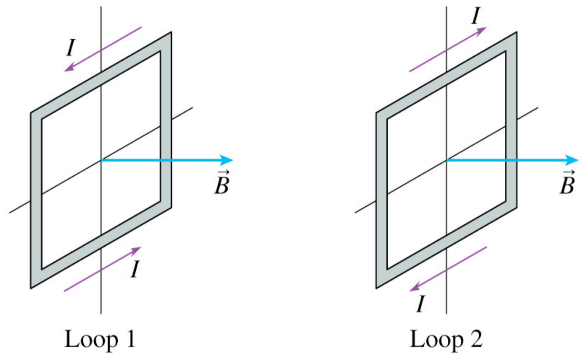
Two square current loops are far apart and do not interact with each other. Each is in an external magnetic field normal to its plane, as shown.

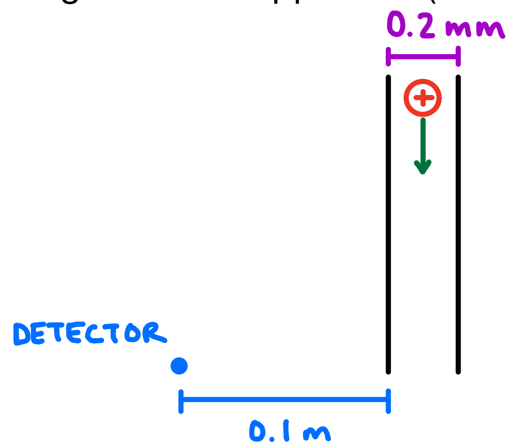


a) Use a force diagram to show that each loop is in equilibrium, having no net force and no net torque acting upon it.
b) One of these loops is in a stable equilibrium: under a small rotation, forces acting upon it will return it to its original equilibrium position. The other loop is in an unstable equilibrium position: under a small rotation, it will flip it over, putting it into a stable equilibrium position, which was not its original equilibrium position. Which loop is in the stable equilibrium and which is in an unstable equilibrium?

b) STABLE : LOOP 1

UNSTABLE : LOOP 2

Consider an apparatus that fires protons between parallel plates. The size of these plates is very large compared to their separation of 0.2 mm. These plates are also at a potential difference of 3.3 V. There is a detector perpendicular to the parallel plates positioned 0.1 m from where the protons exit the parallel plates. Coming into or out of the page is a uniform magnetic field encompassing the entire apparatus (both between and outside the plates).

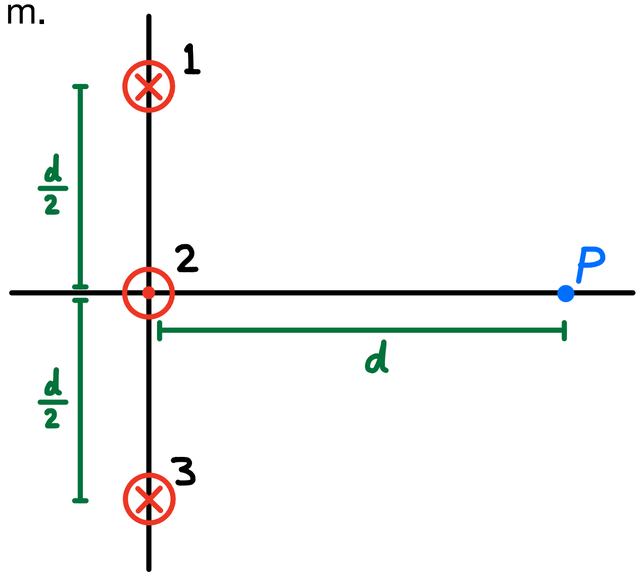


What must be the magnitude and direction of the magnetic field if these protons are to reach the detector?

0.0587 T

OUT OF THE PAGE

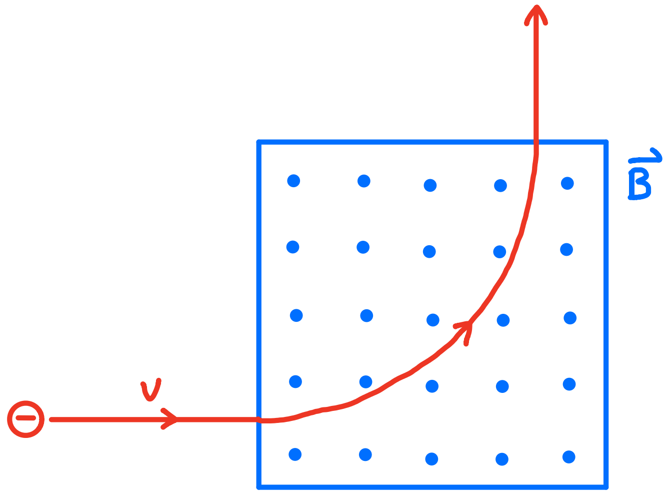
Three long wires each carrying 3 A of current are arranged as shown. *d* is equal to 0.3 m.



a) Find the magnetic field strength and direction at point *P*.
b) If the current through wire 3 is instead going out of the page, would would be the magnetic field strength and direction at point *P*?

a) 1.20×10^{-6} T DOWN
b) 2.56×10^{-6} T 38.7° W OF N

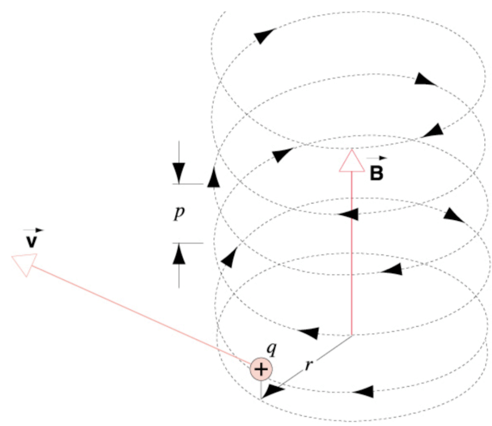
A electron travelling with velocity *v* enters a magnetic field *B* as shown. The electron leaves the field in a direction perpendicular to its original direction.



If the electron travelled a distance *d* in the magnetic field, determine the magnetic field strength in terms of *e, m*_e, *v*, and *d*.

$$\frac{\pi m v}{2ed}$$

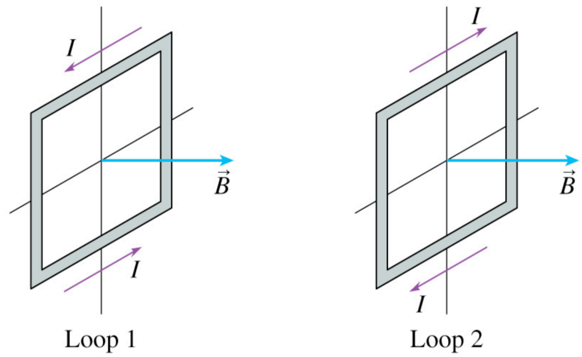
A 22.5 eV positron (the antiparticle of the electron) is projected into a uniform magnetic field B = 455 μT. Its velocity vector makes an angle of 65.5° with B as shown. (1 eV = 1.60 × 10^-19 J)



a) Find the radius r of the helical trajectory.
b) Find the period of oscillation.
c) Find the pitch p of the helical trajectory.

a) 0.0320 m
b) 7.86×10^{-8} s
c) 0.0917 m

Two square current loops are far apart and do not interact with each other. Each is in an external magnetic field normal to its plane, as shown.



a) Use a force diagram to show that each loop is in equilibrium, having no net force and no net torque acting upon it.
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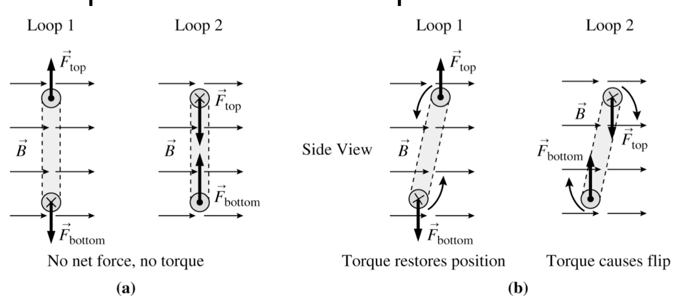
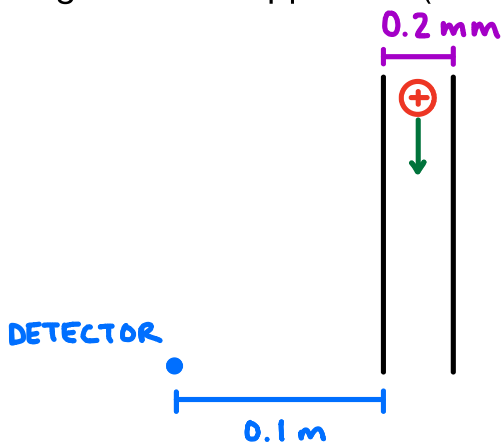
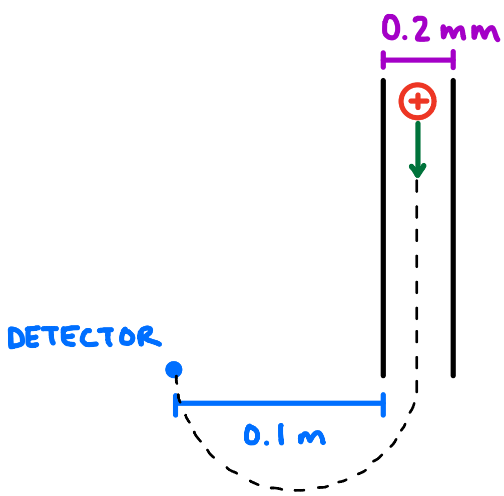


a) The torque on the current loop due to the magnetic field is shown. Use the right hand rule to find the force direction on the currents at the top, bottom, front and back segments of the loops. We see *F*_top and *F*_bottom are qual and opposite to each other (*F*_front and *F*_back are not seen in the figure because they are equal and opposite to each other.) Thus, *F*_top + *F*_bottom = 0 and *F*_front + *F*_back = 0. Sind the top-bottom or front-back forces act along the same line, they cause no torque. Thus, both the loops are in static equilibrium.
b) Now rotate each loop slightly and reexamine the forces. The forces on loop 1 still give *F*_net = 0, but now there is a torque that tends to rotate loop 1 *back* to its upright position. This is a restoring torque, so this loop position is stable. But for loop 2, the torque causes the loop to rotate even further. Any small angular displacement gets magnifies into a large displacement until the loop gets flipped over. Therefore, the position of loop 2 is unstable.

Consider an apparatus that fires protons between parallel plates. The size of these plates is very large compared to their separation of 0.2 mm. These plates are also at a potential difference of 3.3 V. There is a detector perpendicular to the parallel plates positioned 0.1 m from where the protons exit the parallel plates. Coming into or out of the page is a uniform magnetic field encompassing the entire apparatus (both between and outside the plates).



What must be the magnitude and direction of the magnetic field if these protons are to reach the detector?



BETWEEN THE PLATES THE NET FORCE ON THE PROTONS IF THEY ARE TO PASS STRAIGHT THROUGH.

$$F_E = F_B$$

$$\cancel{q}E = \cancel{q}vB$$

$$\frac{\Delta V}{d} = vB \quad (1)$$

OUTSIDE THE PLATES THE PROTONS EXPERIENCE A CENTRIPETAL FORCE CAUSING UNIFORM CIRCULAR MOTION.

$$F_c = ma_c$$

$$F_B = m\frac{v^2}{R}$$

$$q\cancel{v}B = m\frac{v^{\cancel{2}}}{R}$$

$$v = \frac{qBR}{m} \quad ②$$

② INTO ①

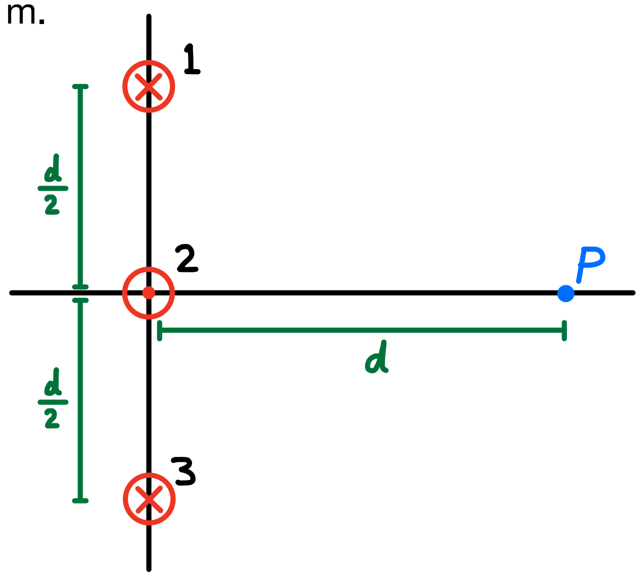
$$\frac{\Delta V}{d} = vB$$

$$\frac{\Delta V}{d} = \frac{qB^2R}{m}$$

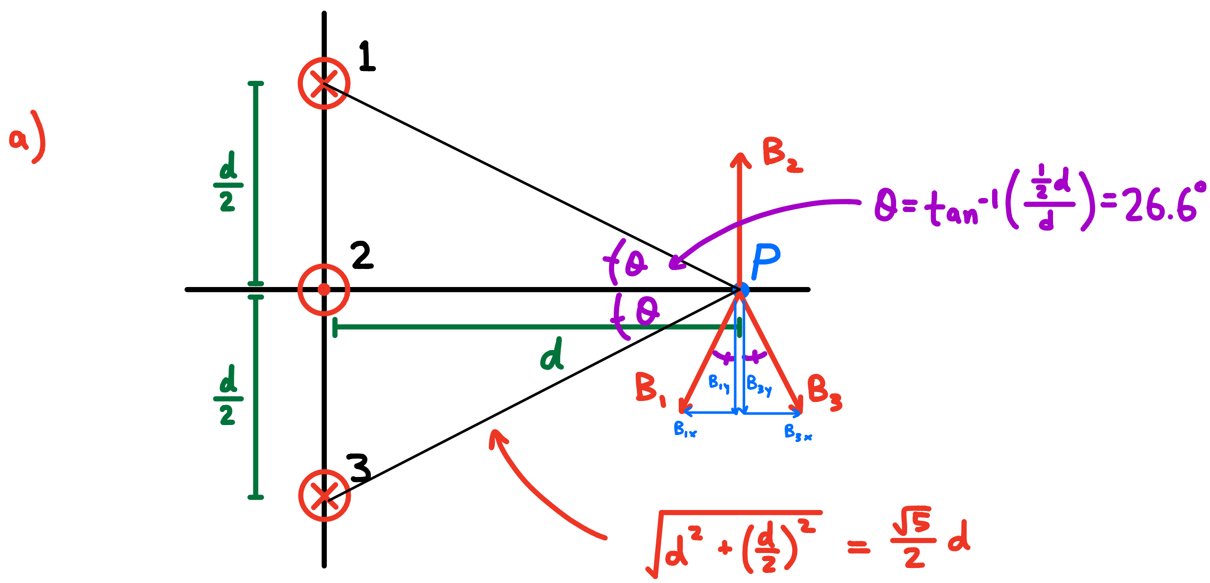
$$B = \sqrt{\frac{m\Delta V}{qRd}} = \sqrt{\frac{(1.67\times10^{-27})(3.3)}{(1.60\times10^{-19})(0.05)(0.0002)}}$$

$$= \boxed{\begin{array}{l} 0.0587\ \text{T} \\ \text{OUT OF THE PAGE} \end{array}}$$

Three long wires each carrying 3 A of current are arranged as shown. d is equal to 0.3 m.



a) Find the magnetic field strength and direction at point P.
b) If the current through wire 3 is instead going out of the page, would would be the magnetic field strength and direction at point P?



$$B_2 = \frac{\mu_0 I}{2\pi d} = \frac{(4\pi \times 10^{-7})(3)}{2\pi(0.3)} = 2.0 \times 10^{-6} \text{ T} \quad \text{UP}$$

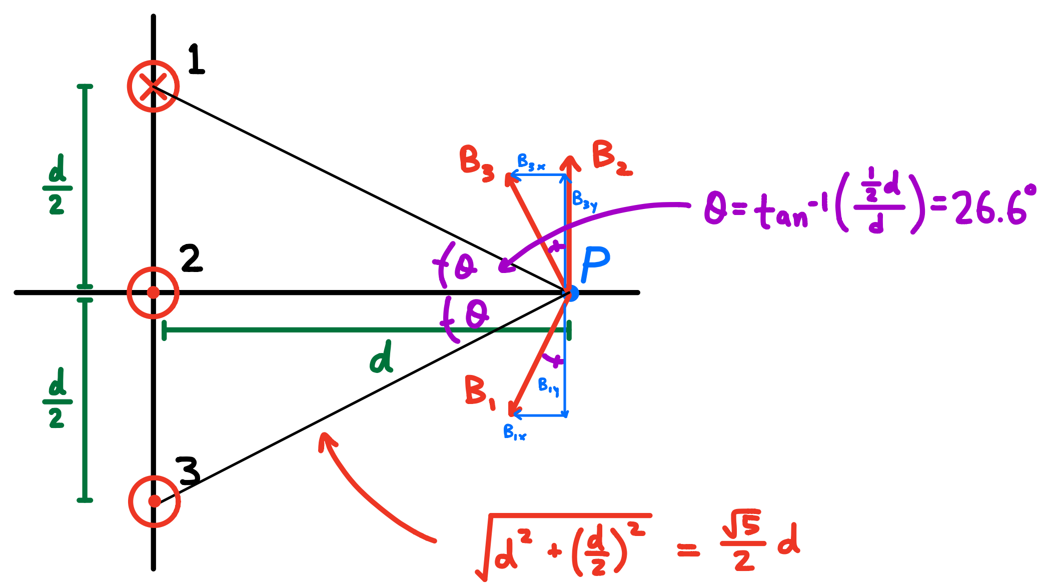
$$|B_1| = |B_3| = \frac{\mu_0 I}{\cancel{2}\pi\left(\frac{\sqrt{5}}{\cancel{2}} d\right)} = \frac{(4\pi \times 10^{-7})(3)}{\sqrt{5}\,\pi(0.3)} = 1.79 \times 10^{-6} \text{ T}$$

$$|B_{1x}| = |B_{3x}| \longrightarrow \underline{B_{TOT\,x} = 0}$$

$$B_{1y} = B_{3y} = |B_1| \cos 26.6^\circ = 1.60 \times 10^{-6}\ T \quad \text{DOWN}$$

$$B_{TOT} = B_2 - B_{1y} - B_{3y}$$
$$= (2.0 \times 10^{-6}) - (1.60 \times 10^{-6}) - (1.60 \times 10^{-6})$$
$$= -1.20 \times 10^{-6}\ T$$
$$\longrightarrow \boxed{1.20 \times 10^{-6}\ T \quad \text{DOWN}}$$

b)



$$B_2 = \frac{\mu_0 I}{2\pi d} = \frac{(4\pi \times 10^{-7})(3)}{2\pi(0.3)} = 2.0 \times 10^{-6}\ T \quad \text{UP}$$

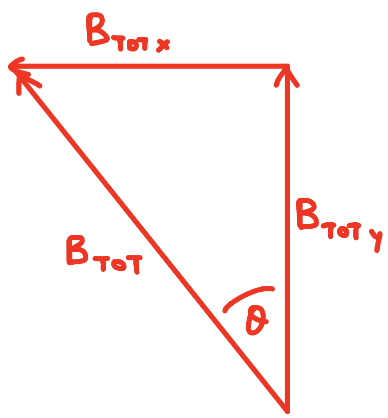
$$|B_1| = |B_3| = \frac{\mu_0 I}{\cancel{2}\pi\left(\frac{\sqrt{5}}{\cancel{2}} d\right)} = \frac{(4\pi \times 10^{-7})(3)}{\sqrt{5}\,\pi(0.3)} = 1.79 \times 10^{-6}\ T$$

$$|B_{1y}| = |B_{3y}|$$

$$B_{1x} = B_{3x} = |B_1| \sin 26.6^\circ = 8.0 \times 10^{-7}\ \text{T} \quad \text{DOWN}$$

$$B_{TOT\,x} = B_{1x} + B_{3x} = (8.0 \times 10^{-7}) + (8.0 \times 10^{-7}) = 1.60 \times 10^{-6}\ \text{T} \quad \text{LEFT}$$

$$B_{TOT\,y} = B_2 + \cancel{B_{3y}} - \cancel{B_{1y}} = 2.0 \times 10^{-6}\ \text{T} \quad \text{UP}$$

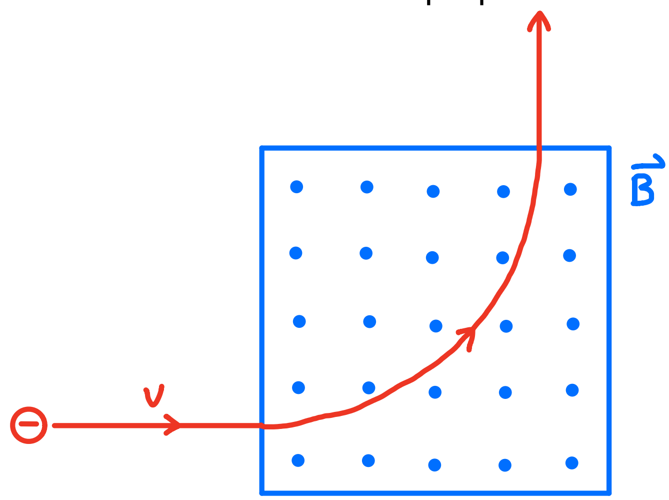


$$B_{TOT} = \sqrt{B_{TOT\,x}^2 + B_{TOT\,y}^2}$$
$$= \sqrt{(1.60 \times 10^{-6})^2 + (2.00 \times 10^{-6})^2}$$
$$= 2.56 \times 10^{-6}\ \text{T}$$

$$\theta = \tan^{-1}\left(\frac{B_{TOT\,x}}{B_{TOT\,y}}\right)$$
$$= \tan^{-1}\left(\frac{1.60 \times 10^{-6}}{2.00 \times 10^{-6}}\right)$$
$$= 38.7^\circ$$

$$\boxed{2.56 \times 10^{-6}\ \text{T} \quad 38.7^\circ \text{ W OF N}}$$

A electron travelling with velocity *v* enters a magnetic field *B* as shown. The electron leaves the field in a direction perpendicular to its original direction.



If the electron travelled a distance *d* in the magnetic field, determine the magnetic field strength in terms of *e, m*_e, *v*, and *d*.

$$F_c = ma_c$$

$$F_B = m\frac{v^2}{R}$$

$$q\cancel{v}B = m\frac{v^{\cancel{2}}}{R}$$

$$B = \frac{mv}{qR}$$

$$d = \frac{1}{4}(2\pi R)$$

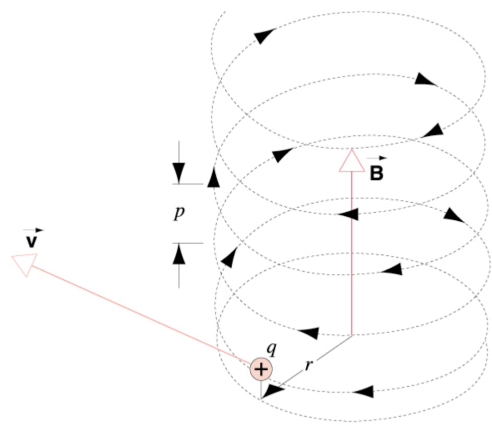
$$d = \frac{\pi R}{2}$$

$$R = \frac{2d}{\pi}$$

$$B = \frac{\pi mv}{qR}$$

$$\boxed{B = \frac{\pi m_e v}{2ed}}$$

A 22.5 eV positron (the antiparticle of the electron) is projected into a uniform magnetic field B = 455 μT. Its velocity vector makes an angle of 65.5° with B as shown. (1 eV = 1.60 × 10^-19 J)



a) Find the radius r of the helical trajectory.
b) Find the period of oscillation.
c) Find the pitch p of the helical trajectory.

a) $E_K = 22.5\ eV = 3.60\times10^{-18}\ J$

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

$$v = \sqrt{\frac{2E_K}{m}} = \sqrt{\frac{2(3.60\times10^{-18})}{9.11\times10^{-31}}} = 2.81\times10^{6}\ \frac{m}{s}$$

$$v_{\parallel} = v\cos 65.5^\circ$$

$$v_{\perp} = v\sin 65.5^\circ$$

$$F_c = ma_c$$

$$q\cancel{v_{\perp}}B = m\frac{v_{\perp}^{\cancel{2}}}{r}$$

$$r = \frac{mv_{\perp}}{qB}$$

$$= \frac{mv\sin 65.5^\circ}{qB}$$

$$= \frac{(9.11\times10^{-31})(2.81\times10^{6})\sin 65.5^\circ}{(1.60\times10^{-19})(455\times10^{-6})}$$

$$= \boxed{0.0320\ m}$$

b) $d = vt$

$2\pi r = v_{\perp} T$

FROM a)

$r = \frac{mv_{\perp}}{qB}$

$T = \frac{2\pi r}{v_{\perp}}$

$= \frac{2\pi m}{qB} = \frac{2\pi (9.11 \times 10^{-31})}{(1.60 \times 10^{-19})(455 \times 10^{-6})} = \boxed{7.86 \times 10^{-8}\ s}$

c)

The pitch is the parallel distance travelled by the electron in one revolution.

$p = v_{\parallel} T$

$= vT \cos 65.5°$

$= (2.81 \times 10^{6})(7.86 \times 10^{-8}) \cos 65.5°$

$= \boxed{0.0917\ m}$