1. (6 points) There are two nested solenoids with radius 3.50 cm and 1.50 cm. The solenoid with the larger radius has 400 turns and both solenoids have the same length of 2.50 cm. If the mutual inductance of this system is 8.50 mH, what is the number of turns in the smaller solenoid?

   (A) 598

   (B) 110

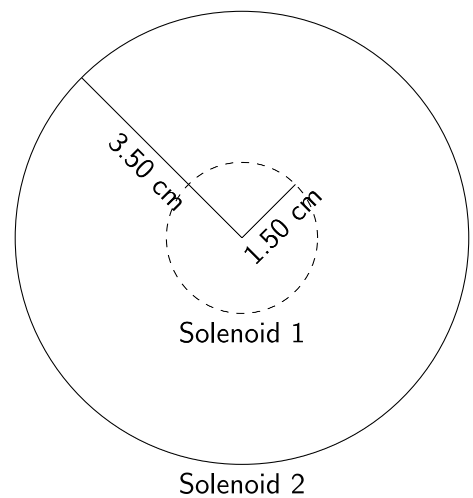
   (C) 446

   (D) 381

   (E) 256

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

Top view of the nested solenoid system



2. (6 points) In the circuit below, what is the current through the 4 Ω resistor?

   (A) 2.57 A

   (B) 2.04 A

   (C) 3.52 A

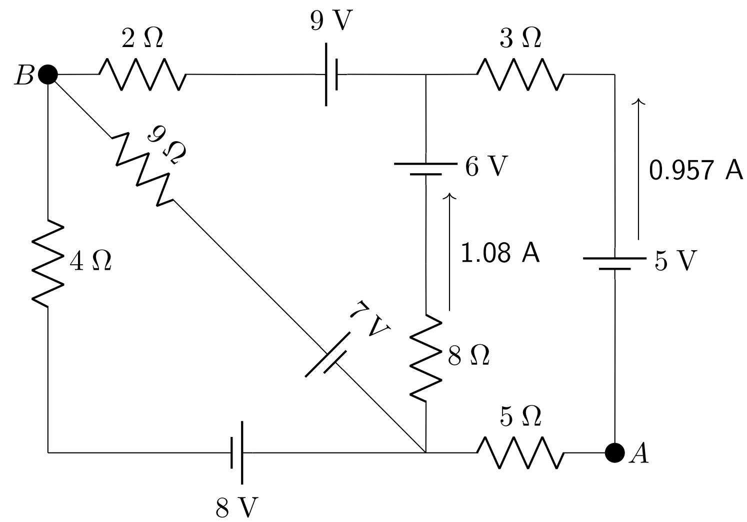
   (D) 1.24 A

   (E) 1.63 A

   (F) 4.77 A

Points Per Response:

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



3. (3 points) In the circuit below, the switch has been open for a long time. What is the current in the circuit just after the switch is closed?

   (A) $\dfrac{\mathcal{E}}{R}$

   (B) $\dfrac{\mathcal{E}}{2R}$

   (C) $\dfrac{\mathcal{E}}{3R}$

   (D) $\dfrac{3\mathcal{E}}{2R}$

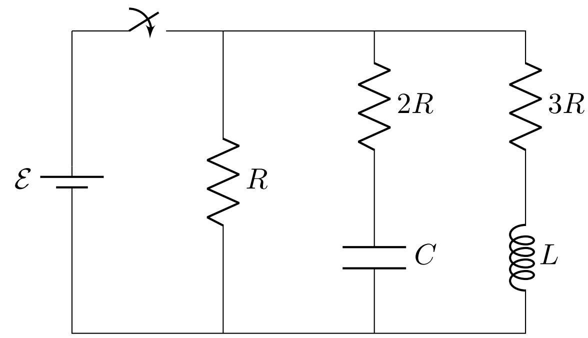
   (E) $\dfrac{4\mathcal{E}}{3R}$

   (F) $\dfrac{11\mathcal{E}}{6R}$

   (G) $\dfrac{5\mathcal{E}}{6R}$

Points Per Response:

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



4. (3 points) In the previous circuit, what is the current after the switch has been closed for a very long time?

(A) $\dfrac{\mathcal{E}}{R}$

(B) $\dfrac{\mathcal{E}}{2R}$

(C) $\dfrac{\mathcal{E}}{3R}$

(D) $\dfrac{3\mathcal{E}}{2R}$

(E) $\dfrac{4\mathcal{E}}{3R}$

(F) $\dfrac{11\mathcal{E}}{6R}$

(G) $\dfrac{5\mathcal{E}}{6R}$

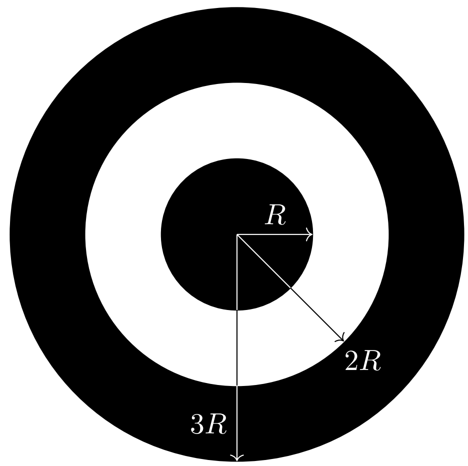
Points Per Response:

A:
B:
C:
D:
E: 3
F:
G:

5. (4 points) In the figure below there is a solid conducting sphere with radius R and total charge $+2Q$ which has its center at the same point as the center of a thick-walled conducting spherical shell that has an inner radius of $2R$ and an outer radius of $3R$ and total charge $-5Q$. Let $E_{1.5}$ be the radial component of the electric field at $1.5R$. Similarly $E_{2.5}$ and $E_{3.5}$ will be the radial component of the electric field at $2.5R$ and $3.5R$ respectively. Rank the radial component of the electric field from most positive to most negative at those three points. Remember that a positive radial component points outward and a negative component points inward.

   (A) $E_{1.5} > E_{2.5} > E_{3.5}$
   (B) $E_{1.5} > E_{3.5} > E_{2.5}$
   (C) $E_{2.5} > E_{1.5} > E_{3.5}$
   (D) $E_{2.5} > E_{3.5} > E_{1.5}$
   (E) $E_{3.5} > E_{1.5} > E_{2.5}$
   (F) $E_{3.5} > E_{2.5} > E_{1.5}$

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



6. (6 points) Calculate the electric flux through a disc of radius R centered on the origin in the xy-plane due to an electric field $\vec{E}(r) = 3r^2\hat{k}$.

   (A) $\frac{3}{2}\pi R^4$
   (B) $3\pi R^4$
   (C) $18\pi R^2$
   (D) $9\pi R^4$
   (E) $\frac{9}{2}\pi R^4$
   (F) $\frac{9}{4}\pi R^2$

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

7. (6 points) A -40.0 nC point charge is fixed at the origin while a +25.0 nC point charge is fixed at $(x, y) = (3.00, 0.00)$ where that position is given in meters. What is the magnitude of the electric field at $(x, y) = (3.00, 4.00)$?

   (A) 9.01 N/C

   (B) 27.0 N/C

   (C) 12.7 N/C

   (D) 25.5 N/C

   (E) 17.9 N/C

   (F) 15.2 N/C

   (G) 31.1 N/C

   (H) 35.0 N/C

   Points Per Response:

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

8. (4 points) In the figure below there are two negative point charges and a uniform semi-circle of positive charge. What is the direction of the net electric field at the origin? Assume the negative charges are equidistant from the y-axis.

   (A) $+\hat{y}$

   (B) $+\hat{x}$

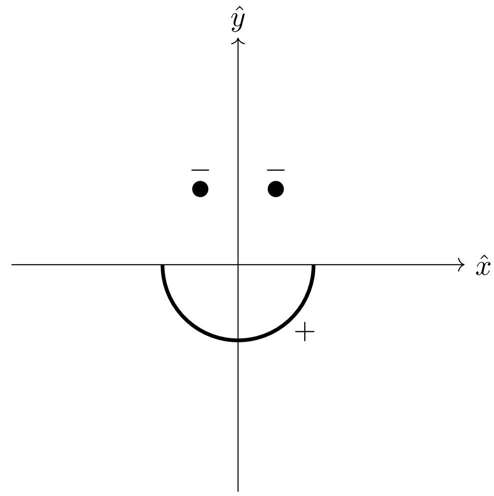
   (C) $+\hat{z}$

   (D) $-\hat{x}$

   (E) $-\hat{y}$

   (F) $-\hat{z}$

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



9. (6 points) There is a uniform electric field of 30,000 N/C pointing in the $+\hat{\imath}$-direction. There is a small charged object with a charge of 2.00 μC and a mass of 5.00 μg that has a speed of 4,000 m/s at the origin. If the trajectory of the object brings it to the point (3.00,4.00) what is the speed of the object at this point?

(A) 9,380 m/s

(B) 10,600 m/s

(C) 11,700 m/s

(D) 4,010 m/s

(E) 6,560 m/s

(F) 13,500 m/s

(G) 7,040 m/s

(H) 12,100 m/s

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

10. (6 points) A 3.00 C charge is moving through a region of space that has a potential $V(x, y) = -8(x^2 + xy^3)$. What is the force vector at position $(x, y) = (2, -3)$?

(A) $-552\hat{x} + 1296\hat{y}$

(B) $+552\hat{x} - 1296\hat{y}$

(C) $-184\hat{x} + 432\hat{y}$

(D) $+184\hat{x} - 432\hat{y}$

(E) $+660\hat{x} - 543\hat{y}$

(F) $-660\hat{x} + 543\hat{y}$

(G) $-349\hat{x} + 868\hat{y}$

(H) $+349\hat{x} - 868\hat{y}$

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

11. (6 points) You know that a parallel plate capacitor has a plate area of 9.00 mm^2, a separation of 0.250 mm, a charge of 470 pF and is filled with air. The capacitor is isolated and is not connected to any sources of emf. If the plate separation was doubled and a dielectric of $\kappa = 12.3$ were inserted into the full volume of the capacitor, how much does the voltage across the capacitor change?

    (A) $\Delta V = -1240$ V

    (B) $\Delta V = -1420$ V

    (C) $\Delta V = +34800$ V

    (D) $\Delta V = +7600$ V

    (E) $\Delta V = -2270$ V

    (F) $\Delta V = +19400$ V

    (G) $\Delta V = +11700$ V

    (H) $\Delta V = -5280$ V

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

12. (4 points) A resistor has an initial length ℓ and cross sectional area A. This resistor is connected to a battery. The resistor is stretched while maintaining a fixed volume. What happens to the power delivered by the battery?

    (A) The power decreases

    (B) The power increases

    (C) The power stays constant

    Points Per Response:
    A: 4
    B:
    C:

13. (6 points) A cylindrical antenna is 1.40 m long and emits radio waves with a power of 150 W. Assume the antenna only emits the waves outward like a cylinder and no waves are generated above or below the antenna. What is the power absorbed by a receiving antenna that is 1.00 mm in diameter, 0.500 m long and is 125 m away? Assume both antennae are parallel to each other.

    (A) 6.82×10^{-5} W

    (B) 3.82×10^{-7} W

    (C) 1.07×10^{-4} W

    (D) 9.56×10^{-8} W

    (E) 7.37×10^{-6} W

    (F) 3.02×10^{-3} W

    Points Per Response:
    A: 6
    B: 3
    C: 4
    D:
    E:
    F:

14. (6 points) The electric field for an EM-wave is given by $\vec{E}(z,t) = 3.00\cos(kz + \omega t)\hat{\imath}$ where $k = 2.93 \times 10^{-3}$ m^{-1} and $\omega = 880,000$ rad/s. The frequency of this wave is 140 kHz. What is the Poynting Vector of this wave at $z = 0.500$ m and $t = 140$ ms?

    (A) $\vec{S} = -0.0141\hat{k}$

    (B) $\vec{S} = +0.0141\hat{k}$

    (C) $\vec{S} = -0.0422\hat{k}$

    (D) $\vec{S} = +0.0422\hat{k}$

    (E) $\vec{S} = -0.0321\hat{k}$

    (F) $\vec{S} = +0.0321\hat{k}$

    (G) $\vec{S} = -0.0183\hat{k}$

    (H) $\vec{S} = +0.0183\hat{k}$

    Points Per Response:
    A: 6
    B: 5
    C: 3
    D: 2
    E:
    F:
    G:
    H:

15. (4 points) The figure below shows the current in a long, straight wire moving into the page. There is a positive point charge moving radially away from the wire with some velocity. What is the direction of the force acting on the point charge?

(A) $-\hat{z}$

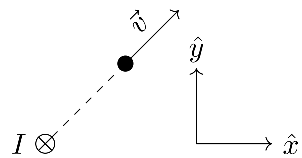
(B) $+\hat{x}$

(C) $+\hat{y}$

(D) $+\hat{z}$

(E) $-\hat{x}$

(F) $-\hat{y}$



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

16. (6 points) A rectangular loop exists in the xy-plane as shown below. A magnetic field changes from $+B_0\hat{z}$ to $-\frac{B_0}{6}\hat{z}$ in a time T. What is the magnitude of the average induced emf in the loop during this change?

(A) $\frac{7B_0\ell h}{6T}$

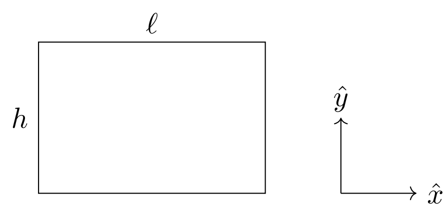
(B) $\frac{5B_0\ell h}{6T}$

(C) $\frac{4B_0\ell h}{3T}$

(D) $\frac{2B_0\ell h}{3T}$

(E) $\frac{3B_0\ell h}{2T}$

(F) $\frac{1B_0\ell h}{2T}$



Points Per Response:
A: 6
B: 3
C:
D:
E:
F:

17. (2 points) What is the direction of the average induced current in the previous circuit?

(A) Counterclockwise

(B) Clockwise

Points Per Response:
A: 2
B:

18. (6 points) A proton is traveling with a speed of 1000 m/s in a circular path of radius 5.00 cm due to a magnetic field. What is the ratio of the magnetic field **created** by the proton at the center of the path (B_p) to the magnetic field **containing** the proton to that path (B_{ext})?

    (A) $\dfrac{B_p}{B_{ext}} = 3.07 \times 10^{-17}$

    (B) $\dfrac{B_p}{B_{ext}} = 1.53 \times 10^{-18}$

    (C) $\dfrac{B_p}{B_{ext}} = 7.92 \times 10^{-17}$

    (D) $\dfrac{B_p}{B_{ext}} = 5.13 \times 10^{-18}$

    (E) $\dfrac{B_p}{B_{ext}} = 8.51 \times 10^{-18}$

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

19. (4 points) Four long, straight, current-carrying wires are all carrying the same current I. Three of the wires are carrying the current into the page and one is carrying it out of the page. What is the direction of the magnetic field at the center of the square?

    (A) Towards wire 1

    (B) Towards wire 2

    (C) Towards wire 3

    (D) Towards wire 4

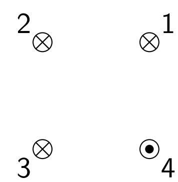
    (E) Up

    (F) Down

    (G) Left

    (H) Right

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



20. (6 points) A 25.0 mC charge is traveling with a speed 75.0 m/s when it is 40.0 cm away from a long, straight current-carrying wire. The wire is carrying 3.00 A of current and the angle between the charge's velocity and the direction parallel to the wire is 30.0°as shown in the figure. What is the magnitude of force acting on the charge?

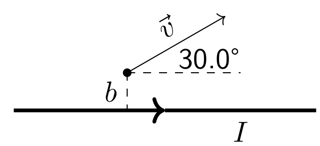
(A) 2.81 μN

(B) 1.41 μN

(C) 3.49 μN

(D) 5.80 μN

(E) 7.82 μN



Points Per Response:

A: 6
B: 3
C:
D:
E: