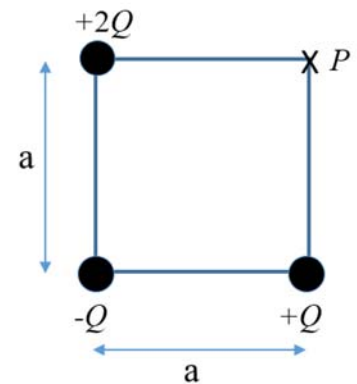**The next four questions pertain to the situation described below.**

Three charges are positioned at three corners of a square of side length $a = 0.5$ m as shown in the figure. The charges have values $+2Q$, $-Q$, and $+Q$, as shown, where $Q = 7$ µC.

1) What is the <u>y-component</u> of the force on the charge $+2Q$?

    a. F = -4.77 N
    b. F = 4.77 N
✓   c. F = -2.28 N
    d. F = -1.14 N
    e. F = -1.76 N

2) What is the work required to create this charge configuration? Assume the charges are brought in from infinity, where the electric potential is zero, and that these are the only charges in the universe.

    a. W = 3.89 J
    b. W = -3.89 J
    c. W = -0.881 J
    d. W = -2.79 J
✓   e. W = -1.4 J
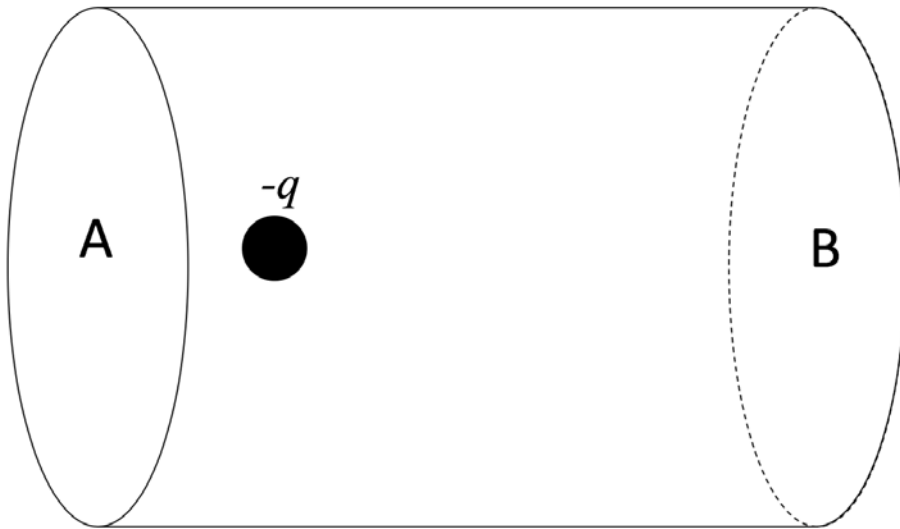
3) What is the electric potential at point P (the fourth vertex of the square)?

    a. V = -3.99 × 10^5 V
✓   b. V = 2.89 × 10^5 V
    c. V = 2.02 V

4) If you bring an additional negative charge $-2Q$ from infinity to point P, the <u>work you do</u> is

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

The next two questions pertain to the situation described below.

For the next 2 problems, a negative point charge -q is inside a cylinder of length L and radius R, closer to one end of the cylinder (side A) than the other (side B).

5) What is the net electric flux integrated over the entire surface of the cylinder?

    a. $\Phi = \frac{q}{\epsilon_o}$

✓   b. $\Phi = \frac{-q}{\epsilon_o}$

    c. $\Phi = \frac{L}{R}\frac{q}{\epsilon_o}$

6) What is the sign of the flux through surface A, the end closest to the charge?

    a. $\Phi_A > 0$

✓   b. $\Phi_A < 0$

    c. $\Phi_A = 0$

The next four questions pertain to the situation described below.

For the next four problems, consider an insulating sphere of radius a centered at the origin, concentric with a conducting spherical shell. The shell has inner radius b, and outer radius c. There is a total charge Q_{sphere} distributed uniformly throughout the volume of the insulating sphere, and a net charge of Q_{shell} on the conducting shell. This is shown in the figure below
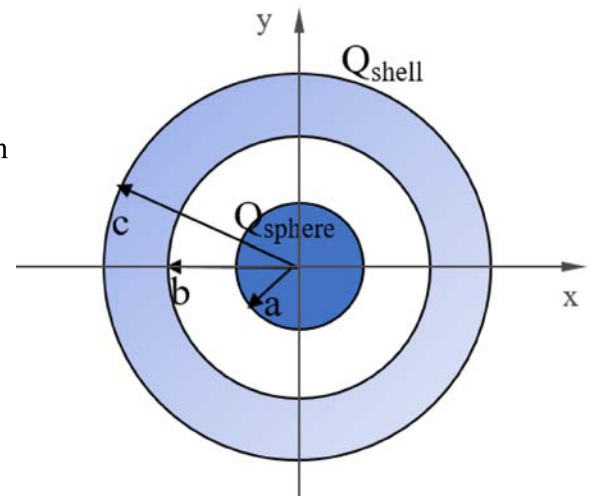
7) What is the magnitude of the electric field at a distance $r < a$ from the center of the insulating sphere?

✓   a. $E(r) = \dfrac{kQ_{\text{sphere}}r}{a^3}$

     b. $E(r) = \dfrac{kQ_{\text{sphere}}}{r^2}$

     c. $E(r) = \dfrac{kQ_{\text{sphere}}a}{r^3}$

8) What is the electric field at a point $\mathbf{r}$ with $a < r < b$?

     a. $\mathbf{E}(\mathbf{r}) = \dfrac{kQ_{\text{shell}}\hat{\mathbf{r}}}{r^2}$

     b. $\mathbf{E}(\mathbf{r}) = \dfrac{k(Q_{\text{sphere}}+Q_{\text{shell}})\hat{\mathbf{r}}}{r^2}$

     c. $\mathbf{E}(\mathbf{r}) = \dfrac{k(Q_{\text{sphere}}-Q_{\text{shell}})\hat{\mathbf{r}}}{r^2}$

✓   d. $\mathbf{E}(\mathbf{r}) = \dfrac{kQ_{\text{sphere}}\hat{\mathbf{r}}}{r^2}$

     e. $\mathbf{E}(\mathbf{r}) = 0$

9) What is the charge on the outer surface of the conducting shell?

     a. $Q = Q_{\text{shell}} - Q_{\text{sphere}}$

     b. $Q = Q_{\text{shell}}$

✓   c. $Q = Q_{\text{shell}} + Q_{\text{sphere}}$

10) What is the electric potential $V(r)$ at a point within the conducting shell, $b < r < c$ assuming the potential is zero infinitely far from the spheres?
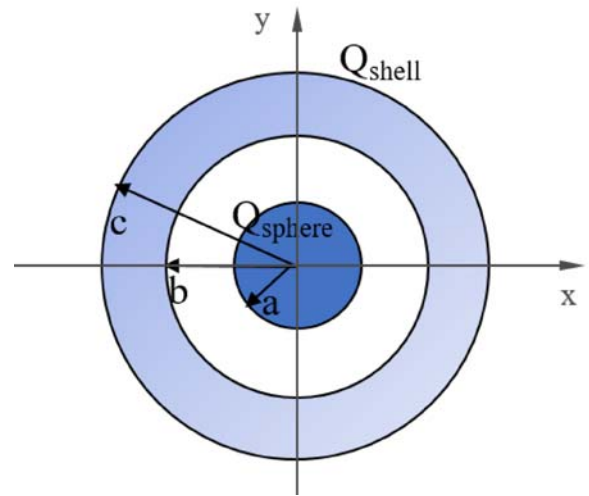
a. $V(r) = \frac{kQ_{shell}}{r}$

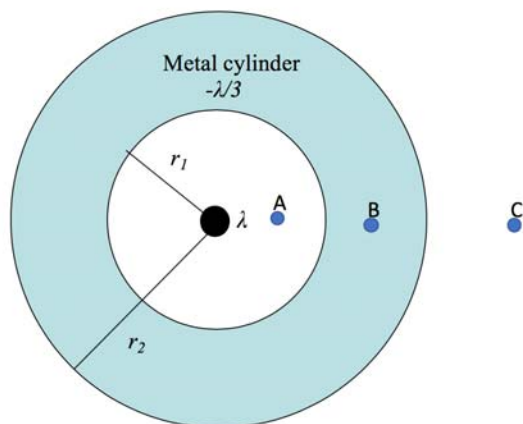✓ b. $V(r) = \frac{k(Q_{sphere} + Q_{shell})}{c}$

c. $V(r) = \frac{kQ_{shell}}{c} + \frac{kQ_{sphere}}{r}$

d. $V(r) = 0$

e. $V(r) = \frac{k(Q_{sphere} + Q_{shell})}{r}$

The next two questions pertain to the situation described below.

For the next 2 problems, a line charge with line charge density $+\lambda$ is at the center of a thick conducting cylindrical shell that has line charge density $-\lambda/3$. The conducting cylindrical shell has inner radius r_1 and outer radius r_2. Consider three points of interest A,B, and C, at radii from the center r_A, r_B and r_C chosen as shown, such that $0 < r_A < r_1$, $r_1 < r_B < r_2$, and $r_C > r_2$.

11) Order the magnitudes of the electric field at the three locations A, B, and C.

    a. $|E_A| > |E_B| > |E_C|$

✓   b. $|E_A| > |E_C| > |E_B|$

    c. $|E_C| > |E_B| > |E_A|$

12) Assuming that $\lambda=1.3$ C/m, $r_1=0.15$ m, $r_2=0.20$m, what is the magnitude of the electric field at position C, a distance $r_C=0.35$ m from the center?

    a. $|E_C| = 8.9 \times 10^{10}$ N/C

    b. $|E_C| = 0$ N/C

✓   c. $|E_C| = 4.5 \times 10^{10}$ N/C

    d. $|E_C| = 1.3 \times 10^{11}$ N/C

    e. $|E_C| = 6.7 \times 10^{10}$ N/C

The next three questions pertain to the situation described below.

Two infinite nonconducting sheets of charge and one infinite conducting slab are placed perpendicular to the x direction as shown in the following figure. The conducting slab is electrically neutral. The charge densities on the two sheets of charge are $\sigma_1 = +4\ \mu C/m^2$ and $\sigma_2 = -5.5\ \mu C/m^2$.
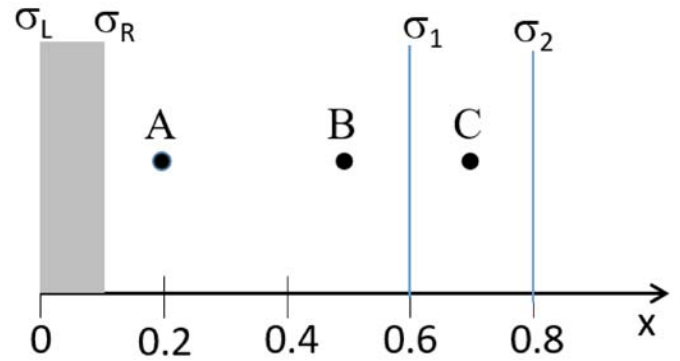
13) The x-component of the electric field at point **C** ($x = 0.7$ m) is:

✓   a. $E_x = 0.536 \times 10^6$ V/m

b. $E_x = -0.085 \times 10^6$ V/m

c. $E_x = 0.226 \times 10^6$ V/m

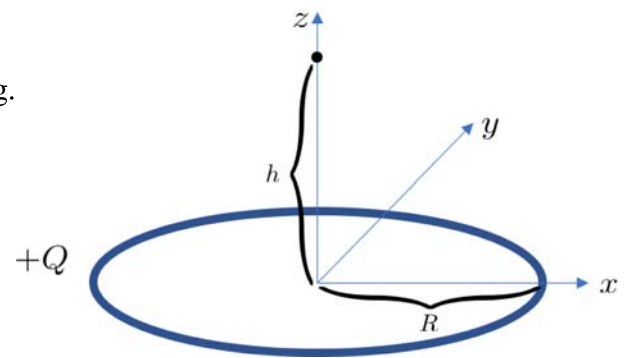14) What is the induced charge density on the right side of the conductor?

a. $\sigma_R = -1.5\ \mu C/m^2$

b. $\sigma_R = -0.75\ \mu C/m^2$

c. $\sigma_R = 1.5\ \mu C/m^2$

d. $\sigma_R = 0\ \mu C/m^2$

✓   e. $\sigma_R = 0.75\ \mu C/m^2$

15) Calculate the potential difference between point **A** ($x = 0.2$ m) and point **B** ($x = 0.5$ m).

✓   a. $V_B - V_A = -0.025 \times 10^6$ Volts

b. $V_B - V_A = -0.068 \times 10^6$ Volts

c. $V_B - V_A = -0.161 \times 10^6$ Volts

d. $V_B - V_A = 0.093 \times 10^6$ Volts

e. $V_B - V_A = 0.068 \times 10^6$ Volts

The next three questions pertain to the situation described below.

For the next three problems, consider the circular ring of radius R lying in the x-y plane and centered at the origin, as pictured. There is a total charge of $+Q$ distributed uniformly over the ring.

16) What is the charge density λ on the ring?

    a. $\lambda = Q/R$

✓   b. $\lambda = Q/(2\pi R)$

    c. $\lambda = Q/(\pi R^2)$

17) Which integral below gives the z-component of the electric field at point on the z axis at a height h above the center of the ring?

    a. $E_z(h) = \int_0^{2\pi} \left(\frac{k\lambda R d\theta}{h^2 + R^2} \right) \left(\frac{R}{\sqrt{h^2 + R^2}} \right)$

    b. $E_z(h) = \int_0^{2\pi} \left(\frac{k\lambda R d\theta}{\sqrt{h^2 + R^2}} \right) \left(\frac{h}{\sqrt{h^2 + R^2}} \right)$

✓ c. $E_z(h) = \int_0^{2\pi} \left(\frac{k\lambda R d\theta}{h^2 + R^2} \right) \left(\frac{h}{\sqrt{h^2 + R^2}} \right)$

    d. $E_z(h) = \int_0^{2\pi} \left(\frac{k\lambda d\theta}{h^2 + R^2} \right) \left(\frac{h}{\sqrt{h^2 + R^2}} \right)$

    e. $E_z(h) = \int_0^{2\pi} \left(\frac{k\lambda R d\theta}{h^2 + R^2} \right)$

18) Now let h be much larger than R. In this limit, which expression best approximates the magnitude of the electric field at this point?

    a. $E(h) = k\lambda/h^2$

✓ b. $E(h) = kQ/h^2$

    c. $E(h) = kQ/R^2$

The next two questions pertain to the situation described below.

A very long insulating cylinder of radius R and length L carries a net positive charge $+Q$ distributed evenly throughout its interior. Assume the electric potential at the surface of the cylinder is $V_R = 0$.
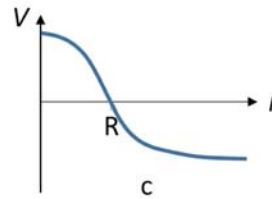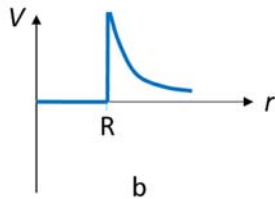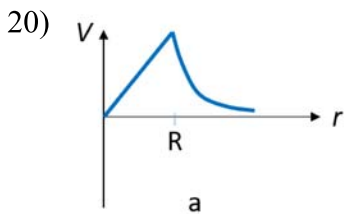

Long insulating cylinder
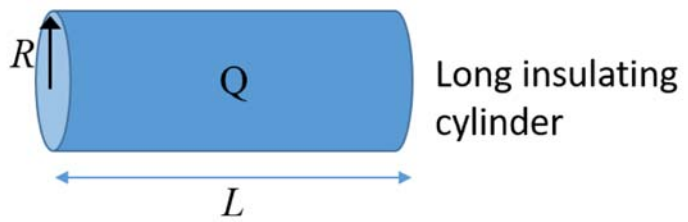
19) Which equation represents the value of the electric potential at a distance $r > R$ from the cylinder. Assume that r = 0 along the center line of the cylinder and the electric potential at the <u>surface</u> of the cylinder is zero.

    a. $V(r) = -\int_{\infty}^{r} \left(\frac{Q}{2\pi r L \epsilon_0} \right) dr$

✓   b. $V(r) = -\int_{R}^{r} \left(\frac{Q}{2\pi r L \epsilon_0} \right) dr$

    c. $V(r) = -\int_{0}^{r} \left(\frac{Q}{2\pi r L \epsilon_0} \right) dr$
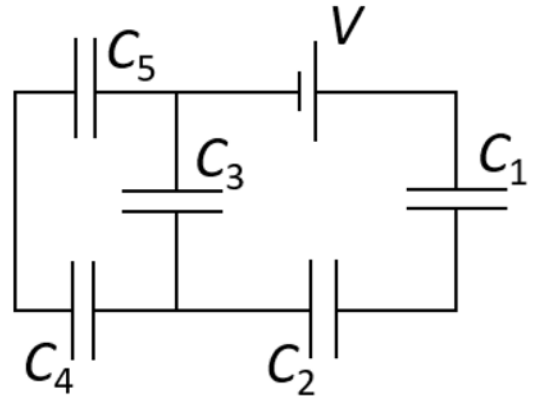
20)

Which graph best represents the electric potential at points inside and outside the cylinder. Again, assume $r = 0$ is along the center line of the cylinder.

    a.
    b.
    c.

The next four questions pertain to the situation described below.

Five identical capacitors with capacitance $C = 25$ µF are connected to a battery with voltage $V = 5$ volts as shown in the figure.

21) Capacitors C_1 and C_3 are in

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

22) Capacitors C_4 and C_5 are in

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

23) What is the equivalent capacitance of the five capacitors in this configuration?

✓   a. $C_{eq} = 9.38$ µF
    b. $C_{eq} = 87.5$ µF
    c. $C_{eq} = 62.5$ µF

24) How much energy is stored in capacitor C_2?

    a. $U_2 = 23.5$ µJ
    b. $U_2 = 117$ µJ
✓   c. $U_2 = 44$ µJ
    d. $U_2 = 312$ µJ
    e. $U_2 = 235$ µJ

The next two questions pertain to the situation described below.

A parallel plate capacitor is constructed from two plates each with area 0.055 m^2, separated by a distance 0.002 m. A charge of Q=+0.42 µC is moved from the bottom plate to the top plate.
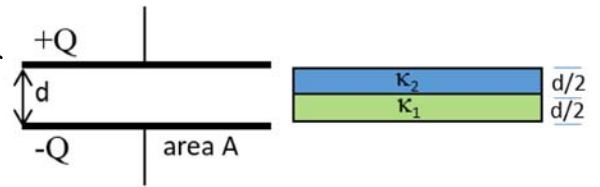
25) What is the voltage across the plates, when the space between the plates is empty?

✓   a. $V_0 = 1730$ volts

      b. $V_0 = 1210$ volts

      c. $V_0 = 1040$ volts

26) A dielectric is now placed between the plates. The bottom half has a dielectric constant κ_1, and the top half has dielectric constant κ_2. Let C_0 represent the capacitance of the plates before the dielectric is inserted. What is the capacitance of the system with the dielectric completely filling the region between the plates?

      a. $C = C_0 (\kappa_1 + \kappa_2)$

      b. $C = C_0 (\kappa_1 + \kappa_2)/2$

✓   c. $C = C_0 (2\kappa_1\kappa_2)/(\kappa_1 + \kappa_2)$