Phys 1B
Solutions
Summer 2010

Ch19

1a) Horizontal, due east

b) Horizontal, 30° north of east.

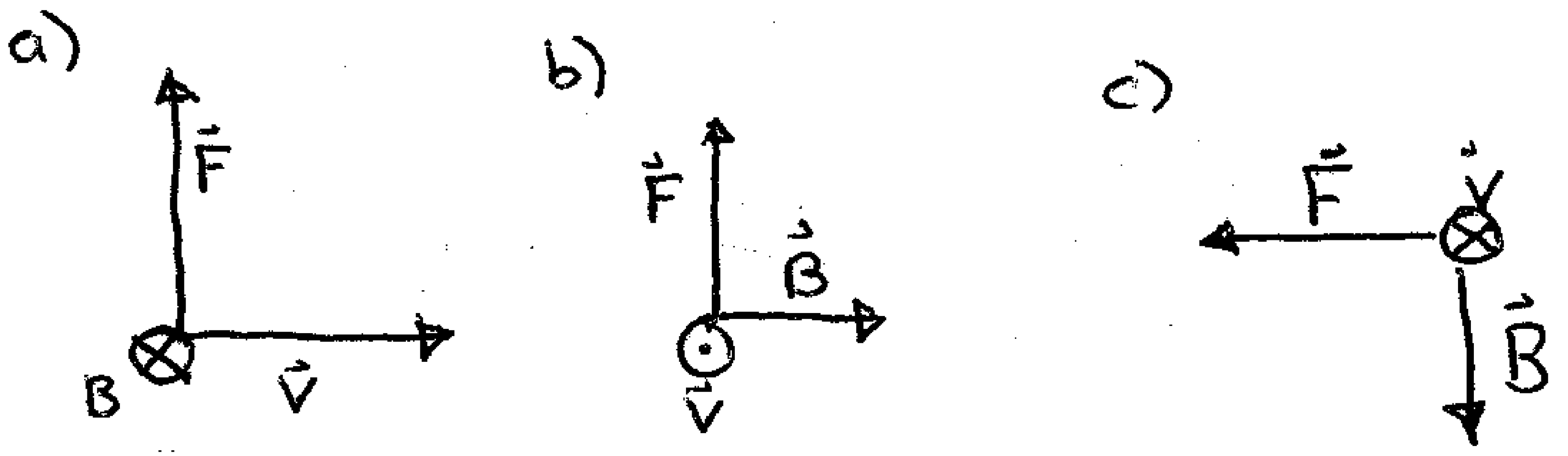
c) Horizontal, due east

d) Since V is parallel to B, there is no force

3 a) into the page

b) to the right

c) downward



5) $F_g = mg$

$m = 9.11 \cdot 10^{-31}$ kg, $g = 9.81$ m/s² $\Big\}$ $F_g = 8.93 \cdot 10^{-30}$ N downward

$F_m = qvB$

$q = 1.602 \cdot 10^{-19}$ C, $V = 6 \cdot 10^{6}$ m/s, $B = 5 \cdot 10^{-5}$ T $\Big\}$ $F_m = 4.81 \cdot 10^{-17}$ N downward

$F_e = qE$

$q = 1.602 \cdot 10^{-19}$ C, $E = 100$ N/C $\Big\}$ $F_e = 1.60 \cdot 10^{-17}$ N upward.

This shows that the gravitational force is a lot smaller than the other two.

8a) If the velocity of the electron is perpendicular to the magnetic field ($\theta = 90^\circ$) $F = qvB\sin\theta = qvB$

v needs to be found, this speed comes from acceleration through the potential V:

$E_i = E_f \Rightarrow \frac{1}{2}mv_i^2 + \cancel{\frac{1}{2}}qV = \frac{1}{2}mv_f^2$ now $v_i = 0$ because the particle starts at rest

$qV = \frac{1}{2}mv_f^2 \quad v_f = \sqrt{\frac{2qV}{m}}$

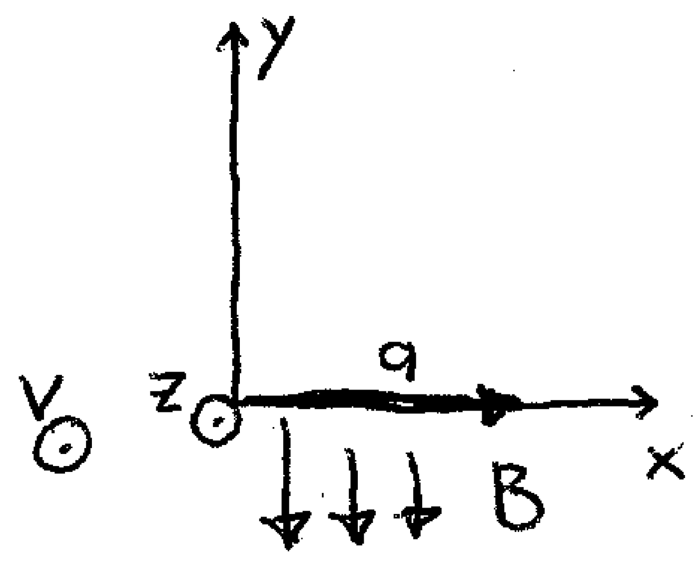
$$\left.\begin{array}{l} q = 1.602 \cdot 10^{-19}\,C \\ V = 2400\,V \\ m = 9.11 \cdot 10^{-31}\,kg \end{array}\right\} v_f = 2.90 \cdot 10^{7}\,m/s$$

$$\left.\begin{array}{l} q = 1.602 \cdot 10^{-19}\,C \\ v_f = 2.90 \cdot 10^{7}\,m/s \\ B = 1.7\,T \end{array}\right\} F = qv_fB = 7.90 \cdot 10^{-12}\,N$$

b) If the velocity of the electron is parallel to the magnetic field $\theta = 0$ and $F = qvB\sin\theta = 0$

0N is the minimum force.

9)



First the direction:

F is paralel to a (since F = ma)

F is in the positive x-direction

V is out of the page, by the right-hand rule, B points in the −y direction (think about it !!)

Since it is a positive charge.

$F = qVB\sin\theta \quad \theta = 90^\circ$ Hence $\sin\theta = 1$

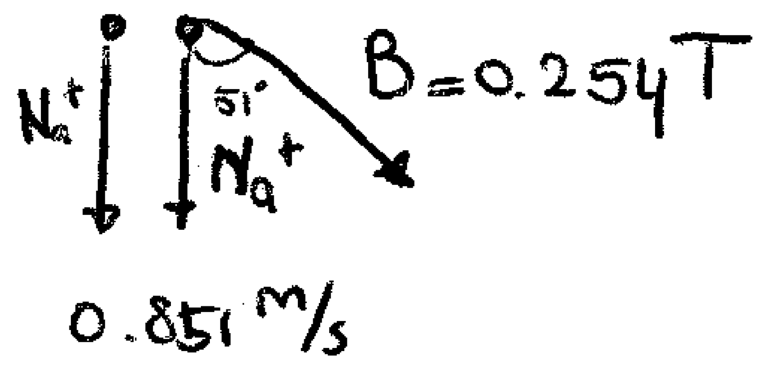
$q = 1.602 \cdot 10^{-19}\,C$

$V = 1 \cdot 10^{7}\,m/s$

$F = ma = 1.67 \cdot 10^{-27}\,kg \cdot 2 \cdot 10^{13}\,m/s^2 = 3.34 \cdot 10^{-14}\,N$

$B = F/qV = 0.0208\,T = 21\,mT$

10)



$F = BqV\sin\theta$

$B = 0.254\,T$

$q = 1.602 \cdot 10^{-19}\,C$

$V = 0.851\,m/s$

$\theta = 51^\circ$

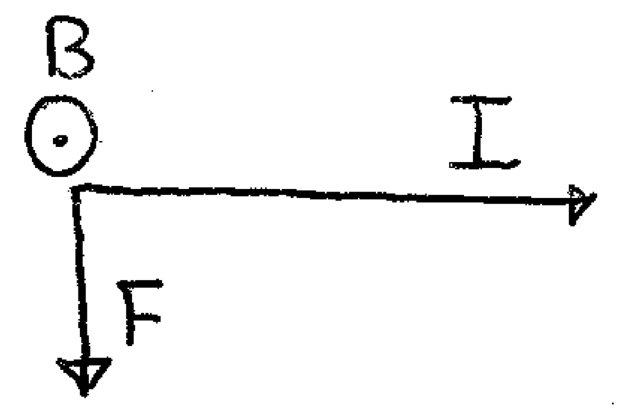
$F = 2.69 \cdot 10^{-20}\,N$

Note that we chose $q = 1e^{+}$ Hence this is the force on 1 Na^{+} ion.

there are: $3 \cdot 10^{20} \times 100\,cm^3 = 3 \cdot 10^{22}$ Na^{+} ions in the arm Hence the total force is:

$F_{tot} = 807\,N$ (This is something you most definetely would feel)

11)

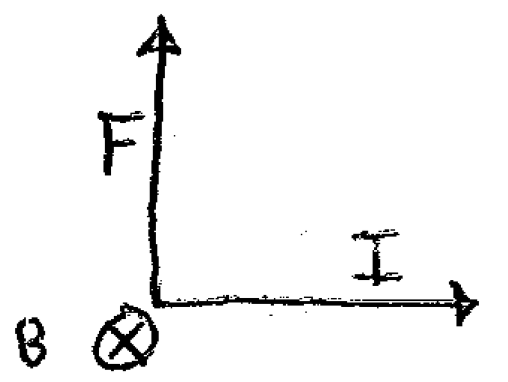


By the right-hand rule B needs to point out of the page (+ z-axis)

$F = BI\ell \sin\theta$

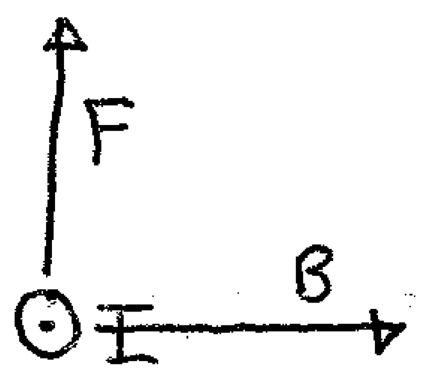
$$\left.\begin{aligned} F/\ell &= 0.12\,N/m \\ I &= 15\,A \\ \theta &= 90^\circ \end{aligned}\right\} \quad B = \frac{F/\ell}{I} = 8\cdot 10^{-3}\,T \text{ in the } +z\text{-axis.}$$

13a)



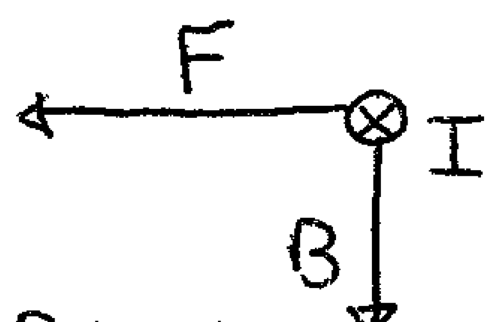
B into the page

b)



B is to the right

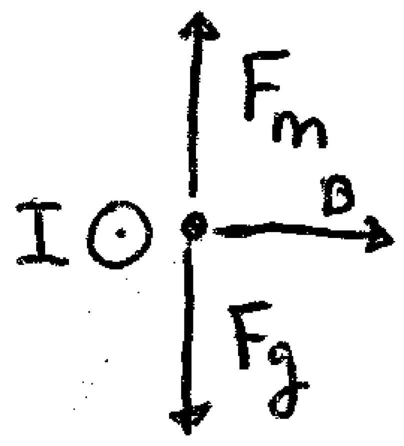
c)



B is downward.

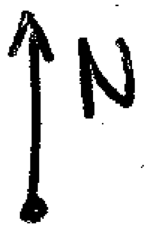
14) Lets assume a wire of length 1cm. the weight of this wire is:

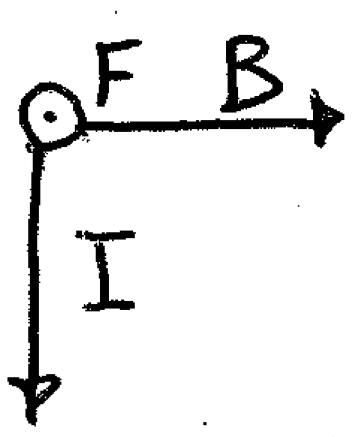
$0.5\,gr = 5\cdot 10^{-4}\,kg$ Force of gravity is $5\cdot 10^{-4}\cdot 9.8\,m/s = 4.91\cdot 10^{-3}\,N$



$$\left.\begin{aligned} F_m &= BI\ell & \ell &= 1\cdot 10^{-2}\,m \\ B &= ? & F_m &= 4.91\cdot 10^{-3}\,N \\ I &= 2.00\,A \end{aligned}\right\} \quad B = \frac{F_m}{I\ell} = 0.246\,T$$

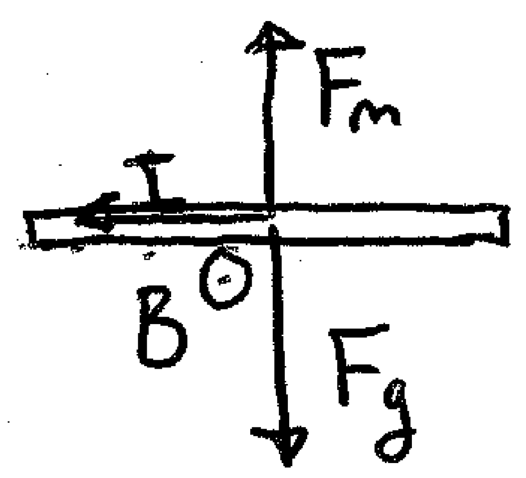
The direction comes from the right-hand rule





B=0.246T in the Eastward direction

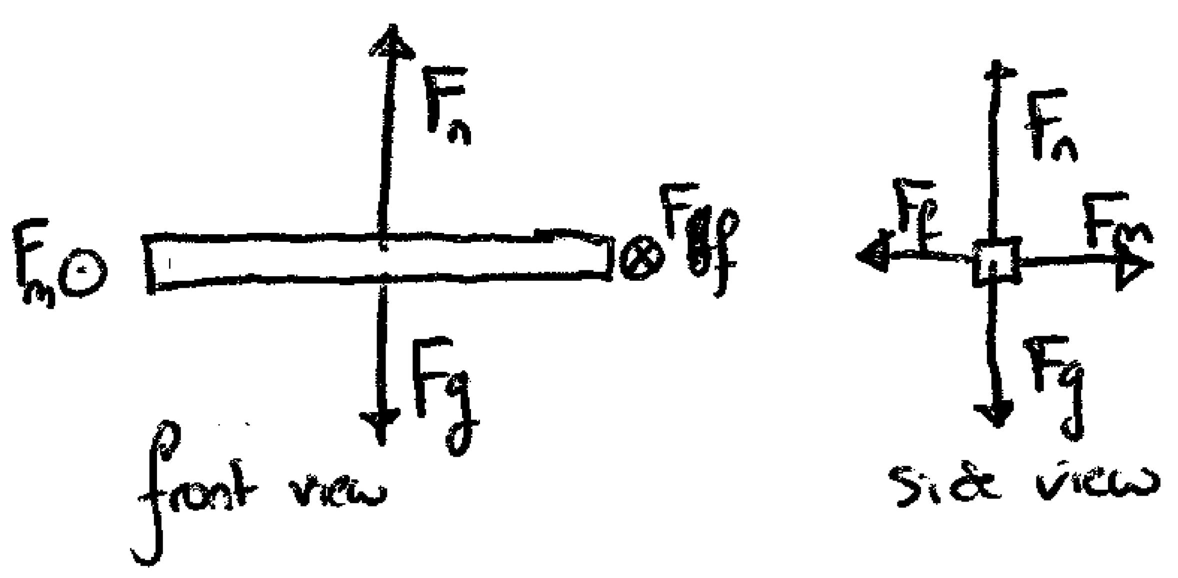
19) The free body diagram is:



$$\left.\begin{array}{l} F_g = mg \\ m = 0.015kg \end{array}\right\} F_g = 0.147N$$

$$\left.\begin{array}{l} F = BIl \\ F = 0.147N \\ I = 5.00A \\ l = 0.15m \end{array}\right\} B = \frac{F}{Il} = 0.196T \text{ out of the page}$$

54) The free-body diagram is:

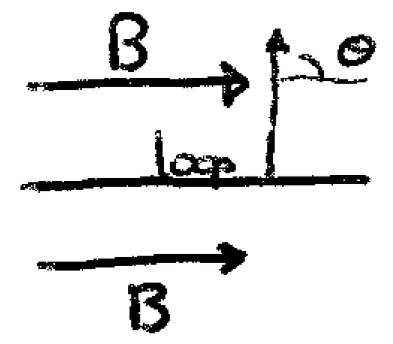


For this to move at <u>constant</u> velocity no net forces can act on the object.
Hence, $F_f = F_m$ and $F_g = F_n$.

$$F_f = \mu_k F_n \qquad F_n = mg \Rightarrow F_f = \mu_k mg = F_m = BIl$$

$$\left.\begin{array}{l} \mu_k = 0.1 \\ m = 0.2kg \\ I = 10A \\ l = 0.5m \end{array}\right\} \mu_k mg = BIl \quad B = \frac{\mu_k mg}{Il} = 0.0392T$$

22) The magnetic force on the loop is maximal because B is parallel to the plane of the loop: $\theta = 90°$

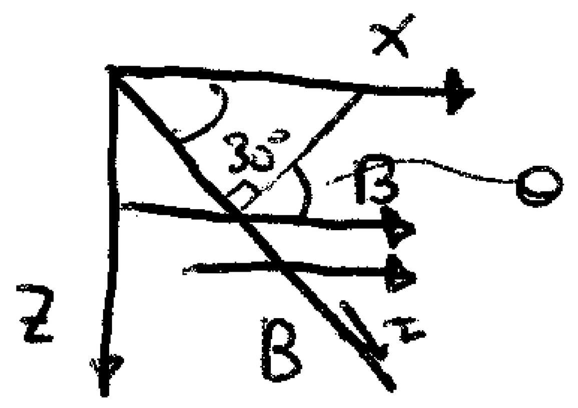


θ is the angle between the B-field and the ~~normal~~ of the surface.

$\tau = BIA\sin\theta$

$$\left.\begin{array}{lll} B = 0.8T & A = \pi r^2 & r = 0.318m \\ I = 0.07A & C = 2\pi r & A = 0.318m^2 \\ \theta = 90° & r = C/2\pi & \end{array}\right\} \tau = 0.00433\ N{\cdot}m$$

24)



$\theta = 60°$ this is the angle the normal makes with the B-field.

$B = 0.8T$ $\quad I = 100 \times 1.2A = 120A$ $\quad A = 0.4m \times 0.3m = 0.12m^2$

$\tau = BIA\sin\theta$ By the right-hand rule, the loop will

$\tau = 9.98\ N{\cdot}m$ rotate towards the z-axis.

26) $R = \rho\, l/A$ $\quad \rho = 1.7\cdot10^{-8}\,\Omega{\cdot}m$ $\quad l = 8m$ $\quad A = 4m^2$ $\quad R = 3.4\cdot10^{-8}\,\Omega$

$A = 4m^2$ because an 8m wire makes a square of 2x2m.

$I = V/R = 2.94\cdot10^{6}A$

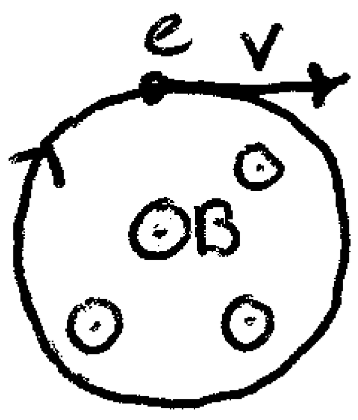
The maximum ~~force~~ torque is when $\theta = 90°$ i.e. the B-field is parallel to the plane of the loop.

$\tau = BIA\sin\theta = (0.4T)(2.94\cdot10^{6}A)(4m^2)(1) = 4.7\cdot10^{6}\ N{\cdot}m$

51) $\theta = 90-35 = 55^\circ$ is the angle wanted.

$$\left.\begin{array}{l} I = 25A \\ B = 0.30T \\ A = \pi r^2 = 0.283 m^2 \end{array}\right\} \tau = BIA\sin\theta = 1.7\ N\cdot m$$

27)



The magnetic force on the proton, causes the proton to go in a circle. ie. it provides the centripetal acceleration:

$$F_m = qBV = \underbrace{m v^2/r}_{\text{Centripetal force}} \Rightarrow B = mv/qr$$

now $V = d/T$ (distance over time) $d = 2\pi r$ is the distance of 1 revolution

therefore: $B = \frac{m 2\pi r}{qTr} = \frac{\cancel{m} 2\pi m}{qT}$

$$\left.\begin{array}{l} m = 1.67\cdot 10^{-27} kg \\ q = 1.602\cdot 10^{-19} C \\ T = 1\cdot 10^{-6} s \end{array}\right\} B = 6.55\cdot 10^{-2} T$$

28) This is the same picture as 27) : $B = mv/qr$

Assume all of its energy is kinetic then $E = \frac{1}{2}mv^2$

$E = 10MeV = 10\cdot 1\cdot 10^{6}\cdot 1.602\cdot 10^{-19} eV = 1.602\cdot 10^{-12} J$

$\cdot \frac{1}{2}mv^2 = E \quad m = 1.67\cdot 10^{-27} kg \quad V = \sqrt{2E/m} = 4.38\cdot 10^{7} m/s$

$$\left.\begin{array}{l} B = mv/qr \\ m = 1.67\cdot 10^{-27} kg \\ q = 1.602\cdot 10^{-19} kg \\ r = 5.80\cdot 10^{10} m \end{array}\right\} B = 7.87\cdot 10^{-12} T.$$

30) Inside the Velocity selector only particles with a certain velocity will go through. i.e. the ones for which the net force on it is 0. The magnetic and electric field must cancel each other:

$$qE = qvB \qquad v = E/B.$$

$$\left.\begin{aligned} E &= 950\ \text{V/m} \\ B &= 0.930\ \text{T} \end{aligned}\right\} \quad v = 1020\ \text{m/s}$$

$$r = mv/qB$$

$$\left.\begin{aligned} B &= 0.930\ \text{T} \\ q &= 1.602 \cdot 10^{-19}\ \text{C} \\ v &= 1020\ \text{m/s} \\ m &= 2.18 \cdot 10^{-26}\ \text{kg} \end{aligned}\right\} \quad r = 1.49 \cdot 10^{-4}\ \text{m}.$$

31) First find the velocity after it is accelerated. Assume it starts from rest. $\frac{1}{2}mv^2 = qV \quad v = \sqrt{2qV/m}$ *

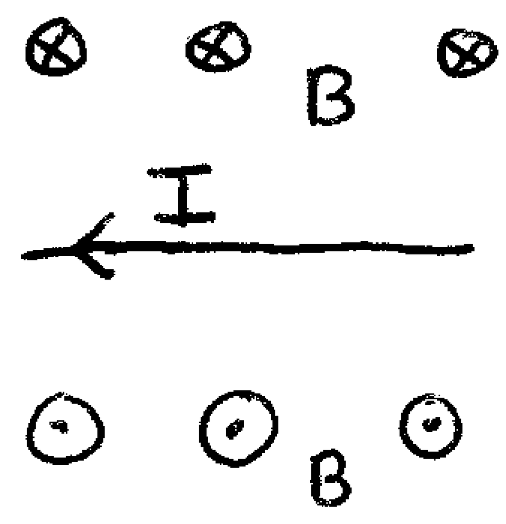
$$\left.\begin{aligned} q &= 1.602 \cdot 10^{-19}\ \text{C} \\ m &= 2.5 \cdot 10^{-26}\ \text{kg} \\ V &= 250\ \text{V} \end{aligned}\right\} \quad v = 5.66 \cdot 10^{4}\ \text{m/s}$$

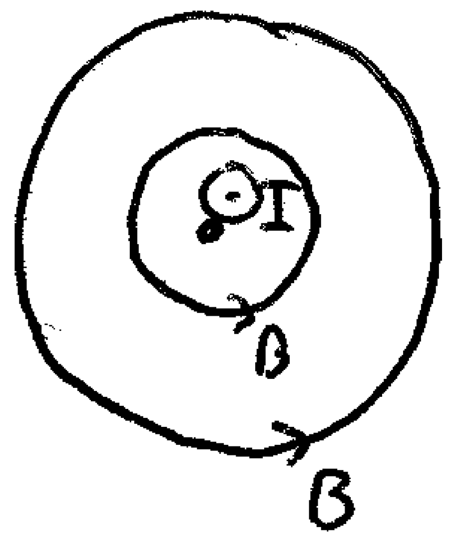
$$r = mv/qB$$

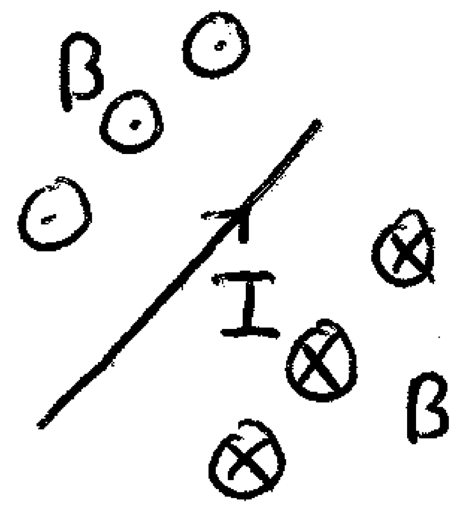
$$\left.\begin{aligned} m &= 2.5 \cdot 10^{-26}\ \text{kg} \\ v &= 5.66 \cdot 10^{4}\ \text{m/s} \\ q &= 1.602 \cdot 10^{-19}\ \text{C} \end{aligned}\right\} \quad r = 1.77 \cdot 10^{-2}\ \text{m}$$

$$B = 0.5\ \text{T}$$

34 a) Using the right-hand rule: b) c)







I is to the left

I is out of the page

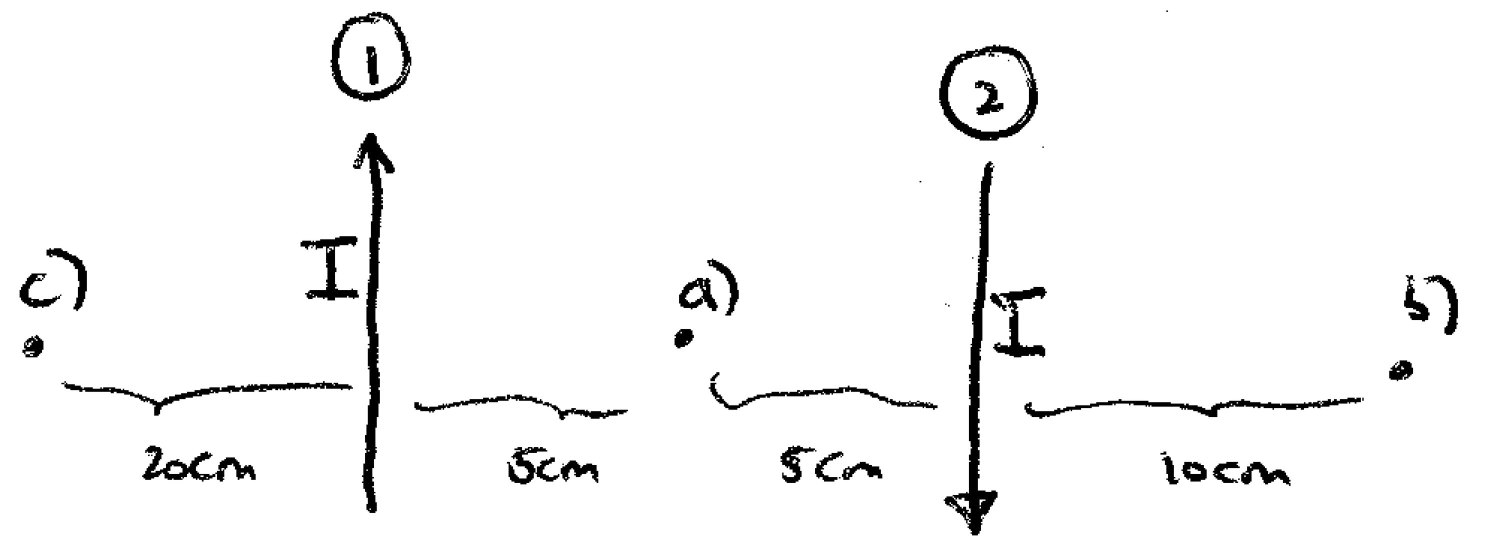
I is to the top right corner.

35) Assume the bolt is a straight wire:

$$\left.\begin{array}{l} B = \mu_0 I / 2\pi r \\ I = 1\cdot10^{4} A \\ r = 100 m \\ \mu_0 = 4\pi\cdot10^{-7}\ T\cdot m/A \end{array}\right\} B = 2\cdot10^{-5} T$$

37) $B = \mu_0 I / 2\pi r$

$$\left.\begin{array}{l} \mu_0 = 4\pi\cdot10^{-7}\ T\,m/A \\ r = ? \\ I = 20 A \\ B = 1.7\cdot10^{-3} T \end{array}\right\} r = \mu_0 I / 2\pi B = 2.35\cdot10^{-3} m.$$

38) 

a) For point a) By the right hand rule B from wire ① is into the page and B from wire ② is into the page. the two will add up

$B_1 = \mu_0 I / 2\pi r$
$I = 5A$
$r = 0.05m$
$\}$ $B_1 = 2\cdot10^{-5}T$

$B_2 = \frac{\mu_0 I}{2\pi r}$
$I = 5A$
$r = 0.05m$
$\}$ $B_2 = 2\cdot10^{-5}T$ $B_T = B_1 + B_2 = 4\cdot10^{-5}T$ into the page

b) B_1 will be into the page B_2 will be out of the page

$B_1 = \mu_0 I / 2\pi r$
$I = 5A$
$r = 0.2m$
$\}$ $B_1 = 5\cdot10^{-6}T$

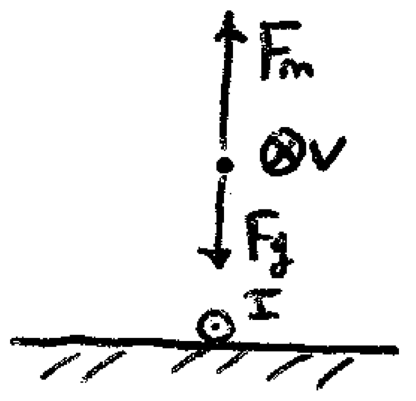
$B_2 = \mu_0 I / 2\pi r$
$I = 5A$
$r = 0.1m$
$\}$ $B_2 = 1\cdot10^{-5}T$ $B_T = B_2 - B_1 = 5\cdot10^{-6}T$ out of the page

c) B_1 will be out of the page B_2 will be into the page

$B_1 = \mu_0 I / 2\pi r$
$I = 5A$
$r = 0.2m$
$\}$ $B_1 = 5\cdot10^{-6}T$

$B_2 = \mu_0 I / 2\pi r$
$I = 5A$
$r = 0.3m$
$\}$ $B_2 = 3.33\cdot10^{-6}T$ $B_T = B_1 - B_2 = 1.67\cdot10^{-6}T$ out of the page

42)



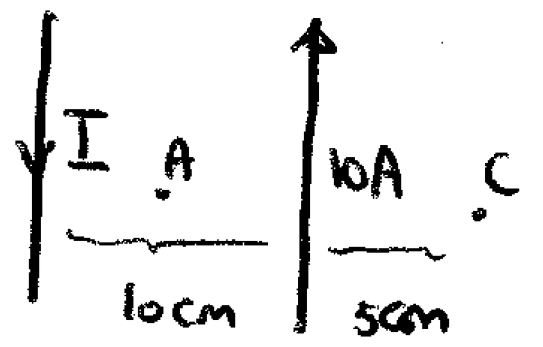
for the proton to move at constant v, the force of gravity must be cancelled by the force of the magnetic field. $F_g = F_m$ $mg = qvB$

$B = \mu_0 I / 2\pi r$ $r = d$ = distance of the wire to the proton giving:

$mg = qv\mu_0 I / 2\pi d$ $d = \dfrac{qv\mu_0 I}{2\pi mg}$

$\left.\begin{matrix} q = 1.602 \cdot 10^{-19}\,C & I = 1.2 \cdot 10^{-6}\,A \\ v = 2.3 \cdot 10^{4}\,m/s & m = 1.67 \cdot 10^{-27}\,kg \\ \mu_0 = 4\pi \cdot 10^{-7}\,Tm/A & g = 9.81\,m/s^2 \end{matrix}\right\}$ $d = 5.4 \cdot 10^{-2}\,m$

56a)



$B_I = B_{10A}$ (i.e. the two magnetic fields must have the same magnitude).

$B_I = \dfrac{\mu_0 I}{2\pi r}$ $\quad I = I \quad r = 0.15m$

$\left.\begin{matrix} B_{10A} = \dfrac{\mu_0 I}{2\pi r} \\ I = 10A \\ r = 0.05m \end{matrix}\right\}$ $\dfrac{\cancel{\mu_0} I}{\cancel{2\pi}(0.15)} = \dfrac{\mu_0\, 10A}{2\pi(0.05)} \Rightarrow \dfrac{I}{0.15} = \dfrac{10}{0.05}$ $I = 30A$.

b) $\left.\begin{matrix} B_{30A} = \dfrac{\mu_0 I}{2\pi r} \\ I = 30A \\ r = 0.05m \end{matrix}\right\}$ $B_{30} = 1.2 \cdot 10^{-4}\,T$ $\quad \left.\begin{matrix} B_{10A} = \dfrac{\mu_0 I}{2\pi r} \\ I = 10A \\ r = 0.05m \end{matrix}\right\}$ $B = 4 \cdot 10^{-5}\,T = B_{10A}$

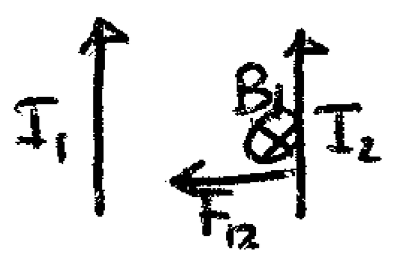
$B_{tot} = B_{10A} + B_{30A} = 1.6 \cdot 10^{-4}\,T$. out of the page

note: we add them, because by the right hand rule, they point in the same direction

44 a) $F/\ell = \frac{\mu_0 I_1 I_2}{2\pi d}$

$$\left.\begin{array}{l} I_1 = 10A \\ I_2 = 10A \\ d = 0.1m \end{array}\right\} F/\ell = 2.10^{-4} N/m$$

By the right hand rule twice,



the force is attractive.

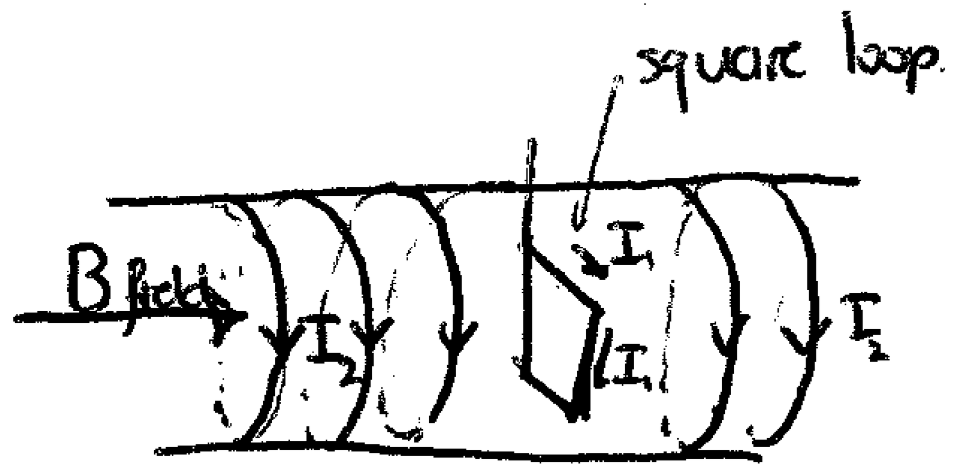
b) The same currents so the magnitude is equal: $F/\ell = 2\cdot10^{-4} N/m$

However, now the force is repulsive.

47) $B = \mu_0 I N/\ell$

$$\left.\begin{array}{l} N = 1000 \text{ turns} \\ B = 1\cdot10^{-4} T \\ I = ? \\ \ell = 0.4m \end{array}\right\} I = B\ell/\mu_0 N = 3.18\cdot10^{-2} A$$

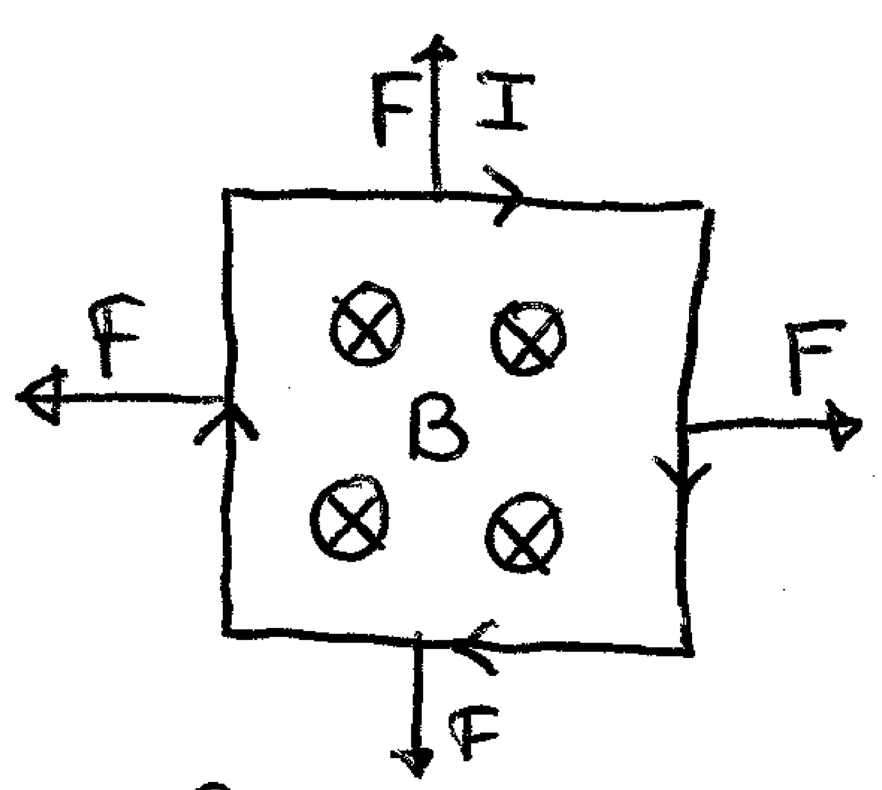
49)



The first thing is to find the B-field inside the solenoid.

$B = \mu_0 I n$

$$\left.\begin{array}{l} n = \text{turns}(\#)/\text{length} = 30\#/cm = 3000\#/m \\ I = 15 A \\ \mu_0 = 4\pi\cdot10^{-7} Tm/A \end{array}\right\} B = 5.65\cdot10^{-2} T \text{ is the B-field inside the solenoid.}$$



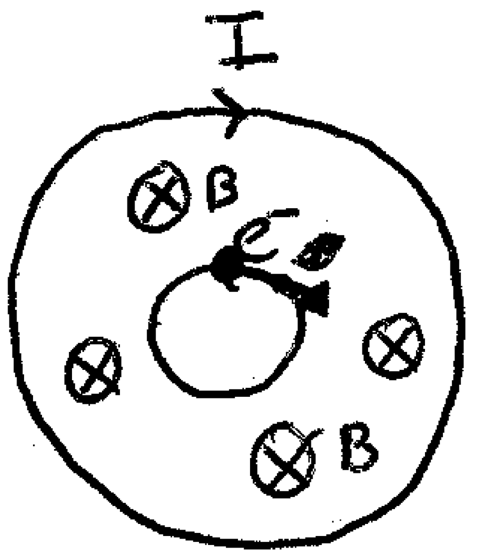
By right hand rule:

$F = BI\ell$

$$\left.\begin{array}{l} I = 0.2A \\ B = 5.65\cdot10^{-2} T \\ \ell = 0.02m \end{array}\right\} F = 2.26\cdot10^{-4} N \text{ outward.}$$

The torque is zero because there is no net force.

50a)



the electron moves in a circle of radius 0.02 m therefore B must equal

$$r = \frac{mv}{qB} \Rightarrow B = \frac{mv}{qr}$$

$\left.\begin{array}{l} V = 1.0 \cdot 10^{4}\ m/s \\ m = 9.11 \cdot 10^{-31}\ kg \\ q = 1.602 \cdot 10^{-19}\ C \\ r = 0.02\ m \end{array}\right\}$ $B = 2.84 \cdot 10^{-6}\ T$ is the magnetic field strength.

$B = \mu_0 n I$ if $n = 25$ turns/cm $= 2500$ turns/m

$I = B/\mu_0 n$

$\left.\begin{array}{l} B = 2.84 \cdot 10^{-6}\ T \\ n = 2500\ \#/m \end{array}\right\}$ $I = 9.04 \cdot 10^{-4}\ A$