

Section instructor \_\_\_\_\_

Section number \_\_\_\_\_

Last/First name \_\_\_\_\_

Last 3 Digits of Student ID Number: \_\_\_\_\_

*Show all work. Show all formulas used for each problem prior to substitution of numbers. Label diagrams and include appropriate units for your answers. You may use an alphanumeric calculator during the exam as long as you do not program any formulas into memory. By using an alphanumeric calculator you agree to allow us to check its memory during the exam. Simple scientific calculators are always OK!*

*A Formula Sheet Is Attached To The Back Of This Examination  
Be Prepared to Show your Student ID Card*

*Score on each problem:*

1. (30) \_\_\_\_\_

2. (20) \_\_\_\_\_

3. (20) \_\_\_\_\_

4. (20) \_\_\_\_\_

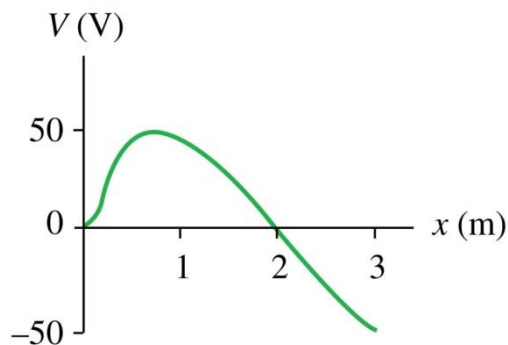
*Total Score (out of 90 pts) \_\_\_\_\_*

## 1. Conceptual Questions

(30 point) Put a circle around the letter that you think is the best answer.

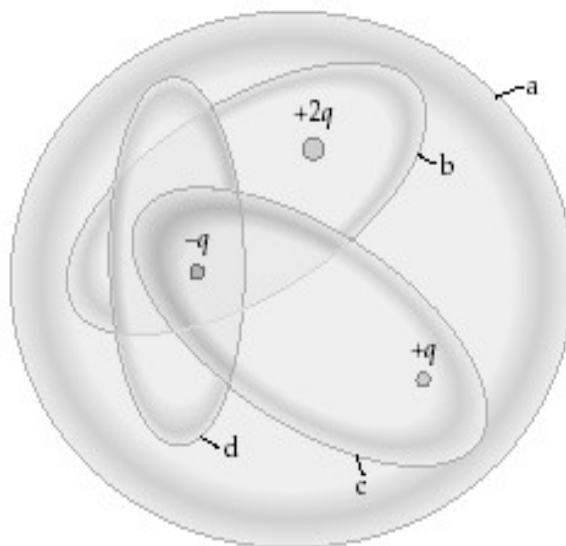
1.1. (6pts) An electron is released from rest at  $x = 2$  m in the potential shown. What does the electron do right after being released?

- A) Stay at  $x = 2$  m
- B) Move to the right ( $+x$ ) at steady speed
- C) Move to the right with increasing speed
- D) Move to the left ( $-x$ ) at steady speed
- E) Move to the left with increasing speed



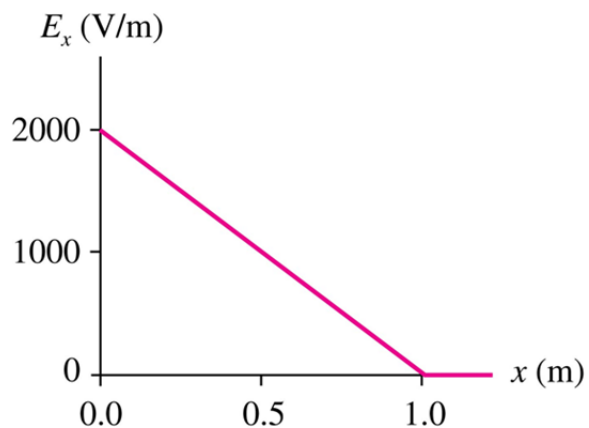
1.2. (6pts) Figure shows four Gaussian surfaces surrounding a distribution of charges. Which Gaussian surfaces have an electric flux of  $+q/\epsilon_0$  through them?

- A) a
- B) b
- C) b and d
- D) b and c
- E) c

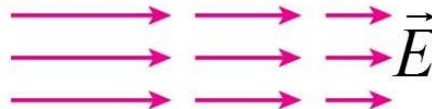


1.3.(6pts) This is a graph of the x-component of the electric field along the x-axis. The potential is zero at the origin. What is the potential at  $x=1m$ ?

- A) 2000 V
- B) 1000 V
- C) 0 V
- D) -1000 V
- E) -2000 V



1.4. (6pts) Which set of equipotential surfaces matches this electric field?



- |  |  |  |
|--|--|--|
| <p>0 V                      50 V</p> <p>A.</p> | <p>0 V                      50 V</p> <p>B.</p> | <p>0 V                      50 V</p> <p>C.</p> |
| <p>50 V                      0 V</p> <p>D.</p> | <p>50 V                      0 V</p> <p>E.</p> | <p>50 V                      0 V</p> <p>F.</p> |

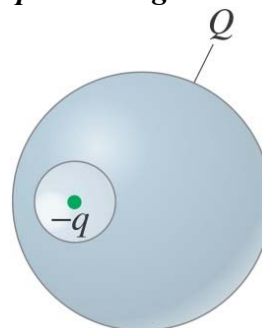
1.5. (6pts) A solid conductor carries a net positive charge  $Q = -3 C$ . There is a hollow cavity within the conductor, at whose center is a negative point charge  $-1 C$ . What is the charge on

(a) the inner surface of the conductor's cavity

$q_{inner} =$

(b) the outer surface of the conductor?

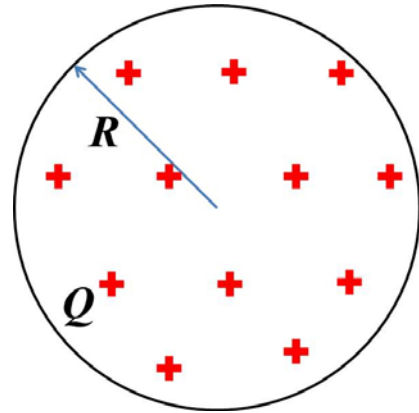
$q_{outer} =$



**Problem 2. (20 pts)**

An electric charge  $+Q$  is distributed uniformly throughout a nonconducting sphere of radius  $R$ .

- (a) (2pts) Draw a Gaussian surface in the figure;
- (b) (2pts) Draw electric field and area vectors;
- (c) (6pts) Determine the electric field outside the sphere ( $r > R$ )
- (d) (10pts) Determine the electric field inside the sphere ( $r < R$ )  
(show how you handle a linear integral)

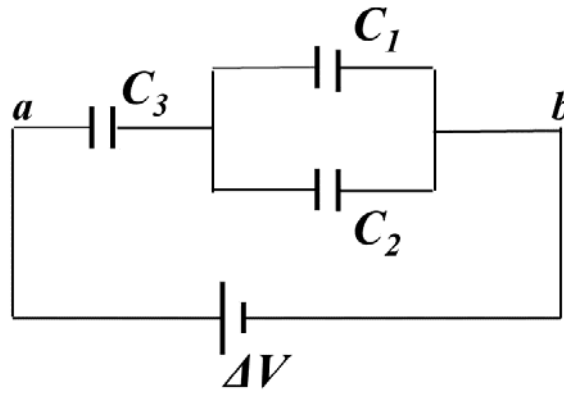


**Problem 3. (20 pts)**

**(a) Determine the equivalent capacitance between points  $a$  and  $b$ .**

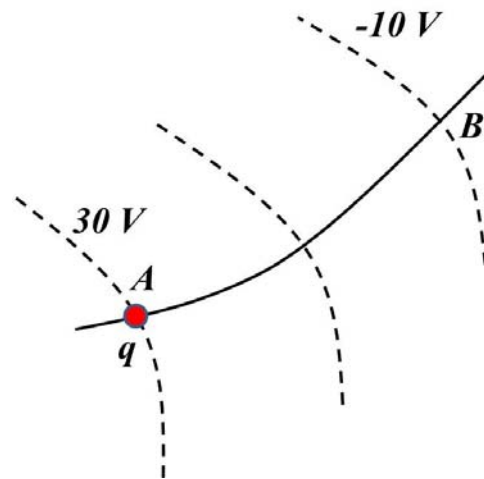
Assume that  $C_1=2\text{ nF}$ ,  $C_2=4\text{ nF}$ ,  $C_3=8\text{ nF}$ ,  $\Delta V=3\text{ V}$ .

**(b) What are the charge on and the potential difference across each capacitor in the figure.**



**Problem 4 (20 pts).**

*A proton's speed as it passes point A is 200,000 m/s. It follows the trajectory shown in the figure with a solid line. The dashed lines in the figure are equipotential lines. What is the proton's speed at point B?*



***Formula Sheet:******Electricity and Magnetism*****Coulomb's law**

$$F = k \frac{qQ}{r^2}$$

**Electric Field**

$$\vec{E} = \frac{\vec{F}}{q}$$

Field of a point charge

$$E = k \frac{Q}{r^2}$$

Electric field inside a capacitor

$$E = \frac{\eta}{\epsilon_0}$$

Principle of superposition

$$\vec{E}_{net} = \sum_{i=1}^N \vec{E}_i$$

Electric flux

$$\Phi_E = \int \vec{E} \cdot d\vec{A}$$

**Gauss's law**

$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{in}}{\epsilon_0}$$

**Electric potential**

$$V = \frac{U}{q}$$

$$\Delta V = V_f - V_i = - \int_i^f \vec{E} \cdot d\vec{s}$$

For a point charge  $V(r) = \frac{1}{4\pi\epsilon_0} \frac{Q}{r}$ 

For a parallel-plate capacitor

$$V = Es$$

**Potential Energy**

$$U = qV$$

Two point charges

$$U = k \frac{qQ}{r}$$

**Capacitors**

$$C = \frac{Q}{\Delta V}$$

Parallel-plate  $C = \epsilon_0 \frac{A}{d}$ 

Capacitors connected in parallel

$$C_{eq} = C_1 + C_2 + \dots$$

Capacitors connected in series

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$$

Energy stored in a capacitor

$$U = \frac{Q^2}{2C}$$

**Constants**

Charge on electron

$$e = 1.60 \cdot 10^{-19} \text{ C}$$

Electron mass  $m = 9.11 \cdot$ 

$$10^{-31} \text{ kg}$$

Proton mass  $m = 1.67 \cdot 10^{-27} \text{ kg}$ 

Permittivity of free space

$$\epsilon_0 = 8.85 \cdot 10^{-12} \text{ C}^2/\text{Nm}^2$$

$$k = \frac{1}{4\pi\epsilon_0} = 8.99 \cdot 10^9 \text{ Nm}^2/\text{C}^2$$

**Kinematic eq-ns with const. accel:**

$$v(t) = v_{0x} + at$$

$$x(t) = x_0 + v_{0x}t + (1/2) at^2$$

$$v^2 = v_{0x}^2 + 2a(x - x_0)$$

$$L = 2\pi R$$

$$A = \pi R^2$$

$$V = (4/3)\pi R^3$$