PHY294 Exam #1

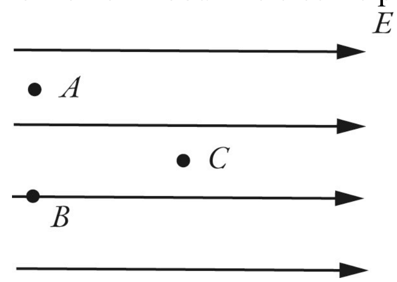
Name:______________________ Student #:_________________

Show work for problems where indicated. Include units in answer.

Some physical constants:

$e = 1.6 \times 10^{-19}$ C
$m_e = 9.1 \times 10^{-31}$ kg
$m_p = 1.67 \times 10^{-27}$ kg
$g = 9.83$ N/kg
$\varepsilon_o = 8.85 \times 10^{-12}\ C^2/N{\cdot}m^2$
$1/4\pi\varepsilon_o = 9 \times 10^9\ N{\cdot}m^2/C^2$

1) Suppose a region of space has a uniform electric field, directed towards the right, as shown in the figure. Which statement about the electric potential is true?



A) The potential at all three locations (*A*, *B*, *C*) is the same because the field is uniform.
B) The potential at points *A* and *B* are equal, and the potential at point *C* is higher than the potential at point *A*.
C) The potential at points *A* and *B* are equal, and the potential at point *C* is lower than the potential at point *A*.
D) The potential at point *A* is the highest, the potential at point *B* is the second highest, and the potential at point *C* is the lowest.

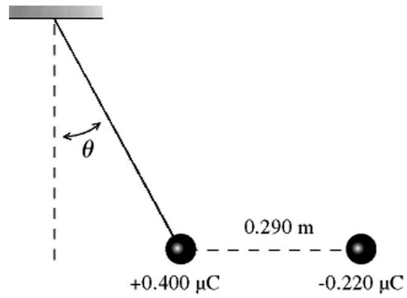
2) The electric field 1.5 cm from a very small charged object points toward the object with a magnitude of 180,000 N/C. What is the charge on the object?

A) -4.5 nC
B) +4.5 nC
C) -5.0 nC
D) +5.0 nC
Negative since the field points to charge

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

$$q = \frac{Er^2}{k} = \frac{(1.8E5N/c)(.015m)^2}{9E9Nm^2/C^2} = 4.5E-9C$$

3) In the figure, a small spherical insulator of mass 6.00×10^{-2} kg and charge +0.400 μC is hung by a thin wire of negligible mass. A charge of -0.220 μC is held 0.290 m away from the sphere and directly to the right of it, so the wire makes an angle θ with the vertical, as shown. What is the angle θ?



A) 0.917°
B) 1.10°
C) 1.30°
D) 1.50°
E) 1.70°

There are 3 forces acting on the charge. The tension in the wire, gravity and the force from the -0.22 μC charge. Decompose the force into horizontal and vertical components.

$$T\cos\theta = mg$$

$$T\sin\theta = F_E$$

$$\tan\theta = \frac{F_E}{mg} = \frac{kq_1q_2/r^2}{mg}$$

$$= \frac{(9E9Nm^2/C^2)(4E-7C)(2.2E-7C)/(0.29m)^2}{(.06kg)(9.8N/kg)}$$

$$= 0.016$$

$$\theta = 0.917^o$$

4) Two large, flat, horizontally oriented plates are parallel to each other, a distance d apart. Half way between the two plates the electric field has magnitude E. If the separation of the plates is reduced to $d/2$ what is the magnitude of the electric field half way between the plates? **Discuss.**

The electric field will not change, since it is constant.

5) The electric field strength in the space between two closely spaced parallel disks is 1.0×10^5 N/C. This field is the result of transferring 3.9×10^9 electrons from one disk to the other. What is the diameter of the disks? **Show work.**

$$E = \frac{\eta}{\varepsilon_o} = \frac{Q}{A\varepsilon_o}$$

$$A = \frac{Q}{E\varepsilon_o} = \frac{(3.9E9 electrons)(1.6E-19C/electron)}{(1E5N/C)(8.85E-12C^2m^2)}$$

$$A = 7.06E-4m^2$$

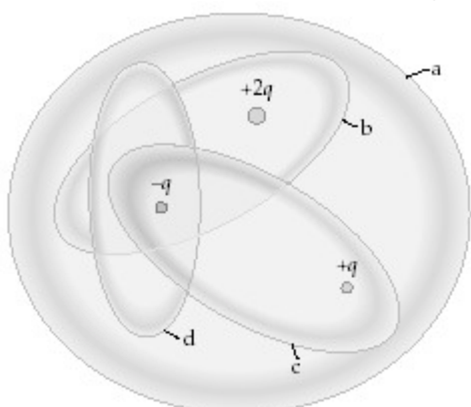
$$D = 0.03cm$$

6) In a certain region, the electric potential due to a charge distribution is given by the equation $V(x,y) = 2xy - x^2 - y$, where x and y are measured in meters and V is in volts. At which point is the electric field equal to zero? **Show work.**

$$E_x = -\frac{\partial V}{\partial x} = -2y + 2x = 0; x = y$$

$$E_y = -\frac{\partial V}{\partial y} = -2x + 1 = 0; x = 0.5 = y$$

7) The figure shows four Gaussian surfaces surrounding a distribution of charges.



(a) Which Gaussian surfaces have an electric flux of $+q/\varepsilon_0$ through them?

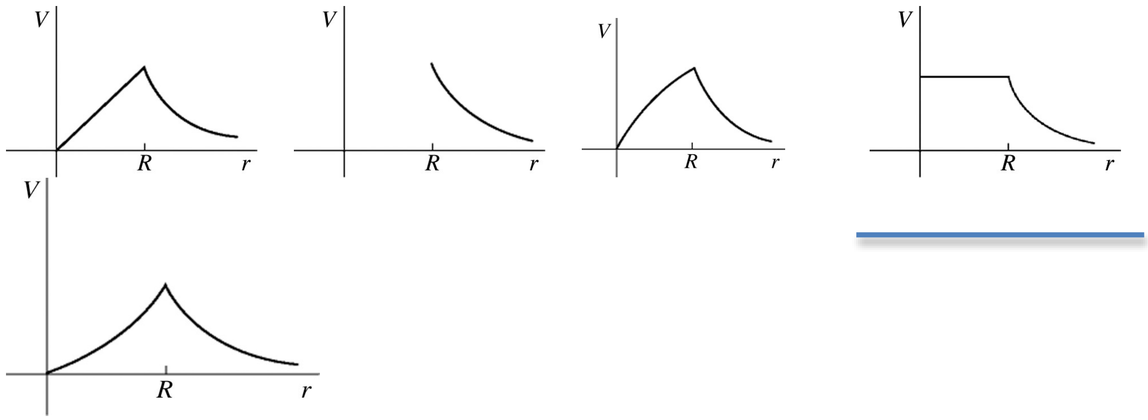
Only b

(b) Which Gaussian surfaces have no electric flux through them?

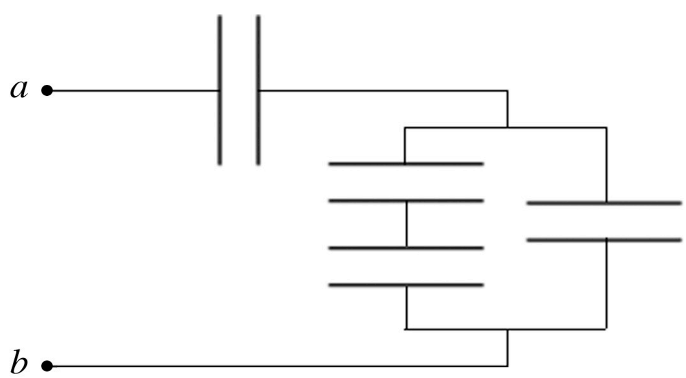
Only c

8) A conducting sphere of radius *R* carries an excess positive charge and is very far from any other charges. Which one of the following graphs best illustrates the potential (relative to infinity) produced by this sphere as a function of the distance *r* from the center of the sphere?

The electric field is zero inside the conductor, so the potential is constant. The potential falls off as 1/r outside the conductor. The potential curves must match at r=R.

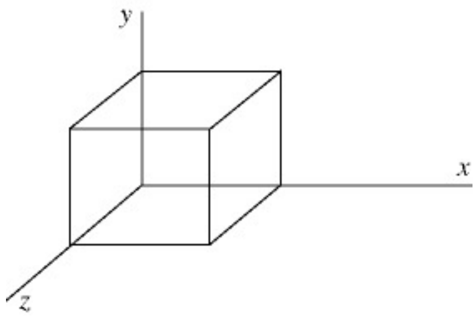


9) The capacitors in the network shown in the figure all have a capacitance of 5.0 µF. What is the equivalent capacitance, C_{ab}, of this capacitor network?



A) 20 µF
B) 3.0 µF
C) 10 µF
D) 5.0 µF
E) 1.0 µF

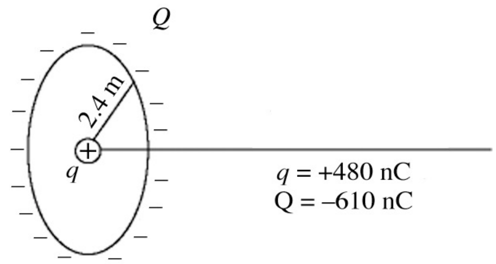
10) The cube of insulating material shown in the figure has one corner at the origin. Each side of the cube has length 0.080 m so the top face of the cube is parallel to the *xz*-plane and is at $y = 0.080$ m. It is observed that there is an electric field $\vec{E} = (3280\ \mathrm{N/C \cdot m})y\hat{j}$ that is in the +*y* direction. Use Gauss's law to calculate the net charge enclosed by the cube. **Show work.**



The only field is directed along the y-direction and is uniform as a function of x and z. There is no field at y=0 and the field at the top of the cube creates a flux of $3280 * 0.08^3 = 1.68 Nm^2/C$. *The charge enclosed is q=1.49E-11C*

11) A charge Q = -610 nC is uniformly distributed on a ring of 2.4-m radius. A point charge q = +480 nC is fixed at the center of the ring, as shown in the figure. An electron is projected from infinity toward the ring along the axis of the ring. This electron comes to a momentary halt at a point on the axis that is 5.0 m from the center of the ring. What is the initial speed of the electron at infinity? **Show work**. As a reminder, the electric potential on the z-axis from a ring of charge Q and of radius R is given by

$$V = \frac{1}{4\pi\varepsilon_o}\frac{Q}{\sqrt{R^2 + z^2}}$$



A) 6.6 × 10^6 m/s
B) 4.5 × 10^6 m/s
C) 3.4 × 10^6 m/s
D) 2.2 × 10^6 m/s
E) 1.1 × 10^6 m/s

$U_{electron} = eV_{ring} + eV_q$
$U_{electron}$ =0 at r=infinity
$KE_{electron}$=0 at r= 5 m

$\Delta U_{electron} = \Delta KE_{electro}$

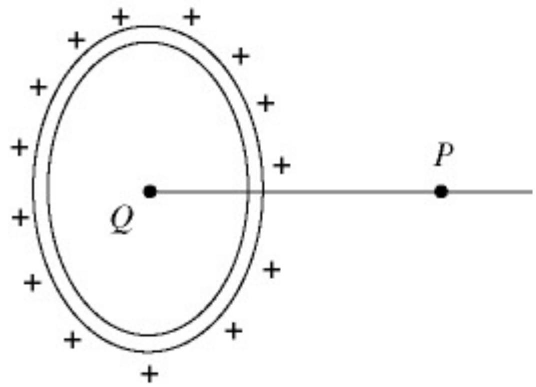
$$U_e = (-1.6E-19C)(9E^9 Nm^2/C^2)\frac{-6.1E-17C}{\sqrt{2.4^2+5^2}}$$

$$-(1.6E-19C)(9E9Nm^2/C^2)\frac{4.8E-7C}{5m}$$

$$= 2.7E-17J = 1/2mv^2$$

$$v = 6.6E6m/s$$

12) In the figure, a ring 0.71 m in radius carries a charge of + 580 nC uniformly distributed over it. A point charge *Q* is placed at the center of the ring. The electric field is equal to zero at field point *P*, which is on the axis of the ring, and 0.73 m from its center. What is the value for the point charge *Q*? **Show work.** [Hint: V for a ring of charge is given above.]



Need to know the electric field from a ring of charge. But we have the potential from the previous problem. Since the ring of charge is positive, the charge Q must be negative. The two equal each other in magnitude at the point P.

$$E_{ring} = -\frac{dV}{dz} = -k\left[\frac{-1/2(2z)q}{\left[R^2+z^2\right]^{3/2}}\right] = k\left[\frac{qz}{\left[R^2+z^2\right]^{3/2}}\right]$$

$$E_{point} = k\frac{Q}{z^2}$$

$$|E_{ring}| = |E_{point}|$$

$$Q = \frac{qz^3}{\left[R^2+z^2\right]^{3/2}} = \frac{(5.8E-7C)(0.73m)^3}{\left[0.712+0.732\right]^{3/2}} = 2.14E-7C$$