1. (8 points) A 50.0 μC charge exists at the position $(2.00, 0.00)$ and a proton exists at the position $(0.00, 3.00)$ where the positions are given in units of meters. There is a uniform electric field in this region of space $\vec{E} = 23,000\hat{\imath}$. What is the magnitude of acceleration of the proton? For this problem, full credit was given to all answers because there was a typo in the magnitude of the electric field. It should have been 23,000 instead of 230,000. The points listed below are what it would have been had there not been a typo.

   (A) 2.78×10^{12} m/s^2

   (B) 4.90×10^{12} m/s^2

   (C) 3.32×10^{12} m/s^2

   (D) 2.20×10^{12} m/s^2

   (E) 9.67×10^{12} m/s^2

   (F) 5.21×10^{12} m/s^2

   (G) 6.44×10^{12} m/s^2

   (H) 7.55×10^{12} m/s^2

Points Per Response:

A: 8
B: 6
C: 3
D: 3
E:
F:
G:
H:

2. (6 points) In the diagram below there are two thick-walled conducting shells that are centered at the same point. The smaller shell has a net charge of $+2Q$ with inner radius R and outer radius $2R$. The larger shell has a net charge $-5Q$ with inner radius $3R$ and outer radius $4R$. The surfaces have been labeled A, B, C and D. Rank the surfaces from most positive surface charge density to most negative surface charge density.

   (A) B>A>D>C

   (B) B>A>C>D

   (C) A>B>C>D

   (D) D>C>B>A

   (E) C>D>A>B

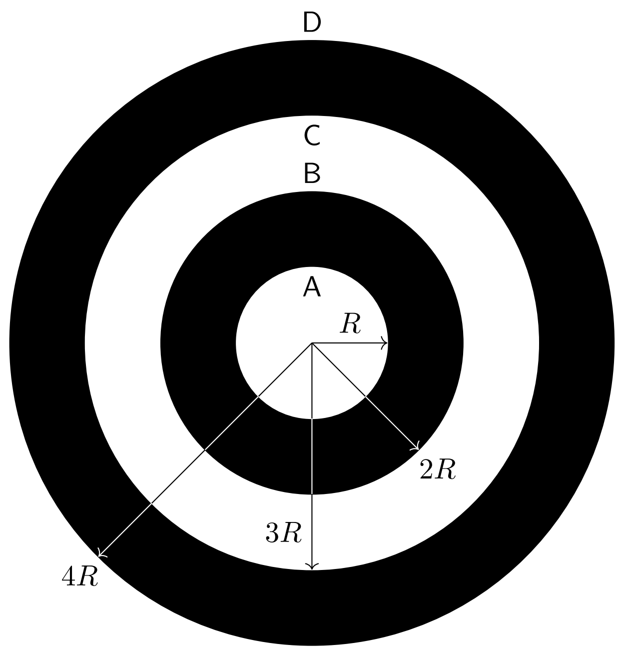
   (F) A>C>B>D

   (G) C>B>D>A

   (H) D>A>B>C

Points Per Response:

- **A: 6**
- B: 3
- C:
- D:
- E:
- F:
- G:
- H:



3. (8 points) A box contains a number of electrons and a number of protons such that the flux through the box is 1.70×10^{-3} Nm^2/C. If the flux changes so that it is now 1.20×10^{-3} Nm^2/C, how many particles changed inside the box? (For this problem, assume that only one type of particle is added or removed, not both.)

   (A) 2.77×10^{4} particles

   (B) 3.13×10^{15} particles

   (C) 6.64×10^{4} particles

   (D) 7.50×10^{15} particles

   (E) 1.87×10^{4} particles

   (F) 4.17×10^{15} particles

   (G) 8.19×10^{4} particles

   (H) 2.68×10^{15} particles

   Points Per Response:
   A: 8
   B: 6
   C: 4
   D: 2
   E:
   F:
   G:
   H:

4. (4 points) In the previous problem, which of the following describes what happened to make the flux change. Remember that only one type of particle was added or removed.

   (A) Protons had to be added

   (B) Protons had to be removed

   (C) Electrons had to be added

   (D) Electrons had to be removed

   (E) Protons could have been added or electrons could have been removed

   (F) Protons could have been added or electrons could have been added

   (G) Protons could have been removed or electrons could have been removed

   (H) Protons could have been removed or electrons could have been added

   Points Per Response:
   A:
   B: 2
   C: 2
   D:
   E:
   F:
   G:
   H: 4

5. (8 points) Three particles all have a mass of 15.0 mg and are initially held at rest at the corners of an equilateral triangle that has sides of 4.00 mm. The particles have charges of $+3.00$, $+6.00$ and $+9.00$ μC. If all three particles are simultaneously released, what is the total kinetic energy of the system when the particles are infinitely far away?

   (A) 223 J

   (B) 365 J

   (C) 40.5 J

   (D) 60.8 J

   (E) 122 J

   (F) 147 J

   (G) 12.0 J

   (H) 28.4 J

   Points Per Response:
   A: 8
   B: 3
   C: 2
   D: 2
   E: 2
   F:
   G:
   H:

6. (4 points) In the previous problem, which charge will have the greatest speed when they are all infinitely far away from each other?

   (A) The 3.00 μC charge

   (B) The 6.00 μC charge

   (C) The 9.00 μC charge

   (D) Since they all have the same mass they will have the same speed.

   (E) It is impossible to tell with the given information.

   Points Per Response:
   A:
   B:
   C: 4
   D: 1
   E: 1

7. (6 points) There are three *infinite* sheets of charge each separated by 2.00 cm. Plate 1 has a charge density of $\sigma_1 = +2\sigma_0$, Plate 2 has a charge density of $\sigma_2 = -3\sigma_0$ and Plate 3 has an unknown charge density, σ_3. At the point A in the figure below you measure the electric field to be exactly 0. What is the charge density of Plate 3?

   (A) $-1\sigma_0$

   (B) $+1\sigma_0$

   (C) $-5\sigma_0$

   (D) $+5\sigma_0$

   (E) $-2\sigma_0$

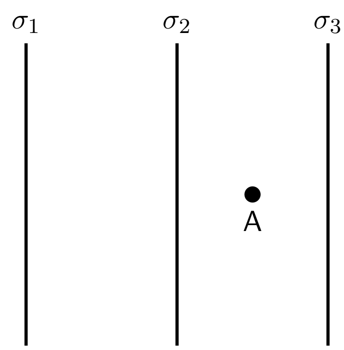
   (F) $+2\sigma_0$

   (G) $-3\sigma_0$

   (H) $+3\sigma_0$

Points Per Response:

A: 6
B: 4
C: 1
D: 1
E:
F:
G:
H:



8. (8 points) A positive point charge of magnitude $q = 6.00$ C is placed in the center of a large, spherical cavity inside a solid insulating material with uniform density $\rho = -3.00$ C/m^3. The cavity has radius $R = 0.600$ m. At what distance from the point charge is the electric field exactly zero?

   (A) 0.885 m

   (B) 0.693 m

   (C) 0.477 m

   (D) 0.782 m

   (E) 0.528 m

   (F) 0.901 m

   (G) 0.730 m

   (H) 0.973 m

   Points Per Response:
   A: 8
   B: 6
   C: 3
   D: 5
   E:
   F:
   G:
   H:

9. (4 points) Below are three combinations of charges. The lines represent uniform rods with total charge Q and the points represent point charges with the same charge Q. Which combination will have the greatest force acting on the two objects?

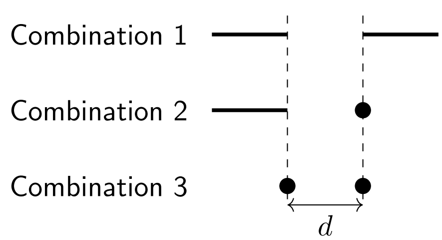
   (A) Combination 1

   (B) Combination 2

   (C) Combination 3

   (D) All three will be the same

   (E) It is impossible to determine



   Points Per Response:
   A:
   B:
   C: 4
   D:
   E:

10. (6 points) Three charges, each with $+q$, are all initially in a line as shown below on the left. What is the work done by an external force to change the configuration to the triangular configuration on the right?

(A) $+\frac{kq^2}{2\ell}$

(B) $+\frac{3kq^2}{\ell}$

(C) $+\frac{3kq^2}{2\ell}$

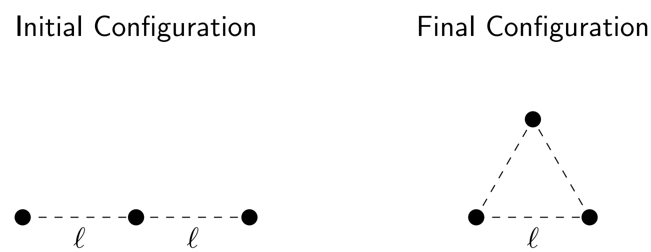
(D) $+\frac{5kq^2}{2\ell}$

(E) $-\frac{kq^2}{2\ell}$

(F) $-\frac{3kq^2}{\ell}$

(G) $-\frac{3kq^2}{2\ell}$

(H) $-\frac{5kq^2}{2\ell}$



Points Per Response:

A: 6
B: 2
C:
D: 2
E: 4
F:
G:
H:

11. (8 points) A uniform arc of total charge $+Q$ is distributed along a quarter circle of radius R in quadrant 1 as shown below. What is the integral that you would use to evaluate the electric potential at the position (R, R)?

(A) $\dfrac{2kQ}{\pi R}\displaystyle\int_0^{\pi/2} \frac{d\theta}{\sqrt{(1-\cos\theta)^2+(1-\sin\theta)^2}}$

(B) $\dfrac{2kQ}{\pi R}\displaystyle\int_0^{2\pi} \frac{d\theta}{\sqrt{(1-\cos\theta)^2+(1-\sin\theta)^2}}$

(C) $\dfrac{kQ}{2\pi R}\displaystyle\int_0^{\pi/2} \frac{d\theta}{\sqrt{(1-\cos\theta)^2+(1-\sin\theta)^2}}$

(D) $\dfrac{kQ}{2\pi R}\displaystyle\int_0^{2\pi} \frac{d\theta}{\sqrt{(1-\cos\theta)^2+(1-\sin\theta)^2}}$

(E) $\dfrac{2kQ}{\pi R}\displaystyle\int_0^{\pi/2} \frac{d\theta}{\sqrt{(\cos\theta)^2+(\sin\theta)^2}}$

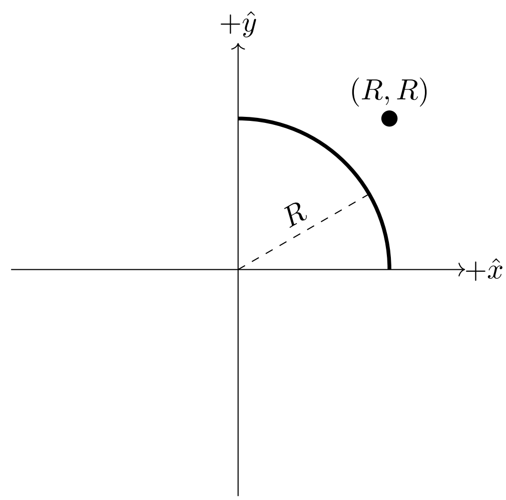
(F) $\dfrac{2kQ}{\pi R}\displaystyle\int_0^{2\pi} \frac{d\theta}{\sqrt{(\cos\theta)^2+(\sin\theta)^2}}$

(G) $\dfrac{kQ}{2\pi R}\displaystyle\int_0^{\pi/2} \frac{d\theta}{\sqrt{(\cos\theta)^2+(\sin\theta)^2}}$

(H) $\dfrac{kQ}{2\pi R}\displaystyle\int_0^{2\pi} \frac{d\theta}{\sqrt{(\cos\theta)^2+(\sin\theta)^2}}$

Points Per Response:

A: 8
B: 5
C: 5
D: 2
E: 5
F: 2
G: 2
H:



12. (8 points) There is an electric field in a region of space given by $\vec{E}(z) = 8.70z^2\hat{k}$. The potential is defined to be 3750 V at $z = -12.0$. How far away is the closest position where the potential is 7100 V?

(A) 2.23

(B) 14.2

(C) 8.31

(D) 3.69

(E) 21.0

(F) 4.10

(G) 13.1

(H) 11.8

Points Per Response:

A: 8
B: 6
C: 5
D: 3
E:
F:
G:
H:

13. (8 points) In a region of space, the potential energy function for an 8.00 C charge is $U(x, y) = x^2y + 3xy^2$. What is the magnitude of the force acting on this charge at the position $(3.00, 4.00)$?

(A) 108 N

(B) 153 N

(C) 13.5 N

(D) 180 N

(E) 248 N

(F) 36.1 N

(G) 22.7 N

(H) 61.3 N

Points Per Response:

A: 8
B: 4
C: 6
D:
E:
F:
G:
H:

14. (6 points) Two solid, insulating, uniform spheres exist with their centers at $x = -2$ and $x = +2$ and both have radii of $R = 2$. The sphere with center at $x = -2$ has a total charge -3 C and the sphere at $x = +2$ has total charge $+2$ C. There are two positions on the x-axis where the potential is equal to zero. Which of the following represents the two locations on the x-axis where the electric potential is equal to zero?

(A) $4 < x$ and $2 < x < 4$

(B) $4 < x$ and $0 < x < 2$

(C) $4 < x$ and $-2 < x < 0$

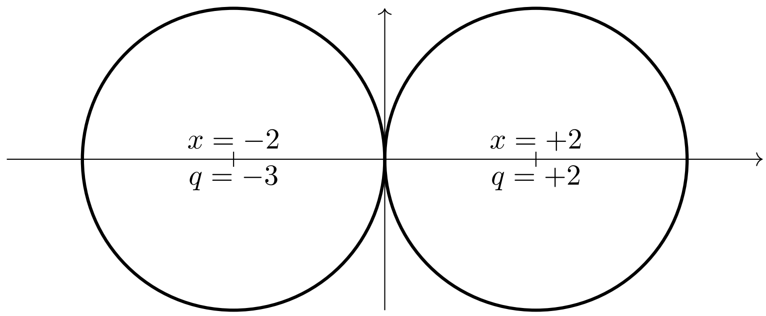
(D) $4 < x$ and $-4 < x < -2$

(E) $2 < x < 4$ and $0 < x < 2$

(F) $2 < x < 4$ and $-2 < x < 0$

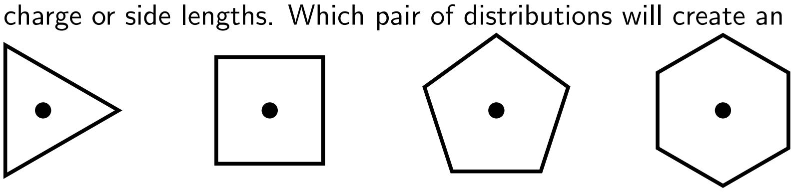
(G) $2 < x < 4$ and $-4 < x < -2$

(H) $0 < x < 2$ and $-2 < x < 0$



Points Per Response:
A: 2
B: 6
C:
D:
E: 4
F:
G:
H: 2

15. (4 points) There are four uniform, linear distributions of charge. They do not necessarily have the same total charge or side lengths. Which pair of distributions will create an electric field that is **NOT** zero at the center?



(A) Triangle and Square

(B) Triangle and Pentagon

(C) Triangle and Hexagon

(D) Square and Pentagon

(E) Square and Hexagon

(F) Pentagon and Hexagon

(G) It is impossible to tell without knowing their charges or side lengths.

Points Per Response:
A: 1
B: 4
C: 1
D: 1
E:
F: 1
G:

16. (4 points) In the diagram below, there are 3 point charges. Charge q_1 is on the left, q_2 is in the middle and q_3 is on the right. Rank the charges from most positive to most negative.

   (A) $q_1 > q_2 > q_3$

   (B) $q_1 > q_3 > q_2$

   (C) $q_2 > q_1 > q_3$

   (D) $q_2 > q_3 > q_1$

   (E) $q_3 > q_2 > q_1$

   (F) $q_3 > q_1 > q_2$

   Points Per Response:
   A: 1
   B: 4
   C:
   D:
   E:
   F: