NAME Solution

BOX NUMBER ______

EXAM 1

PHYSICS 161
MARCH 6, 2013

CIRCLE APPROPRIATE **ANSWER OR ANSWERS** TO EACH QUESTION

POSSIBLE PARTIAL CREDIT FOR WORK SHOWN.

USE BACK OF PAGE IF ADDITIONAL SPACE IS REQUIRED

NO CALCULATORS OR CELLULAR PHONES ALLOWED (OR VISIBLE)

100 POINTS POSSIBLE

1. (20 POINTS) Electric Field Concepts

(a) (5 Points) For the charge distribution provided, indicate the region (A to E) along the horizontal axis where a point exists at which the net electric field is zero. If no such region exists on the horizontal axis choose the last option (nowhere).

A.

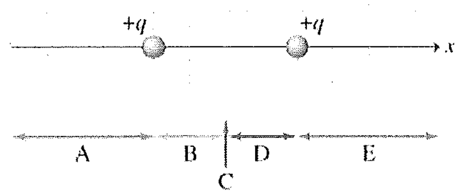
B.

C.

D.

E.

F. Nowhere



(b) (5 Points) For the charge distribution provided, indicate the region (A to E) along the horizontal axis where a point exists at which the net electric field is zero. If no such region exists on the horizontal axis choose the last option (nowhere).

A.

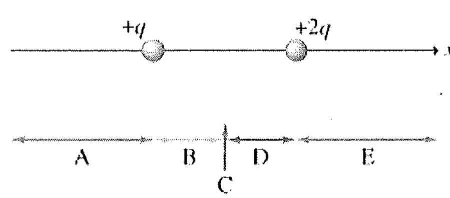
B.

C.

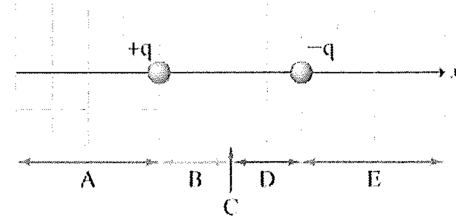
D.

E.

F. Nowhere



(c) (5) Points) For the charge distribution provided, indicate the region (A to E) along the horizontal axis where a point exists at which the net electric field is zero. If no such region exists on the horizontal axis choose the last option (nowhere).



A.

B.

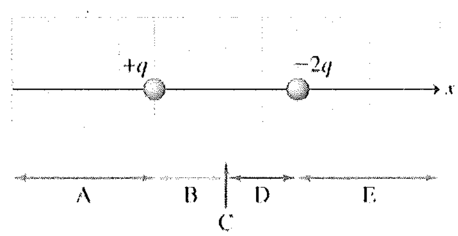
C.

D.

E.

F. Nowhere

(d) (5 Points) For the charge distribution provided, indicate the region (A to E) along the horizontal axis where a point exists at which the net electric field is zero.



A.

B.

C.

D.

E.

F. Nowhere along the finite x-axis

2. (10 POINTS) Particle *0* and particle *1* are positively charged with charge q_0 and q_1 respectively. Both are fixed on the *y*-axis as shown in the figure. Particle *0* is at the origin and particle *1* is at the point $(0, d_1, 0)$. A third negatively charged particle of charge $-q_2$ is fixed at the point $(0, d_2, 0)$. Particle *0* experiences a repulsion *from* particle *1* and an attraction *toward* particle 2. For certain values of d_1 and d_2, the repulsion and attraction should balance each other, resulting in no net force on q_0. For what ratio d_1/d_2 is there no net force on particle *0*?

A. *1*

B. q_1/q_2

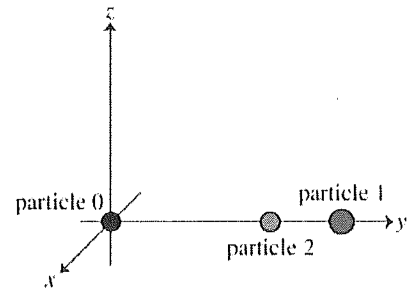
C. q_2/q_1

D. $(q_2/q_1)^{1/2}$

E. $(q_1/q_2)^{1/2}$

G. Zero

H. None of these

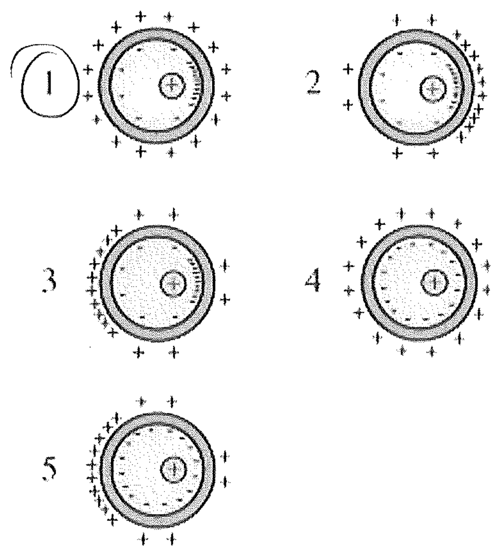


$$\underset{\sim}{F}_{2,1\to 0} = 0 = -K\frac{q_0 q_1}{d_1^2}\hat{j} + \frac{K q_0 q_2 \hat{j}}{d_2^2}$$

$$\Rightarrow \frac{d_1}{d_2} = \left(\frac{q_1}{q_2}\right)^{1/2}$$

3. (10 POINTS). A positive charge is kept at a fixed point off-center inside a fixed spherical conducting shell that is electrically neutral, and the charges in the shell are allowed to reach electrostatic equilibrium. The large positive charge inside the shell is roughly 16 times that of the smaller charges shown on the inner and outer surfaces of the spherical shell.

Circle the number associated with the figure below that best represents the charge distribution on the inner and outer walls of the shell?



4. (20 POINTS) A hollow, conducting sphere with an inner radius R_1 and an outer radius R_2 has a uniform positive surface charge density σ_o. A negative charge, $-Q$, is now introduced into the cavity inside the sphere.

(a) (10 Points) What is the new charge density on the outside of the sphere?

A. σ_o - Q

B. $Q/4\pi R_2^2$

C. $Q/4\pi R_1^2$

D. $\sigma_o - Q/4\pi R_1^2$

E. $\sigma_o - Q/4\pi R_2^2$

F. $\sigma_o + Q/4\pi R_1^2$

$$q_o = \sigma_o 4\pi R_2^2$$

$$q_f = \sigma_o 4\pi R_2^2 - Q$$

$$\sigma_f = \frac{q_f}{4\pi R_2^2} = \sigma_o - \frac{Q}{4\pi R_2^2}$$

(b) (5 Points) What is the strength of the electric field just outside the sphere?

A. $\sigma_o/4\pi\varepsilon_o R_2^2$

B. $Q/4\pi\varepsilon_o R_2^2$

C. $Q/4\pi\varepsilon_o R_1^2$

D. $(1/\varepsilon_o)(\sigma_o - Q/4\pi R_1^2)$

E. $(1/\varepsilon_o)(\sigma_o - Q/4\pi R_2^2)$

F. $\sigma_o + Q/4\pi R_1^2$

GAUSS' LAW $\Rightarrow$

$$E(4\pi R_2^2) = \frac{q_{enc}}{\epsilon_o}$$

$$E = \frac{1}{\epsilon_o}\left(\sigma_o - \frac{Q}{4\pi R_2^2}\right)$$

(c) (5 Points) What is the electric flux through a spherical surface just inside the inner surface of the sphere?

GAUSS' LAW =>

ELECTRIC FLUX $= \frac{q_{enc}}{\epsilon_0} = \frac{-Q}{\epsilon_0}$

A. $-Q/4\pi\varepsilon_o R_1^2$

B. $-Q/4\pi\varepsilon_o R_2^2$

C. Q/ε_o

D. $-Q/\varepsilon_o$

E. $\sigma_o - Q/4\pi R_2^2$

F. Zero because it is inside a conductor

5. (10 POINTS) Three equal point charges of charge q are placed at the corners of an equilateral triangle whose sides are d meters long. What is the potential energy of the system? (Take the potential energy of the three charges to be zero when they are infinitely far apart.)

A. Zero

B. $q/4\pi\varepsilon_o d^2$

C. $-3q/4\pi\varepsilon_o d^2$

D. $3q^2/4\pi\varepsilon_o d^2$

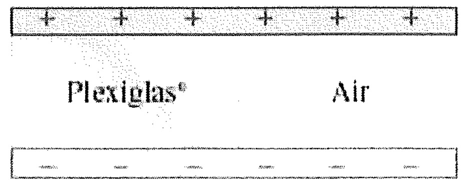
E. $3q^2/4\pi\varepsilon_o d$

F. $q/4\pi\varepsilon_o d$

$$U = \frac{1}{4\pi\epsilon_0}\left\{\frac{q_1 q_2}{r_{12}} + \frac{q_1 q_3}{r_{13}} + \frac{q_{23}}{r_{23}}\right\}$$

$$= \frac{1}{4\pi\epsilon_0}\frac{(3q^2)}{d}$$

6. (10 POINTS) A parallel-plate capacitor is made from two plates each having an area *A* and separated by a distance *d*. Half of the space between these plates contains only air, but the other half is filled with Plexiglas of dielectric constant 3.0 as shown in the Figure below. A battery having an *emf V* is connected across the plates.



6

(a) (~~10~~ Points) What is the capacitance of the combination?

A. $4\varepsilon_o A/d$

B. $(3/4)\varepsilon_o A/d$

C. $2\varepsilon_o A/d$

D. $V/\varepsilon_o A$

E. $3V/\varepsilon_o A$

F. $4V/\varepsilon_o A$

CAPACITORS IN PARALLEL

$$C = C_1 + C_2 = KC_1 + C_1$$
$$= (K+1)C_1 = 4\left(\frac{\epsilon_0 A/2}{d}\right)$$
$$= 2\epsilon_0 A/d$$

2

(b) (~~5~~ Points) How much energy is stored in the capacitor?

A. $\varepsilon_o AV/d$

B. $\varepsilon_o AV^2/d$

C. $2\varepsilon_o AV^2/d$

D. Vd

E. $(1/2)\varepsilon_o V^2/d^2$

F. $\varepsilon_o V^2/d^2$

$$U = \frac{1}{2}CV^2 = \frac{1}{2}\left(\frac{2\epsilon_0 A}{d}\right)V^2$$
$$= \frac{\epsilon_0 A}{d}V^2$$

2

(c) (~~5~~ Points) If we remove the Plexiglas, but change nothing else, how much energy will be stored in the capacitor?

A. $\varepsilon_o AV/d$

B. $\varepsilon_o AV^2/2d$

C. $2\varepsilon_o AV^2/d$

D. Vd

E. $(1/2)\varepsilon_o V^2/d^2$

F. $\varepsilon_o V^2/d^2$

$C = \varepsilon_0 A/d$

$U = \frac{1}{2} C V^2 = \frac{1}{2} \frac{\varepsilon_0 A}{d} V^2$

7. (20 POINTS) The batteries shown in the circuit in the figure have negligibly small internal resistances.

(a) (10 Points) What is the current in the 10 Ω resistor?

A. 1.50 A

B. 1.25 A

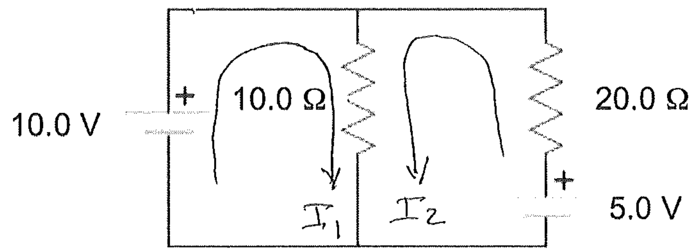
C. 1.0 A

D. 0.75 A

E. 0.50 A

F. 0.25 A

$I = I_1 + I_2$
$= 1.0A$



① $10V - I_1(10\Omega) - I_2(10\Omega) = 0$

② $5V - I_2(20\Omega) - I_2(10\Omega) - I_1(10\Omega) = 0$

2EQ ; 2 UNKNOWNS ⇒ $I_1 = 1.25A$ $I_2 = -0.25A$

(b) (5 Points) What is the current in the 20 Ω resistor?

A. 1.50 A

B. 1.25 A

C. 1.0 A

D. 0.75 A

E. 0.50 A

F. 0.25 A

$I = I_2 = 0.25A$

(c) (5 Points) What is the current in the 10 V battery?

A. 1.50 A

B. 1.25 A

C. 1.0 A

D. 0.75 A

E. 0.50 A

F. 0.25 A

$I = I_1 = 1.25A$