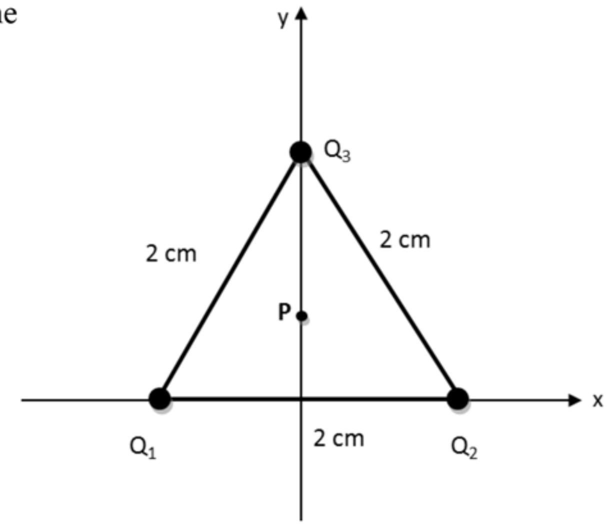
The next three questions pertain to the situation described below.

Three point charges are positioned on the vertices of an equilateral triangle as shown in the figure. The bottom two charges are equal, $Q_1 = Q_2 = 10^{-6}$ Coulombs. The top charge $Q_3 = -5 \times 10^{-6}$ Coulombs.



1) What is the magnitude of the net force on charge Q_1 due to the other two charges? ""

a. $|F_1| = 90$ N
b. $|F_1| = 103$ N
c. $|F_1| = 135$ N

2) What is the magnitude of the electric field at the center of the triangle **P**(x=0, y=$1/\sqrt{3}$)? ""

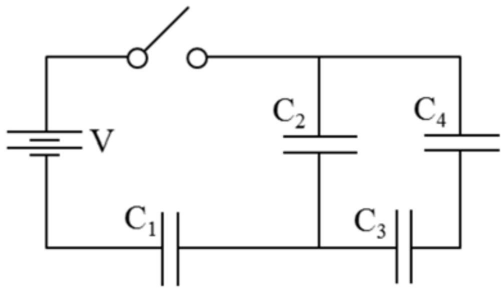
a. $|E_p| = 4.05 \times 10^8$ N/C
b. $|E_p| = 2.7 \times 10^8$ N/C
c. $|E_p| = 2.02 \times 10^8$ N/C
d. $|E_p| = 0$ N/C
e. $|E_p| = 3.37 \times 10^8$ N/C

3) What is the electric potential at the center of the triangle **P**(x=0, y=$1/\sqrt{3}$)? You may assume the potential is defined to be zero at infinity. ""

a. $V_P = 5.46 \times 10^6$ Volts
b. $V_P = 0$ Volts
c. $V_P = -2.34 \times 10^6$ Volts

The next four questions pertain to the situation described below.

Four parallel plate capacitors are connected to a battery as shown in the circuit diagram below. After the switch has been closed for a long time, the charge on capacitor C_4 is observed to be 7.64 μC. (Note $\mu C = 1 \times 10^{-6} C$.)



$C_1 = 6\ \mu F$
$C_2 = 12\ \mu F$
$C_3 = 6\ \mu F$
$C_4 = 12\ \mu F$

4) Capacitors C_2 and C_4 are connected

a. neither in series nor in parallel
b. in series
c. in parallel

5) What is C_{1234}, the equivalent capacitance of the combination of four capacitors? ""

a. $C_{1234} = 22\ \mu F$
b. $C_{1234} = 16\ \mu F$
c. $C_{1234} = 4.36\ \mu F$

6) What is V_3, the voltage across C_3? ""

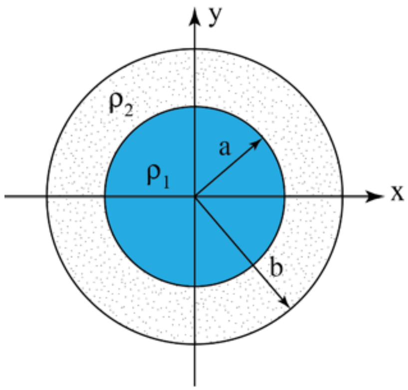
a. $V_3 = 0.64$ Volts
b. $V_3 = 1.3$ Volts
c. $V_3 = 1.9$ Volts

7) What is $V_{battery}$, the voltage across the battery? ""

a. $V_{battery}$ = 5.1 Volts
b. $V_{battery}$ = 1.9 Volts
c. $V_{battery}$ = 0.85 Volts
d. $V_{battery}$ = 6.4 Volts
e. $V_{battery}$ = 7 Volts

The next four questions pertain to the situation described below.

A solid sphere of radius a = 0.03 m is centered on the origin. It is made of an *insulating* material and carries a uniform volume charge density ρ_1 such that the net charge on the sphere Q_1= -0.00226 Coulombs. Concentric with this sphere is an *insulating* spherical shell of inner radius a = 0.03 m and outer radius b = 0.05 m, that carries a uniform volume charge density ρ_2 such that the net charge on the outer shell Q_2 = 0.00421 Coulombs.



8) What is the volume charge density of the outer spherical shell?

a. ρ_2 = 10.3 C/m^3
b. ρ_2 = 8.04 C/m^3
c. ρ_2 = 37.2 C/m^3

9) What is the electric potential a distance 0.23 m from the center of the sphere? Let V($r = \infty$) = 0. ""

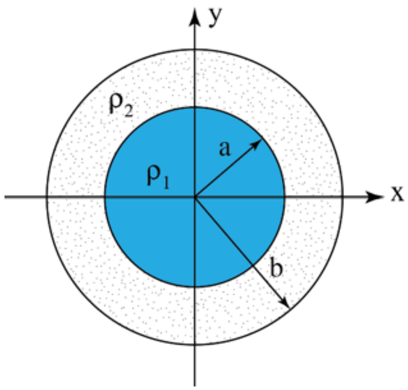
a. V = -2.53 × 10^8 Volts
b. V = 1.65 × 10^8 Volts
c. V = 2.53 × 10^8 Volts
d. V = 7.63 × 10^7 Volts
e. V = -8.84 × 10^7 Volts

10) At what (nonzero) radius is the electric field zero? ""

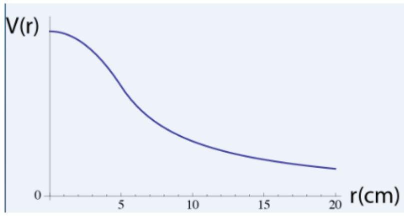
a. 0.05 m
b. 0.043 m
c. 0.0407 m
d. The electric field is not zero for any positive r.
e. 0.03 m

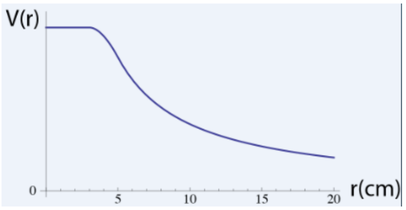
11) **Problem repeated from previous page**

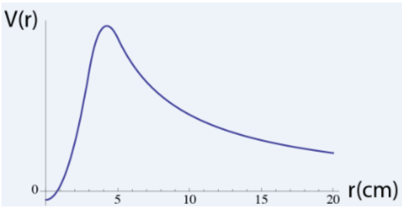
A solid sphere of radius a = 0.03 m is centered on the origin. It is made of an insulating material and carries a uniform charge density ρ_1 such that the net charge on the sphere Q_1= -0.00226 Coulombs. Concentric with this sphere is an insulating spherical shell of inner radius a = 0.03 m and outer radius b = 0.05 m, that carries a uniform charge density ρ_2 such that the net charge on the outer shell Q_2 = 0.00421 Coulombs.



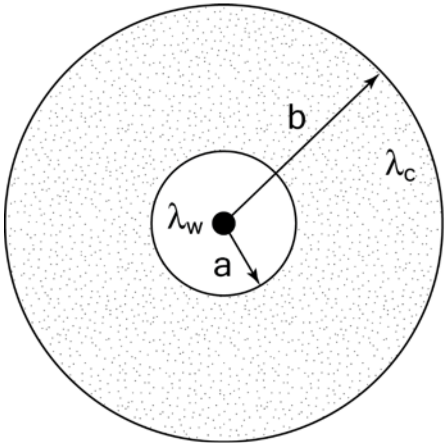
Which plot best represents the electric potential as a function of r?

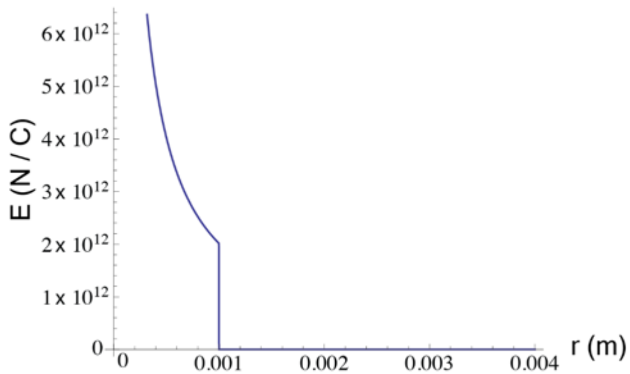
a.


b.


c.


The next two questions pertain to the situation described below.





A long thin wire has a uniform linear charge density λ_W. Concentric with the wire is a long thick conducting cylinder, with inner radius a = 1 mm, and an outer radius b = 3 mm. The conducting cylinder has a net linear charge density λ_C. The figure above shows a plot of the electric field as a function of the radial distance from the center of the cylinder.

12) Based on the plot of the electric field, what is the value of λ_W?

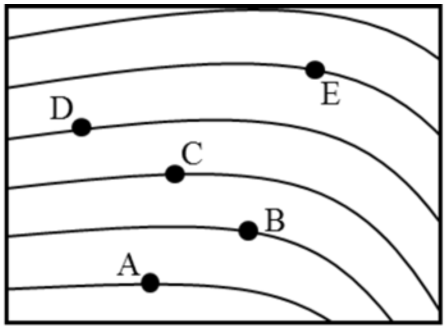
a. λ_W = 0.112 C/m
b. λ_W = 0.0 C/m
c. λ_W = 2.22 x 10^{-4} C/m

13) Based on the plot of the electric field, what is the value of λ_C?

a. λ_C = -0.336 C/m
b. λ_C = -0.112 C/m
c. λ_C = 0.0 C/m

The next two questions pertain to the situation described below.

Equipotential lines associated with an electric field are shown in the figure below. Adjacent curves are separated by a potential difference of 10 Volts. The potential is **higher** (closer to $+\infty$) at the top of the figure and **lower** (closer to $-\infty$) at the bottom of the figure.



14) A positive charge is released from rest at the point labeled C. It begins to accelerate

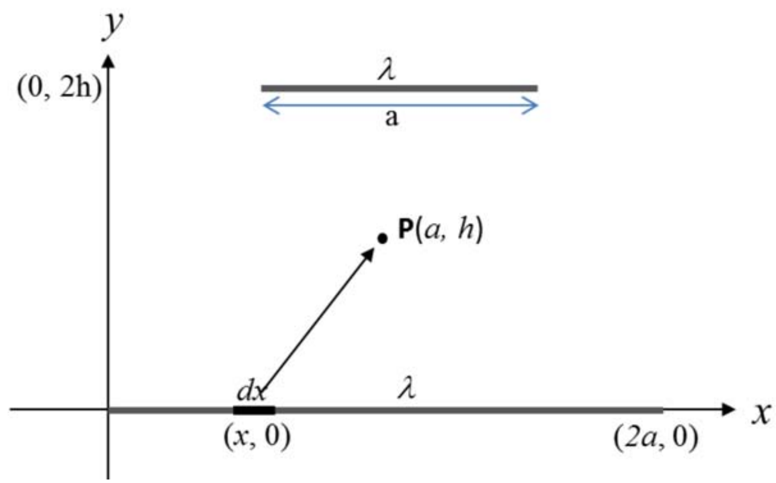
a. toward the left and slightly downwards.
b. toward the bottom of the figure, and slightly to the right.
c. toward the top of the figure and slightly to the left.

15) The same positive charge is now carried by a physics student along various trajectories. In which one of the following paths is the total work done **by the student** both positive in sign and greatest in magnitude?

a. $E \rightarrow A$
b. $A \rightarrow E \rightarrow B \rightarrow C$
c. $B \rightarrow D \rightarrow C \rightarrow E$
d. $D \rightarrow C \rightarrow A \rightarrow E \rightarrow C$
e. $A \rightarrow C \rightarrow E$

The next two questions pertain to the situation described below.

Two finite lines of charge with uniform positive linear charge density λ are arranged horizontally as shown in the figure. The top line is half the length of the bottom line. The following questions refer to the electric field at the point labeled P, which is midway between the two lines of charge.



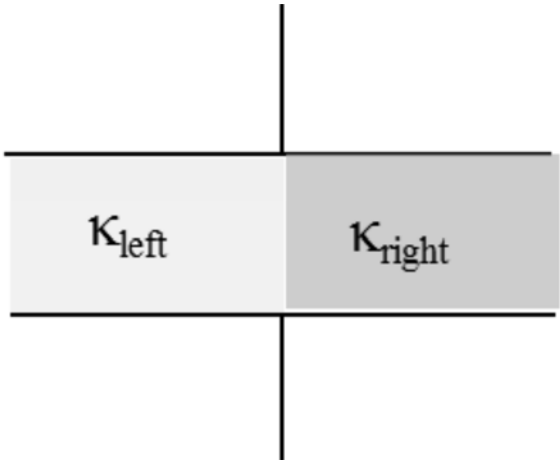
16) The y-component of the electric field at point P is

a. positive.
b. zero.
c. negative.

17) Which of the following is the correct formula to calculate E_y the y-component of the electric field due to the bottom line of charge?

a. $E_y = \frac{\lambda k}{h} \int_0^{2a} dx \frac{a^2}{[(a-x)^2+h^2]^{3/2}}$
b. $E_y = \lambda k \int_0^{2a} dx \frac{a-x}{[(a-x)^2+h^2]^{3/2}}$
c. $E_y = \frac{\lambda k}{h} \int_0^{2a} dx \frac{1}{[(a-x)^2+h^2]^{1/2}}$
d. $E_y = \lambda k \int_0^{2a} dx \frac{h}{[(a-x)^2+h^2]^{3/2}}$
e. $E_y = \lambda k \int_0^{2a} dx \frac{1}{(a-x)^2+h^2}$

The next three questions pertain to the situation described below.



A parallel plate capacitor consists of two square conducting plates seperated by a distance of 0.0025 m. When the space between the plates is empty (κ = 1), the capacitance is measured to be 3.7×10^{-9} F.

18) What is the length L of the side of each square plate? ""

a. L = 0.255 m
b. L = 1.02 m
c. L = 0.51 m

19) The space between the capacitor is now filled with two dielectrics. The left half is filled by a material with κ_L=1.7 and the right half by a material with κ_R=2.4. What is the new capacitance of the capacitor? ""

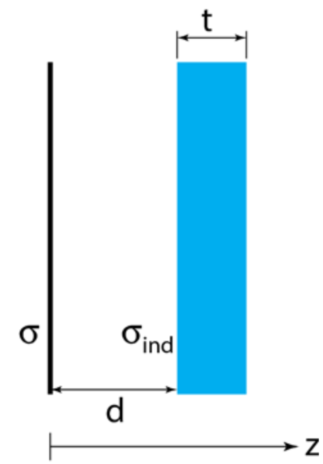
a. $C = 1.8 \times 10^{-9}$ F
b. $C = 1.5 \times 10^{-8}$ F
c. $C = 6.3 \times 10^{-9}$ F
d. $C = 3.7 \times 10^{-9}$ F
e. $C = 7.6 \times 10^{-9}$ F

20) With the dielectrics inserted, the capacitor is connected to a 5 V battery. Compare σ_L the charge density on the left side of the positive plate, with σ_R the charge density on the right side of the positive capacitor plate.

a. $\sigma_L = \sigma_R$
b. $\sigma_L < \sigma_R$
c. $\sigma_L > \sigma_R$

The next two questions pertain to the situation described below.

An infinite plane with surface charge density σ is placed a distance d away from a neutral conducting plane of thickness t.



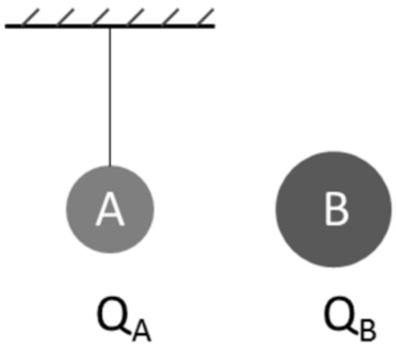
21) What is the electric field between the charged plane and the neutral conducting plane ($0 < z < d$) ?

a. $E = \sigma/(2\epsilon_0)$
b. $E = -\sigma/\epsilon_0$
c. $E = \sigma/\epsilon_0$
d. $E = 3\sigma/(2\epsilon_0)$
e. $E = -\sigma/(2\epsilon_0)$

22) What is the induced charge density σ_{ind} on the left conducting surface ($z = d$) ?

a. $\sigma_{ind} = \sigma$
b. $\sigma_{ind} = -\frac{1}{2}\sigma$
c. $\sigma_{ind} = \frac{1}{2}\sigma$
d. $\sigma_{ind} = -\sigma$
e. $\sigma_{ind} = 0$

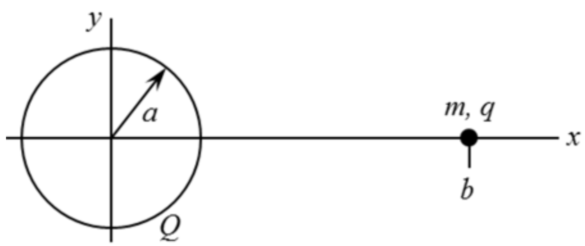
A conducting sphere A with no net charge ($Q_A = 0$) is hanging from a ceiling through an insulating thread, as shown below. A second conducting sphere B with a net charge ($Q_B \neq 0$)is brought close to sphere A.



23) Which of the following statements on the behavior of sphere A is true?

a. Sphere A will feel no force from sphere B.
b. Sphere A will be attracted towards sphere B.
c. Sphere A will be repelled away from sphere B.

An object of mass *m* with electric charge *q* is released from rest at *x=b, y=z=0* near a charged, **insulating** spherical shell of radius *a*. The shell is fixed in place and carries a total charge *Q* distributed unifromly over its surface. Since *q* and *Q* are of opposite sign, the mass accelerates along the *x* axis and crashes into the sphere.



24) Which expression represents the speed of the mass just before it collides with the sphere?

a.
$$v = \sqrt{\frac{2kQq}{m}\left(\frac{1}{a} - \frac{1}{b}\right)}$$

b.
$$v = \sqrt{\frac{2kQq}{m}(\ln b - \ln a)}$$

c.

$$v = \sqrt{\frac{2kQq}{m}(b-a)}$$

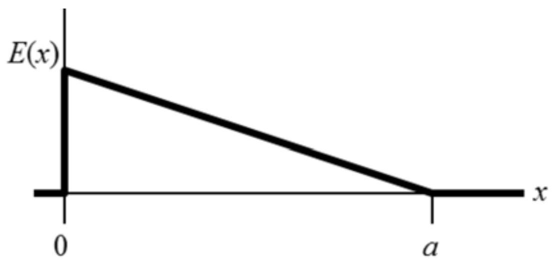
d.

$$v = \sqrt{\frac{2kQq}{m}\left(\frac{1}{a^2} - \frac{1}{b^2}\right)}$$

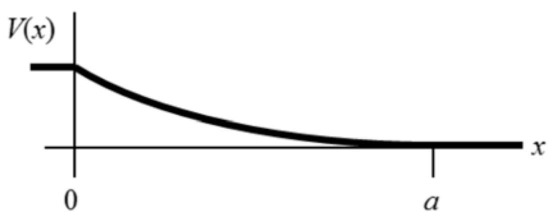
e.

$$v = \sqrt{\frac{4\pi a^3}{3}\frac{kQq}{m}\cos^{-1}\left(\frac{a}{b}\right)}$$

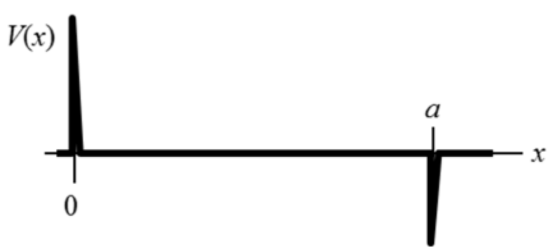
A region of space extending from x=0 to x=a is filled with a non-zero electric field pointing in the positive x direction. (The electric field is independent of y and z) The strength of the field as a function of x is shown in the graph below.



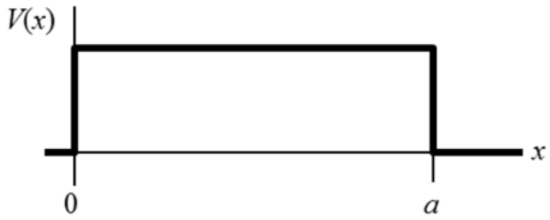
25) Assuming that the potential $V(x)$=0 at $x = \infty$, which of the following graphs best represents $V(x)$?



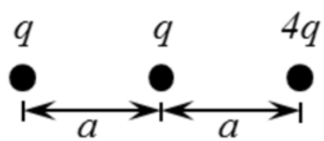
a.



b.

c. 

26) Three charges are assembled from infinitely far away to lie on a line as shown below. The right charge has four times the magnitude of the other two charges. Let $q = 7 \times 10^{-6}$ Coulomb's and $a = 0.38$ meters.



What is the work done **by the electric field** when the charges are moved from infinitely far away to their final location.

a. W_{field} = -8.12 Joules
b. W_{field} = -10.4 Joules
c. W_{field} = 10.4 Joules
d. W_{field} = 21.4 Joules
e. W_{field} = -21.4 Joules