Science 122

Handout – Circular Trajectories and Applications

From

Physics – Principles and Processes

Merrill – Red Text

2. Electrons moving at 3.6×10^4 m/s pass through an electric field of intensity 5.8×10^3 N/C. How large a magnetic field must the electrons also experience for their path to be undeflected?

3. The electrons in a beam are moving at 2.8×10^8 m/s in an electric field of 1.4×10^4 N/C. What value must the magnetic field have if the electrons pass through the crossed fields undeflected?

4. A proton moves across a 0.36-T magnetic field in a circular path of radius 0.2 m. What is the speed of the proton?

5. Electrons move across a 4.0-mT magnetic field. They follow a circular path, radius 2.0 cm.
   a. What is their speed?
   b. An electric field is applied perpendicularly to the magnetic field. The electrons then follow a straight-line path. Find the magnitude of the electric field.

6. What energy must be given to an electron to transfer it across a potential difference of 4.0×10^5 V?

7. A proton enters a 6.0×10^{-2}-T magnetic field with a speed of 5.4×10^4 m/s. What is the radius of the circular path it follows?

8. A proton enters a magnetic field of 6.4×10^{-2}T with a speed of 4.5×10^4 m/s. What is the circumference of the circular path that it follows?

9. An alpha particle has a mass of approximately 6.6×10^{-27} kg and bears a double elementary positive charge. Such a particle is observed to move through a 2.0-T magnetic field along a path of radius 0.15 m.
   a. What speed does it have?
   b. What is its kinetic energy?
   c. What potential difference would be required to give it this kinetic energy?

10. A 3.0×10^{-2}-T magnetic field in a mass spectrometer causes an isotope of sodium to move in a circular path with a radius of 0.081 m. If the ions have a single positive charge and are moving with a speed of 1.0×10^4 m/s, what is the isotope's mass?

11. An alpha particle, a doubly-ionized helium atom, has a mass of 6.7×10^{-27} kg and is accelerated by a voltage of 1.0 kV. If a uniform magnetic field of 6.5×10^{-2} T is maintained on the alpha particle, what will be the particle's radius of curvature?

12. An electron is accelerated by a 4.5-kV potential difference. How strong a magnetic field must be experienced by the electron if its path is a circle of radius 5.0 cm?

13. A mass spectrometer yields the following data for a beam of doubly-ionized sodium atoms: $B = 8.0 \times 10^{-2}$ T; $q = 2(1.60 \times 10^{-19}$ C); $r = 0.077$ m; and $V = 156$ V. Calculate the mass of a sodium atom.

Answers To

PROBLEMS

1. 2.0×10^8 m/s
2. 0.16 T
3. 50 μT
4. 7×10^6 m/s
5. a. 1.4×10^7 m/s
   b. 5.6×10^4 N/C
6. 6.4×10^{-14} J
7. 9.6×10^{-3} m 9.4×10^{-3} m (using $m = 1.67 \times 10^{-27}$ kg)
8. 4.7×10^{-2} m 4.6×10^{-2} m
9. a. 1.5×10^7 m/s
   b. 7.4×10^{-13} J
   c. 2.3 MV
10. 3.9×10^{-26} kg
11. 0.10 m
12. 4.5×10^{-3} T
13. 3.9×10^{-26} kg

Science 122 – Circular Trajectories + Applications
(Physics – Principles and Processes)

2. electron

$q = 1.60 \times 10^{-19} C$

$v = 3.6 \times 10^{4} m/s$

$E = 5.8 \times 10^{3} N/C$

$B = ?$

$v = \frac{E}{B}$

$B = \frac{E}{v}$

$B = \frac{5.8 \times 10^{3}}{3.6 \times 10^{4}}$

$B = 0.16\ T$

3. electron

$v = 2.8 \times 10^{8} m/s$

$q = 1.60 \times 10^{-19} C$

$m = 9.1 \times 10^{-31} kg$

$E = 1.4 \times 10^{4} N/C$

$v = \frac{E}{B}$

$B = \frac{E}{v}$

$B = \frac{1.4 \times 10^{4}}{2.8 \times 10^{8}}$

$B = 5.0 \times 10^{-5} T$ or $50 \times 10^{-6} T$

$B = 50\ \mu T$

4. proton

$q = 1.60 \times 10^{-19} C$

$B = 0.36\ T$

$r = 0.2\ m$

$v = ?$

$m = 1.67 \times 10^{-27} kg$

$r = \frac{mv}{qB}$

$v = \frac{rqB}{m}$

$v = \frac{(0.2)(1.60 \times 10^{-19})(0.36)}{1.67 \times 10^{-27}}$

$v = 7 \times 10^{6} m/s$

5. electrons:

$q = 1.60 \times 10^{-19} C$

$B = 4.0 mT = 4.0 \times 10^{-3} T$

$r = 2.0 cm = 0.020 m$

$m = 9.1 \times 10^{-31} kg$

a) $v = ?$ $\quad r = \frac{mv}{qB}$

$v = \frac{rqB}{m}$

$v = \frac{(0.020)(1.60 \times 10^{-19})(4.0 \times 10^{-3})}{9.1 \times 10^{-31}}$

$v = 1.4 \times 10^{7} m/s$

b) $E = ?$ $\quad v = \frac{E}{B}$

$E = vB$

$E = (1.4 \times 10^{7})(4.0 \times 10^{-3})$

$E = 5.6 \times 10^{4} N/C$

6. electron

$E = ?$

$V = 4.0 \times 10^{5} V$

$V = \frac{W}{q} = \frac{E}{q}$

$E = Vq$

$E = (4.0 \times 10^{5})(1.60 \times 10^{-19})$

$E = 6.4 \times 10^{-14} J$

7. proton

$q = 1.60 \times 10^{-19} C$

$v = 5.4 \times 10^{4} m/s$

$r = ?$

$B = 6.0 \times 10^{-2} T$

$r = \frac{mv}{qB}$

$r = \frac{(1.67 \times 10^{-27})(5.4 \times 10^{4})}{(1.60 \times 10^{-19})(6.0 \times 10^{-2})}$

$r = 9.4 \times 10^{-3} m$

8. proton

$q = 1.60 \times 10^{-19} C$

$B = 6.4 \times 10^{-2} T$

$v = 4.5 \times 10^4 m/s$

$C = ?$

$C = 2\pi r$

$r = \frac{C}{2\pi}$

$r = \frac{mv}{qB}$

$\frac{C}{2\pi} = \frac{mv}{qB}$

$C = \frac{2\pi mv}{qB}$

$C = \frac{2\pi (1.67 \times 10^{-27})(4.5 \times 10^4)}{(1.60 \times 10^{-19})(6.4 \times 10^{-2})}$

$C = 4.6 \times 10^{-2} m$

9. alpha particle

$m = 6.6 \times 10^{-27} kg$

$q = 2 \times 1.60 \times 10^{-19} C$

$B = 2.0 T$

$r = 0.15 m$

a) $r = \frac{mv}{qB}$

$v = \frac{rqB}{m}$

$v = \frac{(0.15)(3.20 \times 10^{-19})(2.0)}{6.6 \times 10^{-27}}$

$v = 1.5 \times 10^7 m/s$

b) $E_K = \frac{1}{2} mv^2$

$E_K = 7.4 \times 10^{-13} J$

* $W = E_K$

c) $V = \frac{W}{q} = 2.3 \times 10^6 V$

10. $B = 3.0 \times 10^{-2} T$

$r = 0.081 m$

$q = 1.60 \times 10^{-19} C$

$v = 1.0 \times 10^4 m/s$

$m = ?$

$r = \frac{mv}{qB}$

$m = \frac{rqB}{v}$ ✓

$m = \frac{(0.081)(1.60 \times 10^{-19})(3.0 \times 10^{-2})}{1.0 \times 10^4}$

$m = 3.9 \times 10^{-26} kg$

11. $q = 3.2 \times 10^{-19} C$

$m = 6.7 \times 10^{-27} kg$

$V = 1.0 kV = 1.0 \times 10^{3} V$

$B = 6.5 \times 10^{-2} T$

$r = ?$

$$\frac{q}{m} = \frac{2V}{B^2 r^2}$$

$$r = \sqrt{\frac{2Vm}{qB^2}}$$

$$r = \sqrt{\frac{2(1.0 \times 10^{3})(6.7 \times 10^{-27})}{(3.2 \times 10^{-19})(6.5 \times 10^{-2})^2}}$$

$$r = 0.10 m$$

12. electron

$q = 1.60 \times 10^{-19} C$

$m = 9.1 \times 10^{-31} kg$

$V = 4.5 kV = 4.5 \times 10^{3} V$

$B = ?$

$r = 5.0 cm = 0.050 m$

$$\frac{q}{m} = \frac{2V}{B^2 r^2}$$

$$B = \sqrt{\frac{2Vm}{qr^2}}$$

$$B = \sqrt{\frac{2(4.5 \times 10^{3})(9.1 \times 10^{-31})}{(1.6 \times 10^{-19})(0.050)^2}}$$

$$B = 4.5 \times 10^{-3} T$$

13. $q = 3.20 \times 10^{-19} C$

$B = 8.0 \times 10^{-2} T$

~~$q = 3.20$~~

$r = 0.077 m$

$V = 156 V$

$m = ?$

$$\frac{q}{m} = \frac{2V}{B^2 r^2}$$

$$m = \frac{qB^2 r^2}{2V}$$

$$m = \frac{(3.20 \times 10^{-19})(8.0 \times 10^{-2})^2 (0.077)^2}{2(156)}$$

$$m = 3.9 \times 10^{-26} kg$$