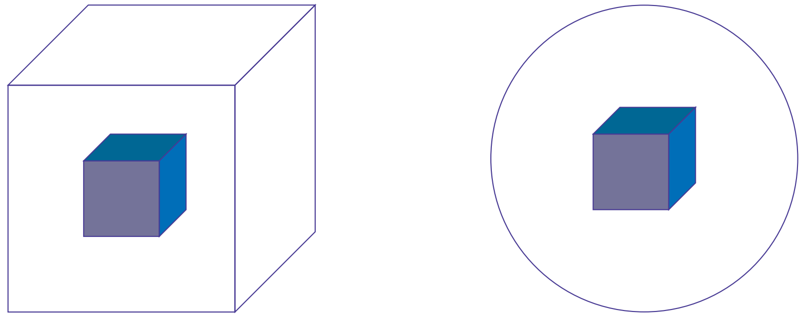

**Problem 3 (3 points)** What is the direction of the electric force you found in the previous problem?
The major concepts used to solve this problem include: Vector Addition

(a) Up [1 points]
(b) Down [3 points]
(c) Left
(d) Right
(e) 45 degrees above horizontal
(f) 45 degrees below horizontal

**Problem 4 (5 points)** A small dielectric cube with uniform distribution of a negative charge -q in its volume is surrounded by either a larger cube with side length $d$ (shown on the left) or a sphere with diameter $d$ (shown on the right). Which of the following statements is true about the flux in these two cases?

The major concepts used to solve this problem include: Gauss's Law

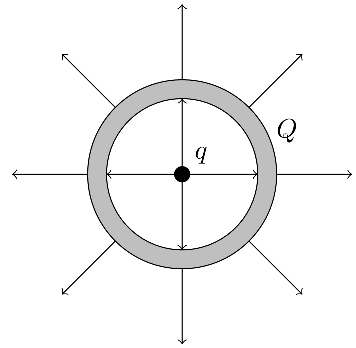
(a) The flux has a greater magnitude through the surface of the cube.
(b) The flux has a greater magnitude through the surface of the sphere.
(c) Both fluxes are equal and positive. [2 points]
(d) Both fluxes are equal and negative. [5 points]
(e) Both fluxes are equal and exactly zero.



**Problem 5 (5 points)** In the figure below, the conducting spherical shell has a total charge $Q$. The point charge $q$ is at the exact center of the shell's cavity. The structure of the electric field lines is provided. What is the charge $Q$ in terms of $q$?

The major concepts used to solve this problem include: Electric Field Diagrams

(a) $Q = -2q$
(b) $Q = -q$
(c) $Q = -q/2$
(d) $Q = 0$
(e) $Q = +q/2$
(f) $Q = +q$ [5 points]
(g) $Q = +2q$ [3 points]




**Problem 6 (10 points)** A positive charge $Q$ is distributed uniformly along a line with length $a$ as shown in the figure. A point charge $q$ with mass $m$ is placed at a distance $r$ from the right side of the line. Find the maximum speed acquired by the charge $q$ if it was released from rest from that point. Hint: calculate the potential at $x = a + r$ (choosing a zero potential at the infinite distance), calculate the potential energy of the set of charges and use an energy conservation law.

The major concepts used to solve this problem include: Calculating Potential by integrating charge, energy conservation

(a) $v = \sqrt{\dfrac{2kqQ}{ma}}$

(b) $v = \sqrt{\dfrac{2kqQ}{mr}}$

(c) $v = \sqrt{\dfrac{2kqQ}{m(a+r)}}$ [2 points]

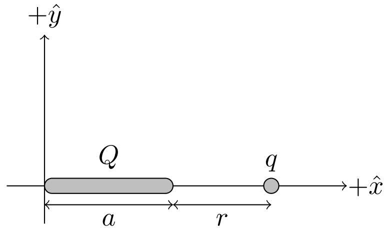
(d) $v = \sqrt{\dfrac{2kqQ}{m\left(\frac{a}{2}+r\right)}}$ [3 points]

(e) $v = \sqrt{\dfrac{2kqQ}{ma}\ln\left(\dfrac{r}{a}\right)}$

(f) $v = \sqrt{\dfrac{2kqQ}{ma}\ln\left(\dfrac{a}{r}\right)}$

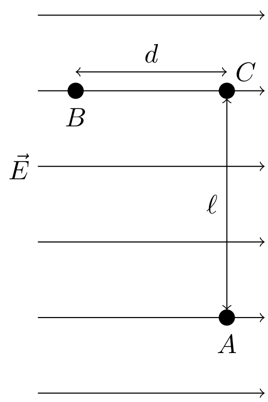
(g) $v = \sqrt{\dfrac{2kqQ}{ma}\ln\left(\dfrac{r+a}{r}\right)}$ [10 points]

(h) $v = \sqrt{\dfrac{2kqQ}{ma}\ln\left(\dfrac{r+a}{a}\right)}$ [7 points]

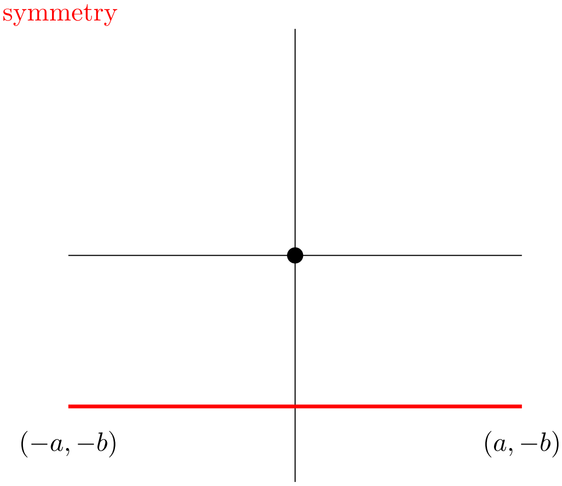


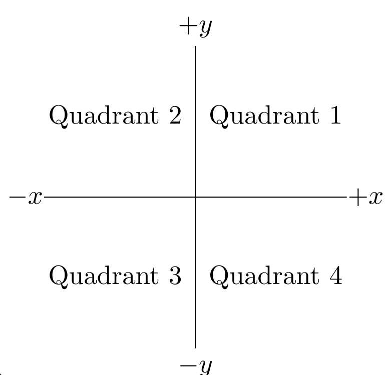
**Problem 7 (8 points)** There exists a uniform electric field with magnitude $E$. The distance between points B and C is $d$ while the distance between points C and A is $\ell$. What is the potential difference between points A and B, $\Delta V = V_A - V_B$?
The major concepts used to solve this problem include: Calculating potential difference by integrating field, Scalar/Dot Products

(a) $+E\ell$
(b) $+Ed$ [6 points]
(c) $+E(\ell + d)$
(d) $+E(\ell^2 + d^2)$ [1 points]
(e) $-E(\ell^2 + d^2)$ [2 points]
(f) $-E(\ell + d)$
(g) $-Ed$ [8 points]
(h) $-E\ell$




**Problem 8 (5 points)** A non-uniform line of charge with $\lambda(x) = \alpha x$ lies in the $xy$-plane from $(-a, -b)$ to $(a, -b)$ as seen in the figure below. Which of the following best describes the direction of the net electric field vector at the origin due to the line of charge?
The major concepts used to solve this problem include: Vector addition, Calculating electric field due to a distribution, symmetry




(a) $+x$
(b) Quadrant 1
(c) $+y$ [3 points]
(d) Quadrant 2
(e) $-x$ [5 points]
(f) Quadrant 3
(g) $-y$
(h) Quadrant 4

**Problem 9 (8 points)** A charge of $q_1 = +8.00$ nC is placed 15.0 cm from another charge $q_2 = +1.50$ nC. At what distance from $q_1$ along the path between the charges should a third charge, $q_3 = +4.33$ nC, be placed so that the net force on $q_3$ is zero?
The major concepts used to solve this problem include: Vector Addition, Coulomb's Law
(a) 0.023 m
(b) 0.045 m [6 points]
(c) 0.056 m
(d) 0.064 m
(e) 0.086 m [2 points]
(f) 0.094 m [2 points]
(g) 0.105 m [8 points]
(h) 0.127 m [2 points]

**Problem 10 (10 points)** An insulating sphere has non-uniform charge distribution $\rho(r) = \alpha r^3$, total charge $Q$ and radius $R$. What is the magnitude of the electric field at $r = R/2$?
The major concepts used to solve this problem include: Gauss's Law

(a) $\dfrac{Q}{2\pi\epsilon_0 R^2}$

(b) $\dfrac{Q}{4\pi\epsilon_0 R^2}$

(c) $\dfrac{Q}{8\pi\epsilon_0 R^2}$ [4 points]

(d) $\dfrac{Q}{16\pi\epsilon_0 R^2}$ [6 points]

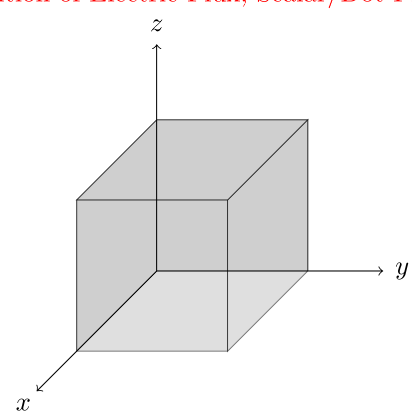
(e) $\dfrac{Q}{32\pi\epsilon_0 R^2}$ [3 points]

(f) $\dfrac{Q}{64\pi\epsilon_0 R^2}$ [10 points]

(g) $\dfrac{Q}{128\pi\epsilon_0 R^2}$ [7 points]

(h) $\dfrac{Q}{256\pi\epsilon_0 R^2}$ [6 points]

**Problem 11 (8 points)** A cube of side length 0.400 m is placed with one corner at the origin so that it exists in the positive $x$, $y$ and $z$ directions. There is an electric field in this region of the form $E(x, y, z) = 1.30x\hat{\imath} - 3.90z\hat{\jmath}$ in SI units. What is the net flux through the cube?
The major concepts used to solve this problem include: Definition of Electric Flux, Scalar/Dot Products

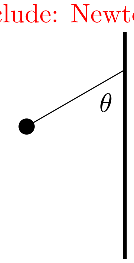



(a) +0.249 $\mathrm{Nm^2/C}$
(b) +0.183 $\mathrm{Nm^2/C}$
(c) +0.166 $\mathrm{Nm^2/C}$ [3 points]
(d) +0.0832 $\mathrm{Nm^2/C}$ [8 points]
(e) -0.0832 $\mathrm{Nm^2/C}$ [6 points]
(f) -0.166 $\mathrm{Nm^2/C}$ [5 points]
(g) -0.183 $\mathrm{Nm^2/C}$
(h) -0.249 $\mathrm{Nm^2/C}$

**Problem 12 (8 points)** A given region of space has an electric potential of the form $V(x, y) = 4x^2 - 9xy^2 + 2y^{-2}$. Which of the following describes the direction of the electric field at the point $(3, -1)$? Note that all properties are given in SI units.
The major concepts used to solve this problem include: Calculating electric field by taking the gradient of potential, trigonometry
(a) 47.6 degrees away from $+\hat{\jmath}$ towards $+\hat{\imath}$
(b) 75.5 degrees away from $+\hat{\imath}$ towards $+\hat{\jmath}$ [6 points]
(c) 3.43 degrees away from $+\hat{\jmath}$ towards $-\hat{\imath}$ [4 points]
(d) 61.2 degrees away from $-\hat{\imath}$ towards $+\hat{\jmath}$
(e) 14.5 degrees away from $-\hat{\jmath}$ towards $-\hat{\imath}$ [8 points]
(f) 42.4 degrees away from $-\hat{\imath}$ towards $-\hat{\jmath}$
(g) 28.8 degrees away from $-\hat{\jmath}$ towards $+\hat{\imath}$
(h) 86.6 degrees away from $+\hat{\imath}$ towards $-\hat{\jmath}$ [2 points]

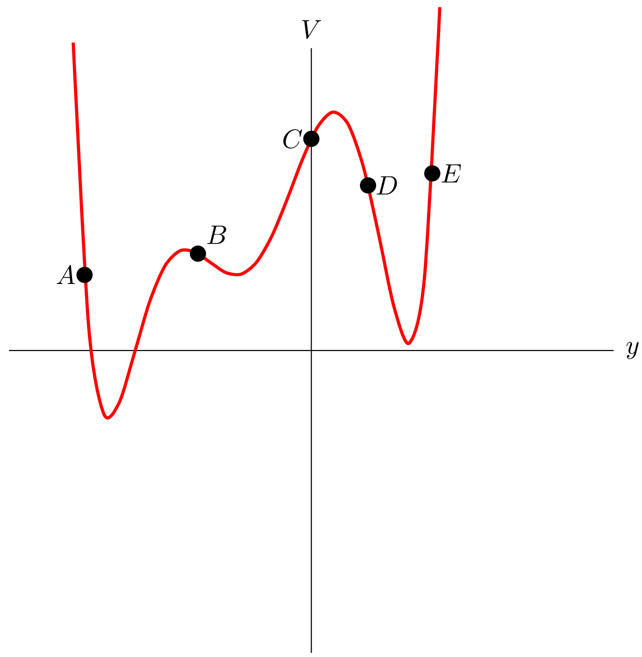
**Problem 13 (8 points)** Two identical positive charges, both 3.0 nC, are placed: one at the origin and another at (0,4.0). How much work is done by an outside force to bring a third positive charge of magnitude 4.0 nC from an infinite distance away and place it at the location (-3.0,4.0)? All positions are given in units of meters.
The major concepts used to solve this problem include: Work of conservative forces and their relationship to potential energy
(a) $+1.2 \times 10^{-8}$ J
(b) $-1.2 \times 10^{-8}$ J
(c) $+4.3 \times 10^{-8}$ J
(d) $-4.3 \times 10^{-8}$ J
(e) $+5.8 \times 10^{-8}$ J [8 points]
(f) $-5.8 \times 10^{-8}$ J [7 points]
(g) $+7.8 \times 10^{-8}$ J [4 points]
(h) $-7.8 \times 10^{-8}$ J [3 points]

**Problem 14 (6 points)** There exists a very large sheet with uniform charge density $\sigma$. There is an insulating string connected to the sheet and a small sphere with charge $q$ at the end of the string. There are three forces acting on the sphere, the electric force $F_E$ due to the sheet, the gravitational force $F_g$ (acting downward in the figure) due to the earth and a tension force $F_T$ due to the string. Which of the following represents the correct ranking of the magnitudes of those forces if the angle of the string relative to vertical, $\theta$, is greater than 45 degrees?
The major concepts used to solve this problem include: Newton's First Law, Vector Addition
(a) $F_E > F_g > F_T$ [1 points]
(b) $F_E > F_T > F_g$ [1 points]
(c) $F_g > F_E > F_T$
(d) $F_g > F_T > F_E$
(e) $F_T > F_E > F_g$ [6 points]
(f) $F_T > F_g > F_E$ [4 points]



**Problem 15 (4 points)** The figure below provides the one-dimensional electric potential as a function of $y$. What is the direction of the force acting on a positive charge that exists at point $C$?

The major concepts used to solve this problem include: Calculating electric field by taking the gradient of potential, Relationship between field and force




(a) $+\hat{x}$ [1 points]
(b) $-\hat{x}$ [2 points]
(c) $+\hat{y}$ [2 points]
(d) $-\hat{y}$ [4 points]
(e) $+\hat{z}$
(f) $-\hat{z}$
(g) 0