Physics 121 - Midterm 2

Last Name	First Name	Student Number	Signature

Tutorial T.A. (circle one): Ricky Chu Firuz Demir Maysam Emadi Alireza Jojjati

Answer **ALL 8** questions. Show all your work and explain your reasoning for full credit. Neatness and clarity of presentation will be considered when assigning a grade. For multiple choice questions, circle one answer only. No aids other than the course calculator and the provided formula sheet may be used.

Useful Constants

elementary charge	$e = 1.602 \times 10^{-19}$ C
electron mass	$m_e = 9.11 \times 10^{-31}$ kg
proton mass	$m_p = 1.67 \times 10^{-27}$ kg
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12}$ C^2/Nm^2
electrostatic constant	$K = 9.0 \times 10^9$Nm^2/C^2
speed of light in vacuum	$c = 2.998 \times 10^8$ m/s

Useful P120 Formulae

$$f = ma$$
$$d = vt$$
$$v = v_0 + at$$
$$d = v_0 t + \frac{1}{2}at^2$$

Electricity

Coulomb's Law: $\vec{\mathbf{F}} = \frac{kq_1q_2}{r_{12}^2}\,\hat{\mathbf{r}} = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r_{12}^2}\hat{\mathbf{r}} = \vec{\mathbf{E}}q$

Electric Flux: $\phi = \vec{\mathbf{E}} \cdot \vec{\mathbf{A}}$

Gauss's Law: $\oint \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = \frac{Q}{\epsilon_0}$

Electric Potential: $V = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$

Problem	1	2	3	4	5	6	7	8	**Total**
Maximum	1	1	6	4	4	4	10	10	**40**
Grade									

1. (1pts) If two macroscopic objects are electrically attracted to each other,

   a) One object must be negatively charged and the other must be positively charged.

   b) both objects must be positively charged

   c) both objects must be negatively charged

   d) none of the above statements are absolutely true

2. (1pts) A positive test charge q is released near a positive fixed charge Q. As q moves away from Q it will move with

   a) increasing acceleration

   b) constant acceleration

   c) constant velocity

   d) decreasing acceleration

3. (6 pts) Please circle either True or False:

   (a) Suppose you have two positive point charges and want to move them closer together. To do the least amount of work you should move them directly towards each other; any other path will require more work because the charges must move through a greater distance.
   TRUE **FALSE**

   (b) Two infinite parallel plastic sheets contain equal negative charge densities uniformly spread over the surfaces. The electric field is zero everywhere between the sheets, not just midway between them.
   TRUE **FALSE**

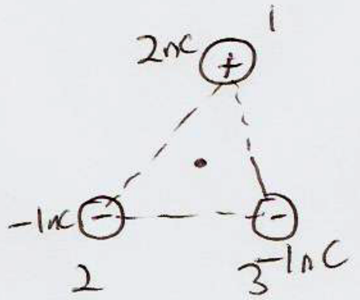
   (c) If one bag contains a charge $8Q$ and another one contains a charge Q, the $8Q-$bag exerts 8 times as much force on the $Q-$bag as the $Q-$bag exerts on the $8Q-$bag.
   TRUE **FALSE**

   (d) Two protons slightly separated from each other form an electric dipole.
   TRUE **FALSE**

   (e) Two unequal point charges q_1 and q_2 are held in place separated from each other. A point charge Q is placed somewhere between them at a point where it remains stationary when released. From this observation, we can conclude that q_1 and q_2 must either both be positive or both be negative.
   TRUE **FALSE**

   (f) If a Gaussian surface contains no charges, then the electric field at its surface must be zero.
   TRUE **FALSE**

4. (4 pts) Three charges form the points of an equilateral triangle with 1.6cm long sides. One of the charges is +2nC, the other two are each -1nC. What is the electric potential at the center of the triangle?



$$V_{Tot} = V_1 + V_2 + V_3$$

$$V_1 = -2V_2 = -2V_3$$

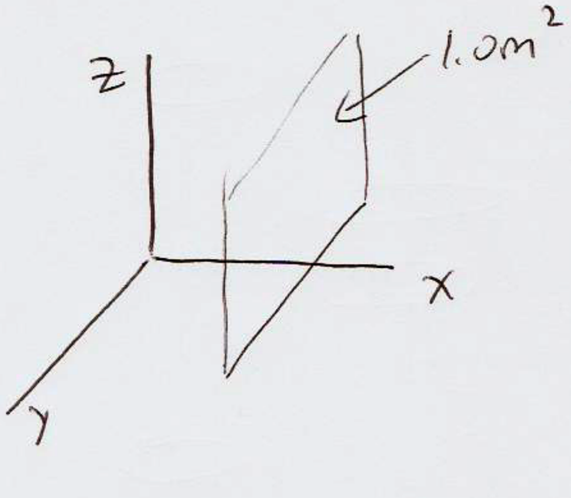
$$\boxed{V_{Tot} = V_1 - \frac{V_1}{2} - \frac{V_1}{2} = \emptyset}$$

$V_x = \frac{1}{4\pi\epsilon_0} \frac{q}{r_x}$

r is same for all

q is twice as big for top one

5. (4 pts) A flat $1.0m^2$ surface is vertical at $x = 2.0m$ and parallel to the $y-z$ plane. What is the flux through the surface if it is located in a uniform electric field given by $\vec{E} = 25.0\hat{\imath} + 24.0\hat{\jmath} + 62.0\hat{k}$?



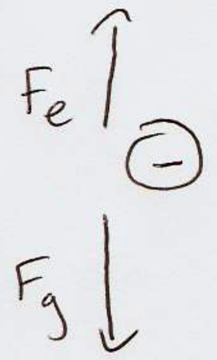
$\vec{E} = 25.0\hat{i} + 24.0\hat{j} + 62.0\hat{k}$

x-component.

$\Phi = EA = 25.0 \times 1.0m^2$

$$\boxed{\Phi = 25 \frac{Nm^2}{C}}$$

6. (4 pts) What is the magnitude of an electric field that balances the weight of a plastic sphere of mass 6.4g that has been charged to $-3.0nC$?



$q = -3.0nC$
$m = 6.4g$

gravity must balance F_e

$$F_g = mg = Eq$$

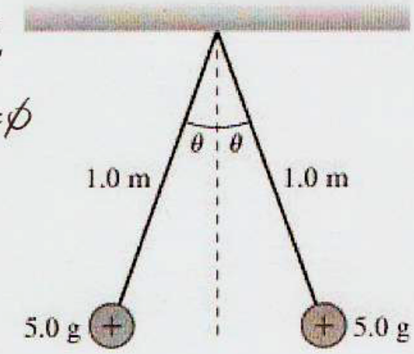
$$\frac{mg}{q} = E$$

$$E = \frac{(0.0064kg)(9.80\,N/kg)}{3.0\times10^{-9}C}$$

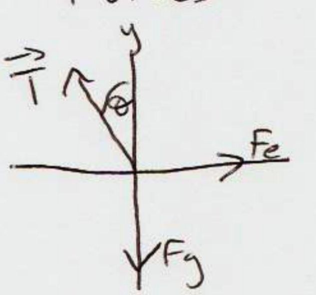
$$\boxed{E = 2.1\times10^{7}\,\frac{N}{C}}$$

7. (10 pts) The figure shows two 5.0g spheres suspended from 1.0m long threads. The spheres repel each other after being charged to +91nC. What is the angle θ? (hint: assume the angle is small)

Forces are balanced;
gravity + repulsion + tension = $\emptyset$



Forces



$$\vec{F}_{net} = \vec{T} + \vec{F}_g + \vec{F}_e = \emptyset$$

x - component

$$(F_{net})_x = T_x + (F_g)_x + (F_e)_x = 0$$

$$-T\sin\theta + \emptyset N + \frac{kq^2}{d^2} = \emptyset$$

$$T\sin\theta = \frac{kq^2}{d^2} = \frac{kq^2}{(2L\sin\theta)^2}$$

y - component

$$(F_{net})_y = T_y + (F_g)_y + (F_e)_y = \emptyset$$

$$T\cos\theta - mg + \emptyset = \emptyset N$$

$$T\cos\theta = mg$$

Divide x & y expressions to get rid of T:

$$\tan\theta = \frac{kq^2}{(2L\sin\theta)^2 mg}$$

$$\sin^2\theta\tan\theta = \frac{kq^2}{4L^2 mg} = \frac{(9.0\times10^9 \frac{Nm^2}{C^2})(91\times10^{-9}C)^2}{4(1.0m)^2(5.0\times10^{-3}kg)(9.8 N/kg)}$$

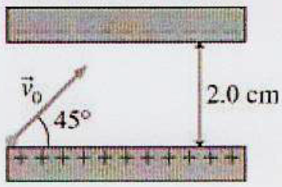
$$\sin^2\theta\tan\theta = 3.80\times10^{-4}$$

Small angle: $\sin\theta \sim \tan\theta \sim \theta$

$$\sin^3\theta = 3.80\times10^{-4}$$

$$\boxed{\theta = 4.15^\circ}$$

8. (10 pts) The figure shows two parallel plates that are 2.0cm apart. The electric field between them is $3.4 \times 10^4 N/C$. An electron is launched at a 45° angle and with initial speed v_0 from the positive plate. What is the maximim v_0 such that the electron won't hit the negative plate?



$\sin 45° = \frac{V_{oy}}{V_o}$

$V_{oy} = V_o \sin 45°$

$F = Eq = ma_y$

$a_y = \frac{Eq}{m}$

$V_y = V_{oy} - at$ ($V_y = 0$ at the top)

$0 = V_{oy} - at$

$a = \frac{V_{oy}}{t} = \frac{V_o \sin 45°}{t} = \frac{Eq}{m} \Rightarrow t = \frac{mV_o \sin 45°}{Eq}$

$d = V_{oy} t - \frac{1}{2} a t^2 = V_o \sin 45° t - \frac{1}{2} V_o \sin 45° t$

$d = V_o \sin 45° \frac{t}{2}$

$\frac{2d}{V_o \sin 45°} = t = \frac{mV_o \sin 45°}{Eq}$

$V_o^2 = \frac{2dEq}{m \sin^2 45°}$

$V_o = \sqrt{\frac{2(0.02m)(3.4 \times 10^4 N/C)(1.6 \times 10^{-19} C)}{(9.11 \times 10^{-31} kg) \sin^2 45°}}$

$V_o = 2.2 \times 10^7 \frac{m}{s}$