1. (4 points) The figure shows three metal coils labeled A, B, and C heading towards a region where a uniform static magnetic field exists and is pointing out of the page. The coils move with the same constant velocity and all have the same resistance. Their relative sizes are indicated by the background grid. As they enter the magnetic field the coils will have an induced electric current in them. For which coil will the current be the greatest?

   The concepts necessary to solve this problem correctly: Faraday's Law and Lenz's Law

   (A) Coil A

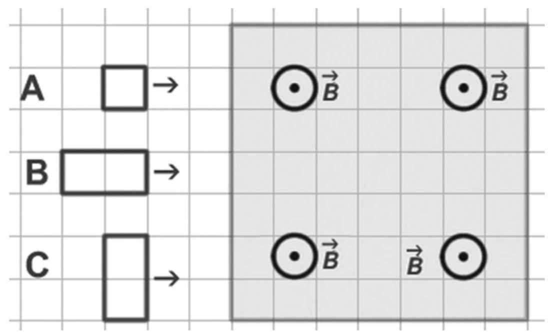
   (B) Coil B

   (C) Coil C

   (D) The induced current is the same in all three since they move at the same constant velocity.

   (E) There is no induced current in any of them since they move at the same constant velocity.

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



2. (4 points) The long straight wire in the figure carries a current I that is decreasing with time at a constant rate. The circular loops A, B, and C all lie in a plane containing the wire. The induced emf in each of the loops A, B, and C is such that

The concepts necessary to solve this problem correctly: Lenz's Law and Magnetic Field created by a current in a long straight wire

(A) There is no emf induced in any loop

(B) A counterclockwise emf is induced in all loops.

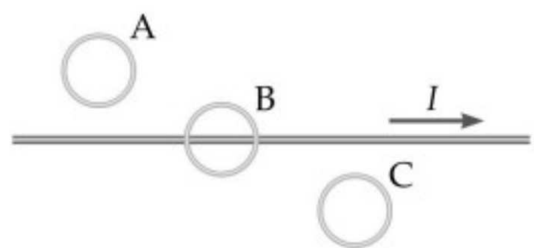
(C) A clockwise emf is induced in all loops.

(D) Loop A has a clockwise emf, Loop B has no emf and Loop C has a counterclockwise emf

(E) Loop A has a counterclockwise emf, Loop B has no emf and Loop C has a clockwise emf

Points Per Response:

A:
B:
C:
D: 1
E: 4



3. (8 points) As shown in the figure, a wire and a 10-Ω resistor are used to form a circuit in the shape of a square, 20 cm by 20 cm. A uniform but nonsteady magnetic field is directed into the plane of the circuit. The magnitude of the magnetic field is decreased from 1.50 T to 0.50 T in a time interval of 63 ms. The average induced current and its direction through the resistor, in this time interval, are closest to

The concepts necessary to solve this problem correctly: Faraday's Law and Lenz's Law

(A) 38 mA from a to b

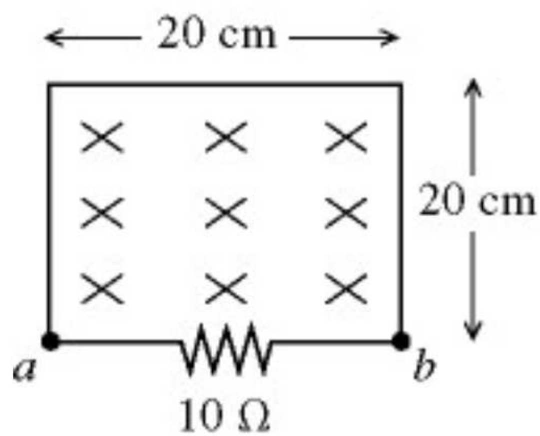
(B) 38 mA from b to a

(C) 63 mA from a to b

(D) 63 mA from b to a

(E) 95 mA from a to b

(F) 95 mA from b to a



Points Per Response:

A:
B: 2
C: 6
D: 8
E:
F: 2

4. (6 points) An Airbus A380 has a wingspan of 79.8 m. At a particular point during a flight, while traveling at 250. m/s parallel to the Earth's surface, the potential difference between the wingtips is measured at 0.600 V. What angle does the Earth's magnetic field make with the vertical if the total magnetic field strength in that region of space is 4.00×10^{-5} T?

The concepts necessary to solve this problem correctly: Motional emf

(A) 41.2 degrees

(B) 48.8 degrees

(C) 36.9 degrees

(D) 53.1 degrees

(E) 80.9 degrees

(F) 26.8 degrees

(G) 67.9 degrees

(H) 21.2 degrees

Points Per Response:

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

5. (8 points) A horizontal wire is free to slide on the vertical rails of a conducting frame, as shown in the figure below. The wire has length $l = 2$ m, and the resistance of the circuit is $R = 5\,\Omega$. If a uniform magnetic field $B_{out} = 10$ T is directed perpendicular to the frame and the terminal speed of the wire as it falls under the force of gravity is measured to be $v = 3$ m/s, what is the mass m of the wire? (take $g = 10$ m/s^2)

The concepts necessary to solve this problem correctly: Motional Emf, Faraday's law, Newton's 1st Law

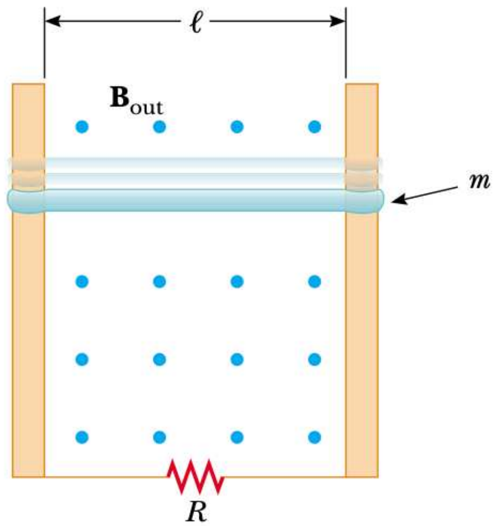
(A) 24 kg

(B) 12 kg

(C) 6 kg

(D) 3 kg

(E) 1 kg



Points Per Response:
A: 8
B: 4
C: 2
D:
E:

6. (6 points) A proton has a velocity in the positive z-direction. The magnetic force on the proton is in the positive y-direction. What can you conclude about the components of the magnetic field at the location of the proton?

The concepts necessary to solve this problem correctly: Magnetic force on a moving charge, cross products

(A) $B_x > 0$, $B_y = 0$, Nothing can be concluded about B_z

(B) $B_x = 0$, $B_y > 0$, $B_z < 0$

(C) Nothing can be concluded about B_x, $B_y = 0$, $B_z < 0$

(D) $B_x > 0$, $B_y = 0$, $B_z = 0$

(E) $B_x > 0$, Nothing can be concluded about B_y, $B_z = 0$

(F) $B_x < 0$, $B_y = 0$, Nothing can be concluded about B_z

(G) B_x, B_y, B_z

Points Per Response:

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

7. (6 points) You need to build a cyclotron to accelerate protons from a kinetic energy of 1.0 MeV up to 29 MeV. The maximum magnetic field in the cyclotron is 2.0 T. What does the minimum radius of this cyclotron need to be? (Do not consider relativistic effects at all for this problem.)

   The concepts necessary to solve this problem correctly: Kinetic Energy and radius of a moving charge in a magnetic field

   (A) 3.4 m

   (B) 2.1 m

   (C) 1.3 m

   (D) 0.39 m

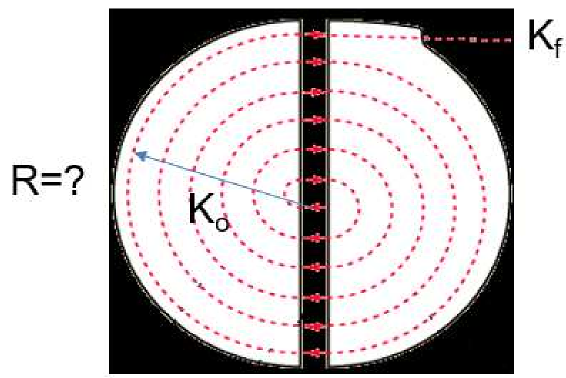
   (E) 0.56 m

   (F) 0.24 m

   (G) 0.072 m

Points Per Response:

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



“Dees”

8. (4 points) An electron enters a velocity selector where $\vec{E}$ and $\vec{B}$ are perpendicular to each other and the velocity as shown below. Find the direction of the magnetic force on the electron and the direction the electron will deflect in this device if $v < E/B$.

The concepts necessary to solve this problem correctly: Electric and Magnetic Forces, cross products

(A) The magnetic force is up and the deflection is up

(B) The magnetic force is up and the deflection is down

(C) The magnetic force is down and the deflection is up

(D) The magnetic force is down and the deflection is down

(E) The magnetic force is out of the page and the deflection is out of the page

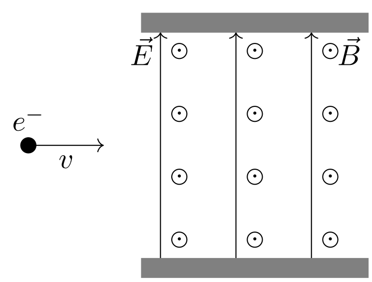
(F) The magnetic force is out of the page and the deflection is into the page

(G) The magnetic force is into the page and the deflection is out of the page

(H) The magnetic force is into the page and the deflection is into the page

Points Per Response:

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



9. (6 points) A square loop with side lengths of 3.0 cm is in the xy-plane and carries a current of 200 mA counter-clockwise from the point of view of the figure. There is a uniform magnetic field vector $\vec{B} = 4\sin(30)\hat{\jmath} + 4\cos(30)\hat{k}$ which is in SI units. What is the magnitude of the torque acting on the loop?

The concepts necessary to solve this problem correctly: Magnetic moment and torque

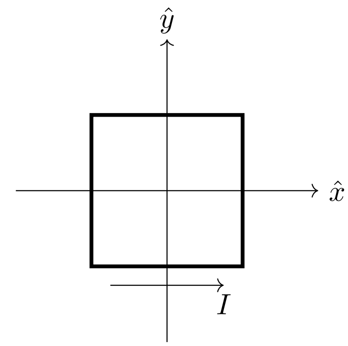
(A) 3.6×10^{-4} Nm

(B) 6.2×10^{-4} Nm

(C) 7.3×10^{-4} Nm

(D) 4.9×10^{-4} Nm

(E) 5.1×10^{-4} Nm



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

10. (2 points) What is the direction of the torque vector in the previous problem?

The concepts necessary to solve this problem correctly: Magnetic moment and cross products

(A) $+\hat{\imath}$

(B) $-\hat{\imath}$

(C) $+\hat{\jmath}$

(D) $-\hat{\jmath}$

(E) $+\hat{k}$

(F) $-\hat{k}$

Points Per Response:
A: 1
B: 2
C:
D:
E:
F:

11. (8 points) You know that the current in Coil 1 follows a function $i(t) = 0.800 - 0.0500t^2$. Coil 1 has 400 turns while Coil 2 has 600 turns. At $t = 3.00$ s an emf of $\mathcal{E} = +75$ mV is induced in Coil 2. What is the average magnetic flux through a single turn of Coil 2 at this instant?

The concepts necessary to solve this problem correctly: Mutual Inductance, Derivatives

(A) 2.19×10^{-4} Wb

(B) 1.46×10^{-4} Wb

(C) 1.88×10^{-4} Wb

(D) 1.25×10^{-4} Wb

(E) 9.12×10^{-5} Wb

(F) 9.56×10^{-5} Wb

(G) 8.80×10^{-5} Wb

(H) 8.53×10^{-5} Wb

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

12. (4 points) An empty region of space contains a uniform electric field with a magnitude of 24,000 N/C and a uniform magnetic field with a magnitude of 2.4 mT. Which field produces a greater energy density in this region?

The concepts necessary to solve this problem correctly: Definition of Electric and Magnetic energy densities

(A) The electric field produces a greater energy density.

(B) The magnetic field produces a greater energy density.

(C) Both fields produce the same energy density.

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

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

13. (8 points) A student creates an inductor in the shape of a solenoid that has a circular cross section with radius $r = 5.00$ mm. The student uses 45.0 m of thin wire and the solenoid itself is 3.00 cm long. The student filled the core of the solenoid with an object that has a relative permeability of 4.00. What is the self inductance of this solenoid.

The concepts necessary to solve this problem correctly: Definition of self inductance

(A) 6.75 mH

(B) 27.0 mH

(C) 12.5 mH

(D) 19.8 mH

(E) 10.6 mH

(F) 17.1 mH

(G) 8.33 mH

(H) 23.3 mH

Points Per Response:

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

14. (10 points) A wire with a circular cross section is made in such a way that the current density has a function of $\vec{j} = j_0 \left(1 - \frac{r}{R}\right)$ where this is in SI units. What is the magnitude of the magnetic field at $r = R/2$?

The concepts necessary to solve this problem correctly: Ampere's Law, Current Density, Integration

(A) $\mu_0 j_0 R$

(B) $\frac{\mu_0 j_0 R}{2}$

(C) $\frac{\mu_0 j_0 R}{3}$

(D) $\frac{\mu_0 j_0 R}{4}$

(E) $\frac{\mu_0 j_0 R}{5}$

(F) $\frac{\mu_0 j_0 R}{6}$

Points Per Response:

A:
B: 5
C: 7
D: 4
E:
F: 10

15. (2 points) Two single loops of wire are parallel to the xy-plane and centered on the z-axis. They both carry current in the same direction. Will the force between these wires be attractive or repulsive?

The concepts necessary to solve this problem correctly: Direction of magnetic field created by a current, direction of magnetic force on a current-carrying wire

(A) Attractive

(B) Repulsive

(C) It will depend on the radii of the loops.

Points Per Response:

A: 2
B:
C:

16. (6 points) A single loop of wire with radius R is carrying a constant current I. At what point along the axis of the loop is the magnitude of the magnetic field half of the magnitude at the center of the loop? Assume this distance is measured from the center of the loop.

The concepts necessary to solve this problem correctly: Magnetic field created by a loop of wire

(A) $0.766R$

(B) $1.30R$

(C) $1.59R$

(D) $0.630R$

(E) $0.500R$

(F) $2.00R$

(G) None of the above since the magnetic field at the center of a coil of wire is 0.

Points Per Response:

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

17. (8 points) Which of the following correctly evaluates the magnetic field at the point (ℓ, ℓ) for a line segment carrying current from $x = \ell$ to $x = 0$?

The concepts necessary to solve this problem correctly: Biot-Savart Law

(A) $\frac{\mu_0 I}{4\pi} \int_0^\ell \frac{\ell dx \hat{k}}{((\ell - x)^2 + \ell^2)^{3/2}}$

(B) $\frac{\mu_0 I}{4\pi} \int_\ell^0 \frac{\ell dx \hat{k}}{((\ell - x)^2 + \ell^2)^{3/2}}$

(C) $\frac{\mu_0 I}{4\pi} \int_0^\ell \frac{(\ell - x) dx \hat{k}}{((\ell - x)^2 + \ell^2)^{3/2}}$

(D) $\frac{\mu_0 I}{4\pi} \int_\ell^0 \frac{(\ell - x) dx \hat{k}}{((\ell - x)^2 + \ell^2)^{3/2}}$

(E) $\frac{\mu_0 I}{4\pi} \int_0^\ell \frac{\ell dx \hat{k}}{((\ell - x)^2 + \ell^2)}$

(F) $\frac{\mu_0 I}{4\pi} \int_\ell^0 \frac{\ell dx \hat{k}}{((\ell - x)^2 + \ell^2)}$

(G) $\frac{\mu_0 I}{4\pi} \int_0^\ell \frac{(\ell - x) dx \hat{k}}{((\ell - x)^2 + \ell^2)}$

(H) $\frac{\mu_0 I}{4\pi} \int_\ell^0 \frac{(\ell - x) dx \hat{k}}{((\ell - x)^2 + \ell^2)}$

Points Per Response:

A: 7
B: 8
C: 4
D: 6
E: 3
F: 4
G:
H: 2