The next three questions pertain to the situation described below.

Consider the collection of two charges separated in the x-axis by a distance 2d:

![Diagram of two charges separated by distance 2d](image)

1) Where should we place a negatively charged test particle so that it is not subject to a force?

   a. Point R  
   b. Point Q  
   c. Point P

2) Now place the negative test charge at point Q. Which statement below is correct?

   a. The test charge is stable to a slight perturbation in the x direction  
   b. The test charge is stable to a slight perturbation in the y direction  
   c. The test charge is stable to a slight perturbation in both x and y directions

3) Write an expression for the force on a negatively charged test particle of charge -q at location P. (\( \hat{x} \) and \( \hat{y} \) are unit vectors in the x and y directions.)

   a. \( \frac{-2kq^2}{(d^2+r^2)} \)  
   b. \( \frac{-2kq^2r}{(d^2+r^2)^{3/2}} \hat{y} \)  
   c. \( \frac{-2kq^2d}{(d^2+r^2)^{3/2}} \hat{y} \)  
   d. \( \frac{-2kq^2dr}{(d^2+r^2)^{3/2}} \hat{x} \)  
   e. \( \frac{2kq^2r}{(d^2+r^2)^{3/2}} \hat{x} \)
The next three questions pertain to the situation described below.

A uniformly charged semi-circular line with linear charge density $\lambda$ is placed in the x-y plane as shown in the Figure on the right. Its radius is $r$ and its total charge $Q = 15 \, \mu\text{C}$.

4) If $r = 5 \, \text{cm}$, what is $\lambda$?

a. $\lambda = 48 \, \mu\text{C/m}$  
b. $\lambda = 95 \, \mu\text{C/m}$  
c. $\lambda = 150 \, \mu\text{C/m}$

5) What is the correct expression for the x-component of the total electric field at the origin, $E_x$, due to this charge?

a. $E_x = -\int_{-\pi/2}^{\pi/2} \frac{k\lambda}{r^2} \cos \theta \, d\theta$

b. $E_x = -\int_{-\pi/2}^{\pi/2} \frac{k\lambda}{r} \cos \theta \sin \theta \, d\theta$

c. $E_x = 0$

d. $E_x = -\int_{-\pi/2}^{\pi/2} \frac{k\lambda}{r} \sin \theta \, d\theta$

e. $E_x = -\int_{-\pi/2}^{\pi/2} \frac{k\lambda}{r} \cos \theta \, d\theta$

6) What kind of point charge should be placed at point $P(-r, 0)$ in order to make the net electric field at the origin vanish?

a. There is no such charge  
b. Positive charge  
c. Negative Charge
The next four questions pertain to the situation described below.

A metal conducting sphere of radius a is centered on the origin. Concentric with it is a spherical shell made of insulating material of inner radius b and outer radius c. A total positive charge $Q_{\text{metal}}$ is placed on the inner metal sphere, while a total negative charge $Q_{\text{insul}}$ is uniformly distributed over the volume of the outer insulating sphere. The values of all parameters are given in the figure below. The figure is not drawn to scale.

![Figure: Spheres](image)

a = 5 cm  
b = 9 cm  
c = 17 cm  
$Q_{\text{metal}} = 6 \ \mu\text{C}$  
$Q_{\text{insul}} = -4 \ \mu\text{C}$

7) Calculate the surface charge density on the inner metal sphere at $a = 5$ cm

a. $\sigma = 190 \ \mu\text{C/m}^2$

b. $\sigma = 2 \times 10^4 \ \mu\text{C/m}^2$

c. $\sigma = 19 \ \mu\text{C/m}^2$

8) Calculate the magnitude of the electric field $E$ at a radius of 7 cm from the origin.

a. $|E| = 1.1 \times 10^7 \ \text{N/C}$

b. $|E| = 1.8 \times 10^7 \ \text{N/C}$

c. $|E| = 7.7 \times 10^5 \ \text{N/C}$

9) Calculate the magnitude of the electric field $E$ at a radius of 13 cm from the origin.

a. $|E| = 8.2 \times 10^6 \ \text{N/C}$

b. $|E| = 7.4 \times 10^7 \ \text{N/C}$

c. $|E| = 2.4 \times 10^6 \ \text{N/C}$

d. $|E| = 0 \ \text{N/C}$

e. $|E| = 5.3 \times 10^6 \ \text{N/C}$
10) An infinite line charge having $\lambda = 4 \mu\text{C/m}$ is now added parallel to the z-axis and centered at $(x,y) = (-30 \text{ cm}, 0)$, as shown. Find the magnitude of electric field at a point $P$ located at $(x,y) = (-21.5 \text{ cm}, 0)$. (The figure is not drawn to scale. Here we assume the line charge does not affect the surface charge distribution on the metal sphere.)

- $|E| = 7.2 \times 10^6 \text{ N/C}$
- $|E| = 8.5 \times 10^5 \text{ N/C}$
- $|E| = 1.9 \times 10^6 \text{ N/C}$
- $|E| = 1.9 \times 10^5 \text{ N/C}$
- $|E| = 4.6 \times 10^5 \text{ N/C}$
The next three questions pertain to the situation described below.

The electric field due to two point charges is given as a cross sectional view in the x-y plane. There are two points labeled A and B on the graph.

11) What is the position of the point charges?
   a. A positive charge at (1,0) and a negative charge at (0,0)
   b. A positive charge at (0,0) and a negative charge at (0,1)
   c. A positive charge at (0,1) and a negative charge at (0,0)

12) Which of these lines is an equipotential?
   a. y=0.5
   b. y=0
   c. x=0.5
   d. x=1
   e. x=0

13) What is the relationship between the potential at A and B?
   a. \( V_A > V_B \)
   b. \( V_A < V_B \)
   c. \( V_A = V_B \)
14) What is the potential difference between point Q , (q cm , 0 cm) and point P, (p cm , 0 cm)? Let q = 17 cm and p = 2 cm.

a. ΔV = 84 kV
b. ΔV = 120 kV
c. ΔV = 34 kV
d. ΔV = 280 kV
e. ΔV = 230 kV
15) For the next two problems, consider Figure 2.

Figure 2

A slab of metal with no net charge (shaded region; left edge at x = 9 cm, right edge at x = 11 cm) is now placed between the two charged, infinite plates.

What are the surface charge densities for the left side of the slab (given by $\sigma_L$) and the right side of the slab (given by $\sigma_R$)?

- a. $\sigma_L = -7 \, \mu C/m^2$, $\sigma_R = 7 \, \mu C/m^2$
- b. $\sigma_L = -2 \, \mu C/m^2$, $\sigma_R = 2 \, \mu C/m^2$
- c. $\sigma_L = 2 \, \mu C/m^2$, $\sigma_R = -2 \, \mu C/m^2$
- d. $\sigma_L = 0 \, \mu C/m^2$, $\sigma_R = 0 \, \mu C/m^2$
- e. $\sigma_L = 7 \, \mu C/m^2$, $\sigma_R = -7 \, \mu C/m^2$

16) With the addition of the metal slab, what is the potential difference between point Q and point P?

- a. $\Delta V = 100 \, kV$
- b. $\Delta V = 34 \, kV$
- c. $\Delta V = 0 \, kV$
- d. $\Delta V = 29 \, kV$
- e. $\Delta V = 120 \, kV$
The next two questions pertain to the situation described below.

Three capacitors and an ideal battery are connected as shown in the figure below. The voltage of the battery is \( U = 9 \) V. The capacitances of the capacitors are \( C_1 = 4 \mu F \), \( C_2 = 4 \mu F \), and \( C_3 = 6 \mu F \).

17) Capacitors \( C_2 \) and \( C_3 \) are connected _______

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

18) What is the total energy stored in all three capacitors?

a. 120 \mu J  
b. 570 \mu J  
c. 26 \mu J  
d. 230 \mu J  
e. 1100 \mu J
The next two questions pertain to the situation described below.

A parallel plate capacitor is constructed with a dielectric slab with $\kappa = 1.7$ inserted between the plates. The area of each plate is $6 \text{ cm}^2$, and the distance between the two plates is $2 \text{ mm}$. Assume the infinite plane approximation.

19) If we fix the charge on the capacitor to be $Q = 6 \times 10^{-11} \text{ C}$, what is the potential difference between the top and bottom plates? Note that in the region containing the dielectric medium, the electric field is $E = E_0 / \kappa$, where $E_0$ is the electric field in vacuum.

   a. $\Delta V = 18 \text{ V}$
   b. $\Delta V = 6.6 \text{ V}$
   c. $\Delta V = 11 \text{ V}$
   d. $\Delta V = 23 \text{ V}$
   e. $\Delta V = 4.2 \text{ V}$

20) If the dielectric slab is removed, the capacitance of the capacitor will

   a. remain the same
   b. decrease
   c. increase