# Solutions to Test #3 Problems

① Which of the following is an accurate statement?

A) North and South magnetic poles are the magnetic charges that are sources of magnetic field lines.
B) A magnetic field line is, by definition, tangent to the direction of the magnetic force on a moving charge at a given point in space.
C) The magnetic force on a moving charge does not change its energy.
D) The magnetic force on a current carrying wire is greatest when the wire is parallel to the magnetic field.
E) A current carrying loop of wire tends to line up with its plane parallel to an external magnetic field in which it is positioned.

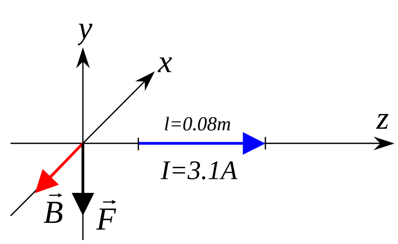
A) Unlike in case of electric field the magnetic field lines are not produced by the magnetic charges. No magnetic charges (monopoles) exist that could be sources of magnetic field lines. All magnetic field lines are continuous and closed (e.g. see Figure 27.11 in the book).
B) For a charge moving in magnetic field, magnetic force is *perpendicular* to the magnetic field line at a given point in space.
C) That is correct statement! Since magnetic force is always perpendicular to the velocity of the moving charge, the force does not change the magnitude of the velocity and the kinetic energy of the moving particle.
D) Magnetic force is a vector product of $I\vec{l} \times \vec{B}$ and is maximal when the wire with current is *perpendicular* to the direction of magnetic field.
E) A current carrying loop of wire tends to line up with its plane being *perpendicular* to an external magnetic field with the magnetic moment vector being align with the field.

② A wire along the *z*-axis carries a current 3.1 A in the positive *z* direction. Find the force (magnitude and direction) exerted on 8.0-cm length segment of the wire by a uniform magnetic field with magnitude 0.3 T in the –*x* direction.

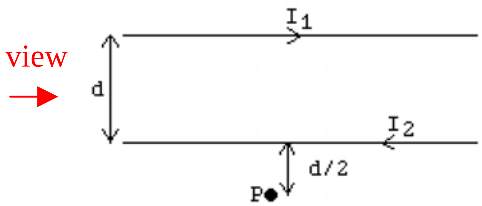
$$\vec{F} = I\vec{l} \times \vec{B}$$

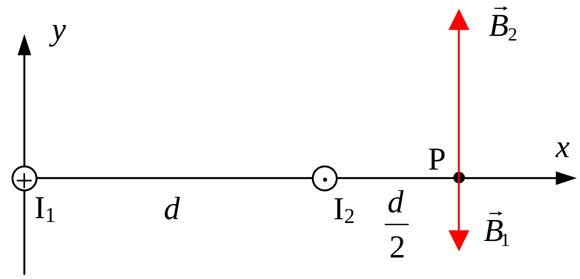
$\vec{F}$ is along $-\hat{y}$

$$F = 3.1A \cdot 0.08m \cdot 0.3T = 74.4mN$$



③ In the figure below, the two long straight wires are separated by a distance of d = 0.60 m. The currents are $I_1$ = 5.0 A to the right in the upper wire and $I_2$ = 6.0 A to the left in the lower wire. What is the magnitude and direction of the magnetic field at point P, that is at the distance d/2 = 0.3 m below the lower wire?




Let's view this wire layout from the left:

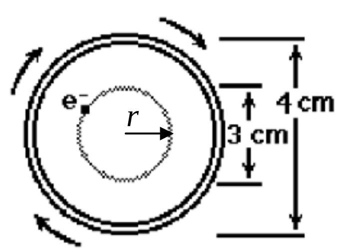
$$\vec{B}_1 = \frac{\mu_0}{2\pi r_1} I_1 \cdot (-\hat{y}) = \frac{\mu_0}{2\pi(3d/2)} I_1 \cdot (-\hat{y})$$

$$\vec{B}_2 = \frac{\mu_0}{2\pi r_2} I_2 \cdot (+\hat{y}) = \frac{\mu_0}{2\pi(d/2)} I_2 \cdot (+\hat{y})$$

$$\vec{B}_P = \vec{B}_1 + \vec{B}_2 = \frac{\mu_0}{2\pi}\left(\frac{I_2}{d/2} - \frac{I_1}{3d/2}\right)\cdot \hat{y} = \frac{4\pi\cdot 10^{-7}\, T\cdot m/A}{2\cdot\pi}\left(\frac{6A}{0.3m} - \frac{5A}{0.9m}\right) = 2.89\times 10^{-6} T$$

Magnetic field at point P is directed along $+y$ axis, i.e. out of the plane of the paper in the original figure.

④ The figure → shows a solenoid with clockwise sense of the current in the windings. An electron is in circular motion near the center of the solenoid with an orbital diameter of 3.0 cm. Find the speed and the sense of the orbital motion of the electron if solenoid has number of turns per unit length $n = 3$ turns/cm and carries the current I = 2.01A.




For electron moving in magnetic field the Lorentz force creates centripetal acceleration:

$$F_B = (-e)\cdot \vec{v}\times\vec{B} = m\vec{a}_{centripetal} = m\frac{v^2}{r}(-\hat{r})$$

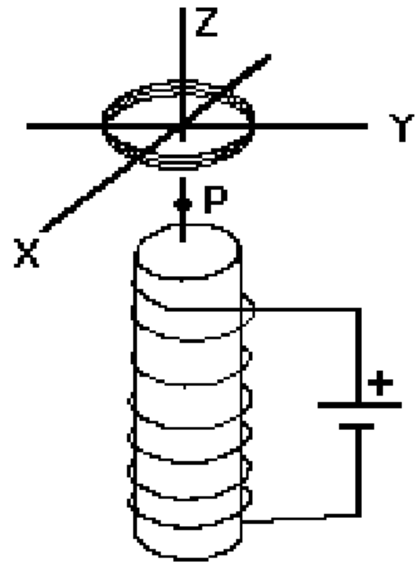
$$|e|vB = m\frac{v^2}{r}; \qquad \text{Magnetic field of the solenoid: } B = \mu_0 n I$$

$$v = \frac{|e|}{m}B\cdot r = \frac{|e|}{m}\cdot r\cdot \mu_0 n I = \frac{1.6\times 10^{-19} C}{9.1\times 10^{-31} kg}\cdot 0.015m\cdot 4\pi\times 10^{-7}\frac{T\cdot m}{A}\cdot 300\frac{1}{m}\cdot 2.01A = 2\times 10^{6}\, m/s$$

Direction of electron motion is clockwise.

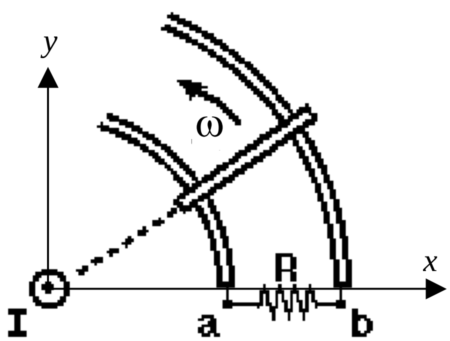
⑤ The figure → shows the coil of wire placed above the axis of a solenoid carrying a DC current. Explain which of the following will NOT result in an *emf* being induced in the coil?

A) Rotate the coil about the *x*-axis.
B) Rotate the coil about the *y*-axis.
C) Rotate the coil about the *z*-axis.
D) Move the coil towards point P.
E) Change the current in the solenoid.




The *emf* in the coil will appear only when magnetic flux through the coil is changing with time. When the coil is rotating about the *z*-axis, magnetic flux doesn't change, therefore only the answer C) will NOT result in an induced *emf* on the coil. In all other cases induced *emf* will appear in the coil.

⑥ In figure → a straight wire carries a steady current I=10 A in the direction out of the plane of the figure. A conducting bar is in contact with a pair of conducting circular rails (radial distance between rails = 14 cm), and rotates about the straight wire with angular velocity ω = 30 rad/s. Find the induced current and its direction through the resistor R = 20Ω.




Let's introduce the *x*-*y* coordinate system in the plane of the figure. Vector of magnetic field created by the wire with current I will be in the x-y plane and directed along the +*y* axis. Although area of the loop formed by the moving bar, rails, and resistor is changing with time, the magnetic flux through this area is zero because the scalar product of $\vec{B}\cdot\vec{A}$ is zero ($\cos\theta=0$). Therefore the induced current through the resistor equal <u>zero</u>.