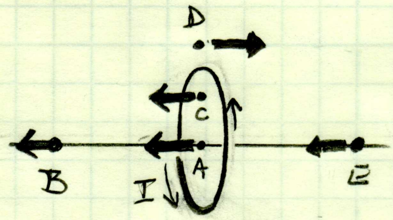
CQ 4, 18 PR 9, 11, 15, 17, 28, 31, 39, 41, 43, 89

CQ 4:

- A CIRCULAR METAL LOOP CARRIES I AS SHOWN. THE POINTS ARE ALL IN THE PLANE OF THE PAGE AND THE LOOP IS $\perp$. DRAW VECTORS AT A, B, C, D, & E TO SHOW $\vec{B}$.



CQ 18. Explain why a constant magnetic field does no work on a point charge moving through the field. Since the field does no work, what can we say about the speed of a point charge acted on only by a magnetic field?

SINCE THE FORCE IS $\perp$ TO $\vec{v}$:

$$\vec{F}_B = q\vec{v} \times \vec{B}$$

THE WORK DONE BY THE FORCE IS ALWAYS ZERO SO IT CAN NOT CHANGE THE KINETIC ENERGY OF THE PARTICLE SO IT CAN NOT CHANGE THE SPEED $\Rightarrow$ THE SPEED REMAINS CONSTANT.

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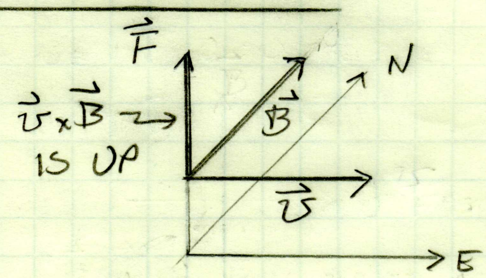
9. Find the magnetic force exerted on a proton moving east at a speed of 6.0×10^6 m/s by a horizontal magnetic field of 2.50 T directed north.



$$|\vec{F}| = |q\vec{v} \times \vec{B}| = qvB\cancel{\sin(90^\circ)} = qvB$$

$$\Rightarrow F = (1.6 \times 10^{-19})(6 \times 10^6)(2.50)$$

$$\boxed{F = 2.4 \times 10^{-12}\ \text{N UP}}$$

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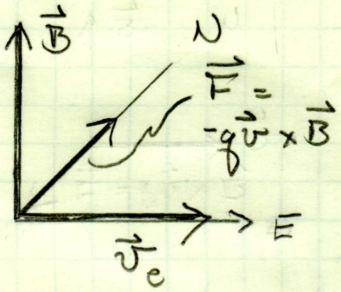
11. A uniform magnetic field points vertically upward; its magnitude is 0.800 T. An electron with kinetic energy 7.2×10^{-18} J is moving horizontally eastward in this field. What is the magnetic force acting on it?



$$|\vec{F}| = |q\vec{v} \times \vec{B}| = qvB\cancel{\sin(90^\circ)} = qvB$$

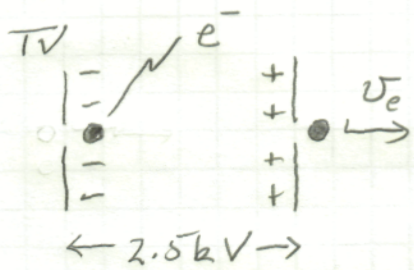
$$KE = \frac{1}{2} m_e v_e^2 \Rightarrow v = \sqrt{\frac{2KE}{m_e}}$$

$$= \sqrt{\frac{2(7.2 \times 10^{-18})}{(9.11 \times 10^{-31})}} = 3.98 \times 10^6\ \text{m/s} = v_e$$

$$F = (1.6 \times 10^{-19})(3.98 \times 10^6)(0.800) = \boxed{5.09 \times 10^{-13}\ \text{N North} = \vec{F}}$$

$\Rightarrow e^-$ HAS NEGATIVE CHARGE

●15. Electrons in a television's CRT are accelerated from rest by an electric field through a potential difference of 2.5 kV. In contrast to an oscilloscope, where the electron beam is deflected by an electric field, the beam is deflected by a magnetic field. (a) What is the speed of the electrons? (b) The beam is deflected by a perpendicular magnetic field of magnitude 0.80 T. What is the magnitude of the acceleration of the electrons while in the field? (c) What is the speed of the electrons after they travel 4.0 mm through the magnetic field? (d) What strength electric field would give the electrons the same magnitude acceleration as in (b)? (e) Why do we have to use an electric field in the first place to get the electrons up to speed? Why not use the large acceleration due to a magnetic field for that purpose?



a) Use energy

$$\Delta U = \frac{1}{2} m_e v_e^2$$

$$\Rightarrow v_e = \sqrt{\frac{2\Delta U}{m_e}} = \sqrt{\frac{2qV}{m_e}}$$

$$v_e = \sqrt{\frac{2(1.6\times10^{-19})(2.5\times10^{3})}{(9.11\times10^{-31})}}$$

$$\boxed{v_e = 2.96\times10^{7}\ \frac{m}{s}}$$

b) For $B = 0.80T$

$$a_B = \frac{F}{m} = \frac{qvB}{m} = \frac{(1.6\times10^{-19})(2.96\times10^{7})(0.80)}{(9.11\times10^{-31})}$$

$$\boxed{a_B = 4.16\times10^{18}\ \frac{m}{s^2}}$$

c) Find speed after 4.0m through $\vec{B}$

- $\vec{B}$ only <u>deflects</u> $\vec{v}$ so $|\vec{v}|$ = constant

$$\Rightarrow \boxed{v_e = 2.96\times10^{7}\ \frac{m}{s}}$$

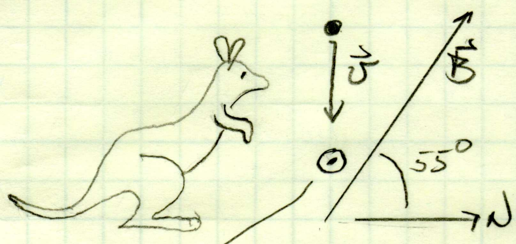
d) Find $\vec{E}$ to give accel in b

$$a_E = \frac{F}{m} = \frac{qE}{m} \Rightarrow E = \frac{ma}{q} = \frac{(9.11\times10^{-31})(4.16\times10^{18})}{(1.6\times10^{-19})}$$

$$\boxed{E = 2.37\times10^{7}\ \frac{V}{m}} = 23.7\ MV/m \Rightarrow \text{\underline{Huge}!}$$

e) We can't use $\vec{B}$ to accelerate the e^- because it can only deflect them!

17. At a certain point on Earth's surface in the southern hemisphere, the magnetic field has a magnitude of 5.0×10^{-5} T and points upward and toward the north at an angle of 55° above the horizontal. A cosmic ray muon with the same charge as an electron and a mass of 1.9×10^{-28} kg is moving directly down toward Earth's surface with a speed of 4.5×10^7 m/s. What is the magnitude and direction of the force on the muon?



$\vec{F} = q\vec{v} \times \vec{B}$ OUT OF PAGE

$\vec{F}$ ON e^- OPPOSITE $\Rightarrow$ WEST

$$|F_\mu| = |q\vec{v} \times \vec{B}| = qvB\sin(145°)$$

$$= (1.6\times10^{-19})(4.5\times10^{7})(5\times10^{-5})\sin(145)$$

$$\boxed{\vec{F} = 2.06 \times 10^{-16}\ \text{N WESTWARD}}$$

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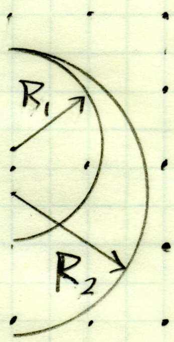
28. Natural carbon consists of two different isotopes (excluding ^{14}C, which is present in only trace amounts). The isotopes have different masses, which is due to different numbers of neutrons in the nucleus; however, the number of protons is the same, and subsequently the chemical properties are the same. The most abundant isotope has an atomic mass of 12.00 u. When natural carbon is placed in a mass spectrometer, two lines are formed on the photographic plate. The lines show that the more abundant isotope moved in a circle of radius 15.0 cm, while the rarer isotope moved in a circle of radius 15.6 cm. What is the atomic mass of the rarer isotope? (The ions have the same charge and are accelerated through the same potential difference before entering the magnetic field.)



$\vec{B}$ OUT OF PAGE

$R_1 = 15.0$ cm
- COMMON ISOTOPE

$R_2 = 15.6$ cm
- RARE ISOTOPE

$m_{COMMON} = m_1 = 12.00u$

$U_{COMMON} = U_{RARE}$

IN THE FIELD

$$qvB = m\frac{v^{\cancel{2}}}{r} \Rightarrow \frac{r}{m} = \frac{v}{qB}$$

IONS HAVE SAME ENERGY: $U = qV = \frac{1}{2}mv^2$

$$\Rightarrow v = \sqrt{\frac{2qV}{m}}$$

THUS

$$\frac{r^2}{m^{\cancel{2}}} = \frac{2\cancel{q}V}{\cancel{m}q^{\cancel{2}}B^2} \Rightarrow \frac{r^2}{m} = \frac{2V}{qB^2} = \text{CONSTANT}: \frac{R_1^2}{m_1} = \frac{R_2^2}{m_2}$$

FIND m_2

$$m_2 = \left(\frac{R_2^2}{R_1^2}\right)m_1 = \left(\frac{15.6^2}{15.0^2}\right)(12.00) = \boxed{12.98u = m_{RARE}}$$

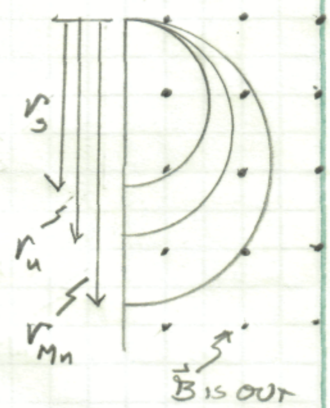
31. A sample containing sulfur (atomic mass 32 u), manganese (55 u), and an unknown element is placed in a mass spectrometer. The ions have the same charge and are accelerated through the same potential difference before entering the magnetic field. The sulfur and manganese lines are separated by 3.20 cm, and the unknown element makes a line between them that is 1.07 cm from the sulfur line. (a) What is the mass of the unknown element? (b) Identify the element.

$m_S = 32u$

$m_{Mn} = 55u$

$r_{Mn} - r_S = 3.20\text{ cm}$

$r_u - r_S = 1.07\text{ cm}$



IONS HAVE SAME ENERGY $qV = \frac{1}{2} m v^2$

$$v = \sqrt{\frac{2qV}{m}}$$

CYCLOTRON RADIUS FROM $qvB = m\frac{v^2}{r}$ (SAME q's & B)

$$\Rightarrow \frac{r^2}{m} = \frac{2V}{qB^2} = \text{CONSTANT (AS IN PROBLEM 28)}$$

SO

$$r_S = \sqrt{\frac{m_{Mn}}{m_S}}\, r_{Mn} = \sqrt{\frac{55}{32}}\, r_{Mn} = 1.31\, r_{Mn} \quad \underline{\text{AND}} \quad r_S = \sqrt{\frac{m_u}{m_S}}\, r_u$$

FIND r_S

$$\Delta r_{MnS} = r_{Mn} - r_S = \sqrt{\frac{m_{Mn}}{m_S}}\, r_S - r_S = \left(\sqrt{\frac{m_{Mn}}{m_S}} - 1\right) r_S = \Delta r_{MnS}$$

$$r_S = \frac{\Delta r_{MnS}}{\sqrt{\frac{m_{Mn}}{m_S}} - 1} = \frac{3.20}{1.31 - 1} = \underline{10.32\text{ cm} = r_S}$$

FIND m_u

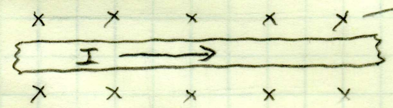
$$\Delta r_{uS} = r_u - r_S = \sqrt{\frac{m_u}{m_S}}\, r_S - r_S = \left(\sqrt{\frac{m_u}{m_S}} - 1\right) r_S = \Delta r_{uS}$$

$$\sqrt{\frac{m_u}{m_S}} - 1 = \frac{\Delta r_{uS}}{r_S} \Rightarrow \sqrt{\frac{m_u}{m_S}} = \frac{\Delta r_{uS}}{r_S} + 1$$

$$m_u = \left(\frac{\Delta r_{uS}}{r_S} + 1\right)^2 m_S = \left(\frac{1.07}{10.32} + 1\right)^2 (32) = 38.9u$$

$$\boxed{m_u = 39u \Rightarrow \text{K, POTASSIUM}}$$

39. A strip of copper 2.0 cm wide carries a current $I =$ 30.0 A to the right. The strip is in a magnetic field $B = 5.0$ T into the page. (a) What is the direction of the average magnetic force on the conduction electrons? (b) The Hall voltage is 20.0 μV. What is the drift velocity?



a) FOR AN e^- IN THE STRIP

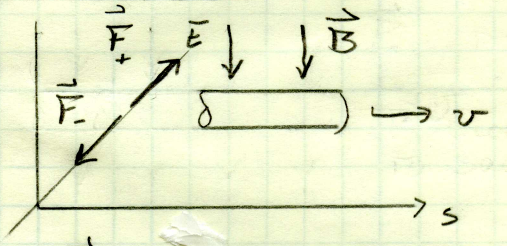
e^- MOVE TO THE LEFT $\Rightarrow -q\vec{v} \times \vec{B}$ IS UP

b) HALL VOLTAGE $\Rightarrow qE = qvB$ AND $V = E\underbrace{W}_{\text{STRIP WIDTH}}$

$$\left(\frac{V}{W}\right) = vB$$

$$\Rightarrow v = \left(\frac{V}{WB}\right) = \frac{20 \times 10^{-6}}{(0.02)(5.0)} = 2 \times 10^{-4} = \boxed{0.20\ \frac{mm}{s} = v_{DRIFT}}$$

41. An electromagnetic flowmeter is used to measure blood flow rates during surgery. Blood containing Na^+ ions flows due south through an artery with a diameter of 0.40 cm. The artery is in a downward magnetic field of 0.25 T and develops a Hall voltage of 0.35 mV across its diameter. (a) What is the blood speed (in m/s)? (b) What is the flow rate (in m^3/s)? (c) The leads of a voltmeter are attached to diametrically opposed points on the artery to measure the Hall voltage. Which of the two leads is at the higher potential?



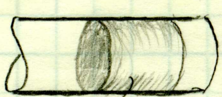
$\vec{F}_+$ TO EAST

F_- TO WEST

a) FROM PROBLEM 39 ABOVE

$$v_d = \frac{V}{WB} = \frac{0.35 \times 10^{-3}}{(0.004)(0.25)} = \boxed{0.35\ \frac{m}{s} = v_d}$$

b) FLOW RATE = VOLUME / TIME



$$V = \pi r^2 v = \frac{\pi d^2}{4} v = \frac{\pi (0.004)^2}{4} (0.35)$$

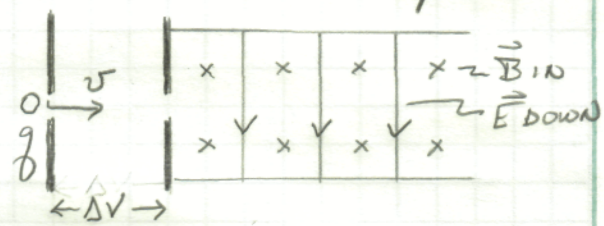
VOLUME FLOW = (AREA) × (VELOCITY)

$$\boxed{V = 4.40 \times 10^{-6}\ \frac{m^3}{s}}$$

c) SINCE + IONS ARE PUSHED TO THE EAST

$\Rightarrow$ $\boxed{\text{EAST LEAD AT HIGHER POTENTIAL}}$

43. A charged particle is accelerated from rest through a potential difference ΔV. The particle then passes straight through a velocity selector (field magnitudes E and B). Derive an expression for the charge-to-mass ratio (q/m) of the particle in terms of ΔV, E, and B.



FORCES BALANCE IN SELECTOR

$$\Rightarrow \cancel{q}E = \cancel{q}vB \quad (\vec{v} \perp \text{ TO } \vec{B})$$

v IS PROVIDED BY VOLTAGE

$$\Delta V = \frac{\Delta U}{q} = \frac{mv^2}{2q} \Rightarrow v = \sqrt{\frac{2q\Delta V}{m}}$$

THUS

$$\frac{E}{B} = \sqrt{\frac{2q\Delta V}{m}} \Rightarrow \boxed{\frac{q}{m} = \frac{E^2}{2B^2\Delta V}}$$