1. (6 points) In the Chapter 21 Part 2 recitation, we found that for an insulating ring of charge with radius a and charge density $\lambda(\theta) = \lambda_0 \sin\theta$ where θ is measured counterclockwise from the positive x-axis, the electric field at the center was $\vec{E} = -\frac{k\lambda_0\pi}{a}\hat{\jmath}$. What is the sign of the potential at the center of this ring due to that charge distribution?

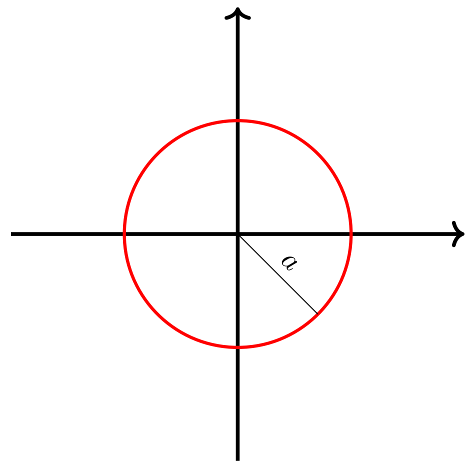
   The concepts necessary to solve this problem correctly: Calculating electric potential from a charge distribution (not from a formula for electric field).

   (A) Positive

   (B) Negative

   (C) Zero

   Points Per Response:
   A: 1
   B: 1
   C: 6



2. (10 points) A *non-uniform* linear charge characterized by the charge per unit length $\lambda(y)$ is located on the y-axis extending from $y = -a$ to $y = +a$. Which of the following integrals give the electric field $\vec{E}$ on the x-axis at $x = +a$? Note that $\lambda(y)$ is not a constant value.

The concepts necessary to solve this problem correctly: Calculating electric field from a charge distribution.

(A) $\vec{E} = \int_{-a}^{+a} \frac{ka\lambda(y)dy}{(y^2+a^2)^{3/2}}\,\hat{\imath} - \int_{-a}^{+a} \frac{ky\lambda(y)dy}{(y^2+a^2)^{3/2}}\,\hat{\jmath}$

(B) $\vec{E} = \int_{-a}^{+a} \frac{ka\lambda(y)dy}{(y^2+a^2)^{3/2}}\,\hat{\imath}$

(C) $\vec{E} = \lambda(y)\int_{-a}^{+a} \frac{kdy}{(y^2+a^2)}\,\hat{\imath}$

(D) $\vec{E} = \int_{-a}^{+a} \frac{k\lambda(y)dy}{(y^2+a^2)^2}\,\hat{\imath} + \int_{-a}^{+a} \frac{ky^2\lambda(y)dy}{(y^2+a^2)^{3/2}}\,\hat{\jmath}$

(E) $\vec{E} = \int_{-a}^{+a} \frac{k\lambda(y)dy}{a^2}\,\hat{\imath}$

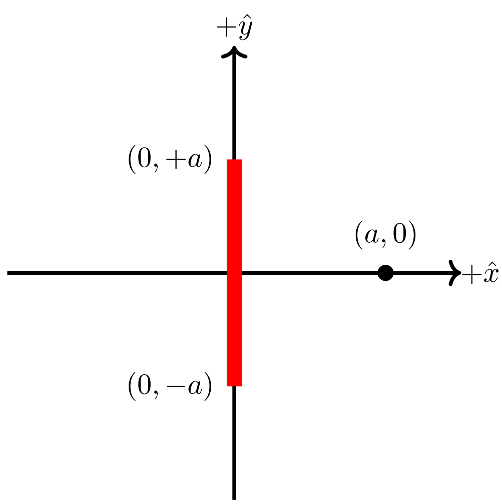
(F) $\vec{E} = 0$

(G) $\vec{E} = \lambda(y)\int_{-a}^{+a} \frac{kady}{(y^2+a^2)^{3/2}}\,\hat{\imath} - \lambda(y)\int_{-a}^{+a} \frac{kydy}{(y^2+a^2)^{3/2}}\,\hat{\jmath}$

(H) $\vec{E} = \lambda(y)\int_{-a}^{+a} \frac{kdy}{(y^2+a^2)^2}\,\hat{\imath} + \lambda(y)\int_{-a}^{+a} \frac{ky^2dy}{(y^2+a^2)^{3/2}}\,\hat{\jmath}$

Points Per Response:

A: 10
B: 7
C:
D: 4
E:
F:
G: 3
H:



3. (8 points) A point charge $Q = -500$ nC and two unknown point charges, q_1 and q_2, are placed as shown in the figure where all positions are given in units of meters. The electric field at the origin O, due to charges Q, q_1 and q_2, is equal to zero. The charge q_1 is closest to

The concepts necessary to solve this problem correctly: Vector addition, Coulomb's Law

(A) 244 nC

(B) -244 nC

(C) 141 nC

(D) -141 nC

(E) 281 nC

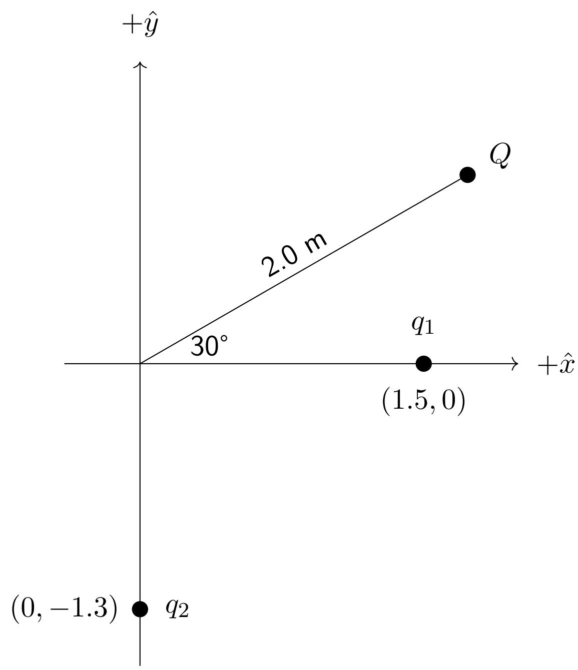
(F) -281 nC

(G) 315 nC

(H) -315 nC

Points Per Response:

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



4. (8 points) In a particular region of space, a 300 mC charge experiences the effects of a potential energy function given by $U(x, y, z) = 4x^2y + 3xyz - 5y^2z^3$. What is the electric field vector at the point (3,2,-1)? Assume all values are in SI units.

   The concepts necessary to solve this problem correctly: Relationship between potential energy and potential, taking the gradient of potential to find electric field.

   (A) $-140\hat{\imath} - 157\hat{\jmath} + 140\hat{k}$

   (B) $-42\hat{\imath} - 47\hat{\jmath} + 42\hat{k}$

   (C) $-240\hat{\imath} + 60\hat{\jmath} - 66.7\hat{k}$

   (D) $-72\hat{\imath} + 18\hat{\jmath} + 20\hat{k}$

   (E) $-360\hat{\imath} - 30\hat{\jmath} + 240\hat{k}$

   (F) $-108\hat{\imath} - 9\hat{\jmath} + 72\hat{k}$

   (G) $-100\hat{\imath} + 170\hat{\jmath} + 260\hat{k}$

   (H) $-30\hat{\imath} + 51\hat{\jmath} + 78\hat{k}$

   Points Per Response:
   A: 8
   B: 6
   C: 3
   D: 2
   E:
   F:
   G:
   H:

5. (6 points) Three protons exist at the corners of an equilateral triangle of side length 2 cm. If two protons are held in place and the third is released from rest, what maximum speed will the third proton reach?

   The concepts necessary to solve this problem correctly: Electrical Potential Energy and Mechanical Energy Conservation.

   (A) 5.26 m/s

   (B) 3.72 m/s

   (C) 27.6 m/s

   (D) 36.7 m/s

   (E) 7.30 m/s

   (F) 14.2 m/s

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

6. (4 points) The figure below shows a series of equipotential surfaces. At which point does the electric field have the greatest magnitude?

The concepts necessary to solve this problem correctly: Attaining qualitative information from electric field and equipotential diagrams.

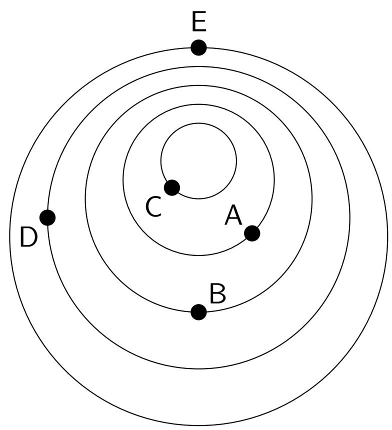
(A) Point A

(B) Point B

(C) Point C

(D) Point D

(E) Point E



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

7. (8 points) A uniform electric field of magnitude 450 N/C is directed in the negative y-direction. Point A is located at (0.25m, -0.5 m) and point B is located at (0.75m, 0.4m). What is the potential difference $V_B - V_A$?

The concepts necessary to solve this problem correctly: Integrating electric field to find potential difference.

(A) 405 V

(B) 315 V

(C) 513 V

(D) -405 V

(E) -315 V

(F) -513 V

(G) 221 V

(H) -221 V

Points Per Response:
A: 8
B: 4
C: 6
D: 7
E: 3
F: 5
G:
H:

8. (10 points) There is an electric field $\vec{E} = 3.00\hat{\imath} - 2.00y\hat{\jmath}$ N/C in the region that includes a cube of side length $L = 10.0$ m and is oriented as shown in the figure below. What is the net charge inside the cube?

The concepts necessary to solve this problem correctly: Calculating electric flux through a surface, Gauss's Law

(A) +8.85 nC

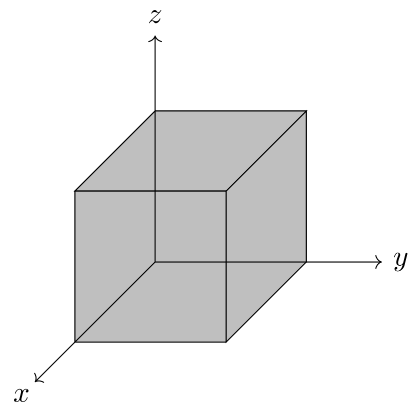
(B) -8.85 nC

(C) +17.7 nC

(D) -17.7 nC

(E) +3.42 nC

(F) -3.42 nC



Points Per Response:
A: 3
B: 5
C: 8
D: 10
E:
F:

9. (4 points) A point charge with magnitude Q is situated in the centrum of two imaginary hemispheres of radii a and b as shown below. Compare the fluxes Φ_a and Φ_b due to this point charge if you know the charge is negative.

The concepts necessary to solve this problem correctly: Definition of electric flux, Coulombs Law.

Both options C and D were given full credit, due to the fact that it was not clear whether these were open surfaces or one complete closed surface.

(A) $\Phi_a > \Phi_b$, Φ_a is positive and Φ_b is negative

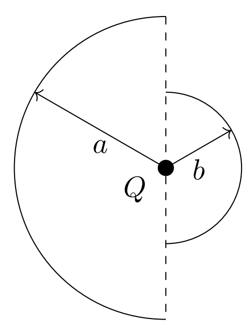
(B) $\Phi_a < \Phi_b$, Φ_a is negative and Φ_b is positive

(C) $\Phi_a = \Phi_b$, both fluxes are positive

(D) $\Phi_a = \Phi_b$, both fluxes are negative

(E) $\Phi_a > \Phi_b$, both fluxes are positive

(F) $\Phi_a < \Phi_b$, both fluxes are negative



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

10. (10 points) A very long insulating cylinder with a radius $R = 4.00$ cm is uniformly charged with a volume charge density $\rho = 5.00$ nC/m^3. Find the magnitude of an electric field at the distance $r = R/2$ from the axis of the cylinder.

The concepts necessary to solve this problem correctly: Gauss's Law as it applies to insulators.

(A) 565 N/C

(B) 5.65 N/C

(C) 341 N/C

(D) 3.41 N/C

(E) 11.3 N/C

(F) 1130 N/C

(G) 30.2 N/C

(H) 3.77 N/C

Points Per Response:
A: 8
B: 10
C:
D:
E: 7
F: 5
G:
H: 4

11. (6 points) An object is comprised of 2,500,000 total particles. The particles can be either protons or electrons. The total charge of this object is -1.44×10^{-13} C. How many of these particles are protons?

The concepts necessary to solve this problem correctly: Quantization of charge ($q = Ne$).

(A) 0

(B) 600,000

(C) 800,000

(D) 900,000

(E) 1,300,000

(F) 1,700,000

(G) 1,900,000

(H) 2,500,000

Points Per Response:

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

12. (4 points) There are two arcs of charge that each create 3/4 of a circle and are centered on the origin as shown below. Both arcs have the same uniform charge density λ where λ is a positive value. What direction will the net electric field point at the origin? (All angles are given as counterclockwise from the positive x-axis.)

The concepts necessary to solve this problem correctly: Calculating electric field from a charge distribution, recognition of effects due to spatial symmetry.

(A) 45°

(B) 135°

(C) 225°

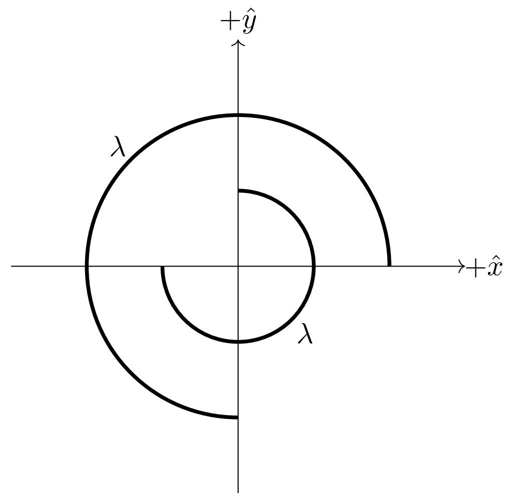
(D) 315°

(E) $+\hat{x}$

(F) $-\hat{x}$

(G) $+\hat{y}$

(H) $-\hat{y}$



Points Per Response:

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

13. (6 points) In the diagram below there is a thick-walled, conducting cubic shell that has total charge of -5 mC. At the center of that is a thick-walled, conducting spherical shell that has a total charge of +4 mC. At the center of that is a point charge. If there is +7 mC on the OUTSIDE surface of the cube, what is the charge of the point charge?

The concepts necessary to solve this problem correctly: Gauss's Law applied to conductors.

(A) +16 mC

(B) -16 mC

(C) +8 mC

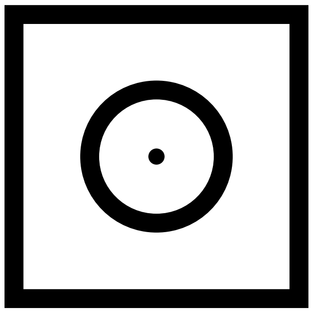
(D) -8 mC

(E) +1 mC

(F) -1 mC

(G) +5 mC

(H) -5 mC



Points Per Response:

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

14. (6 points) In the diagram below there are two very large, thin insulating sheets that are separated by a distance d. You know that the bottom sheet has a surface charge density of $+5\sigma$. You also know that the electric field at a distance d above the top plate has a magnitude of $E = \frac{2\sigma}{\epsilon_0}$ and is pointing down towards the plates. What is the surface charge density on the top plate?

The concepts necessary to solve this problem correctly: Gauss's Law, Vector Addition

(A) -1σ

(B) -3σ

(C) -7σ

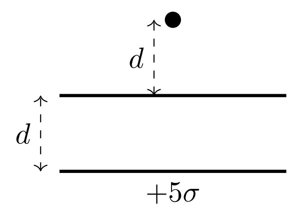
(D) -9σ

(E) $+1\sigma$

(F) $+3\sigma$

(G) $+7\sigma$

(H) $+9\sigma$



Points Per Response:

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

15. (4 points) A metal sphere with a radius R initially has a charge of $-Q$. A second metal sphere with a radius $2R$ initially has a charge of $+9Q$. When the switch below is closed, the two spheres will be connected by a conducting wire. What will happen when this switch is closed?

The concepts necessary to solve this problem correctly: Defining properties of conductors, equipotential surfaces.

(A) The charge will redistribute until there is the same charge on both spheres.

(B) The charge will redistribute until there is the same magnitude of electric field just outside the surface of the spheres.

(C) The charge will redistribute until there is the same potential at the surface of both spheres.

(D) The charges will not redistribute at all and will stay where they are.

Points Per Response:

A:
B:
C: 4
D: