EXPLORING

PHYSICS

YEAR 12 - EXPERIMENTS, INVESTIGATIONS & PROBLEMS

Worked Solutions

The STAWA *Worked Solutions* have been developed through the collaboration of teachers working in Department of Education, Catholic Education WA and Association of Independent Schools of WA. Funding assistance was provided by the Department of Education.

The *Worked Solutions* are intended to support the problem sets of the STAWA ATAR Exploring Physics Year 12: experiments, investigations and problems.

In an endeavour to provide the highest quality publication, the STAWA *Worked Solutions* were written and checked by different teachers. This does not guarantee that all answers are correct. Teachers are advised to work through disputed solutions with their students. If they are sure there is an error then they are asked to forward corrections to STAWA by email: admin@stawa.net

The STAWA *Worked Solutions* are a great example of teachers helping teachers for the benefit of all students.

STAWA
SCIENCE TEACHERS' ASSOCIATION OF WESTERN AUSTRALIA

YEAR 12 ATAR

Electromagnetism

Develop an understanding of electromagnetism through investigations of electromagnetic phenomena.

Field theories have enabled physicists to explain a vast array of natural phenomena and have contributed to the development of technologies that have changed the world. Explore technologies, such as large-scale power generation and distribution, motors and generators, electric cars, synchrotron science and medical imaging.

Investigate the production of electromagnetic waves and electromagnetic interactions to understand the operation of:

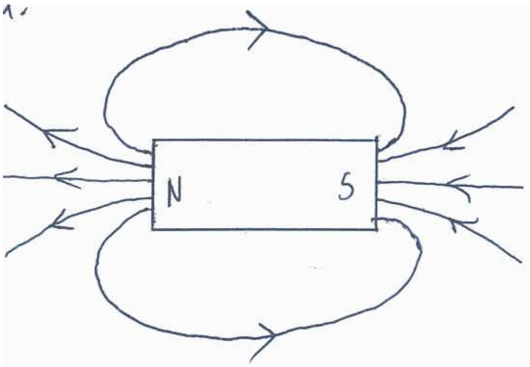
- **direct current motors,**
- **direct current (DC) and alternating current (AC) generators, transformers, and**
- **AC power distribution systems.**

Continue to build skills in planning, conducting and interpreting the results of investigations and in evaluating the validity of data.

Problem Set 6: Magnetic fields and forces

1.

a



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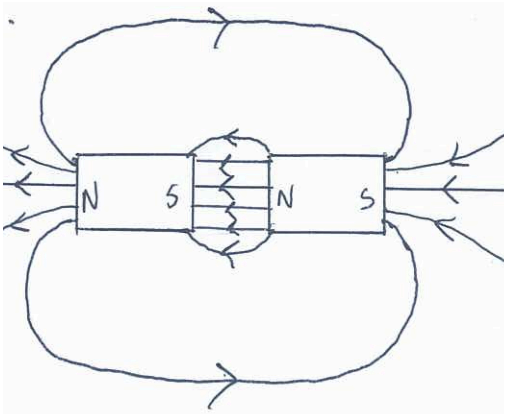

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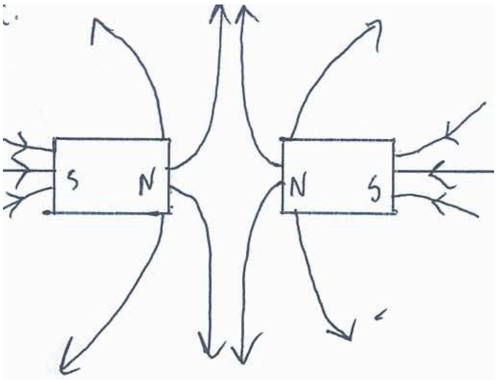

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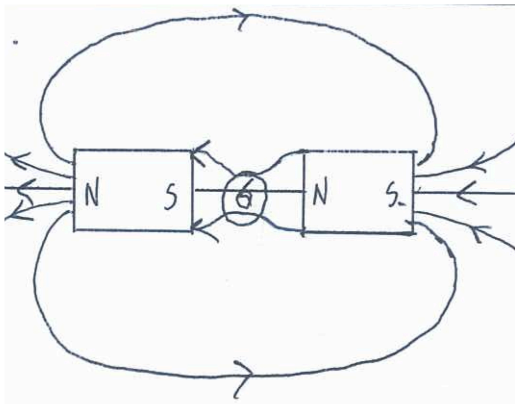
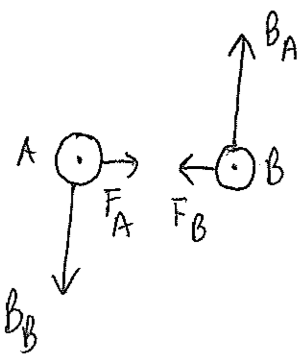
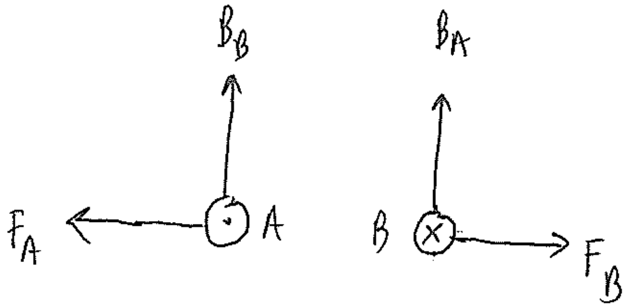


2. The presence of the ferromagnetic materials in the surroundings will alter the direction of the magnetic field lines. This is because ferromagnetic objects contain magnetic domains, making them more permeable to magnetic flux. This results in magnetic flux lines changing direction in order to pass through iron objects instead of passing through air or a vacuum.

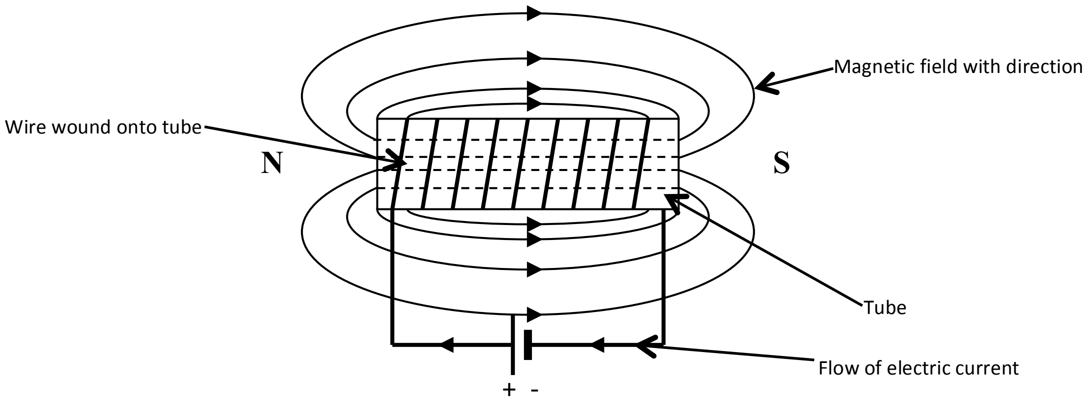
3. a) If both wires carry current in the same direction they will experience a force of attraction towards each other.



b) If the wires carry current in the opposite direction to each other then they will experience a force of repulsion away from each other.



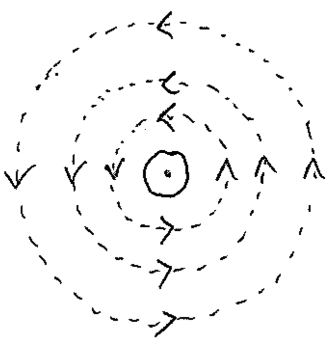
4.



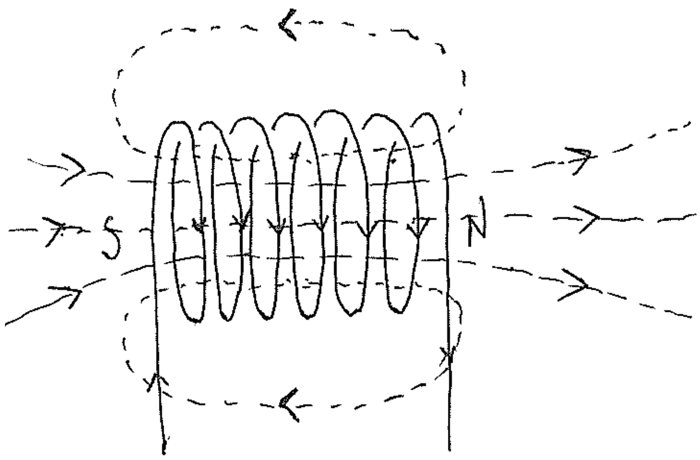
5. Assume the whole of the side length is contained in the field.

$\Sigma\tau = 2 \times Fr$
$= IBlnw$
$= 0.200 \times 0.350 \times 0.1 \times 200 \times 0.0300$
$\mathbf{= 4.20 \times 10^{-2}\ N\ m}$

6.a) A current carrying wire



b) A circular coil



7. Electrical power cords produce magnetic fields when a current is flowing through them. The information is stored on the tapes as specific alignments of magnetic domains in the tape's material. The cords' magnetic fields could alter the magnetic information stored on the tape by causing the domains on the magnetic tape to realign. This can result in the loss of the information.

8. a) Towards the top of the page.
   b) Towards the top of the page.
   c) Towards the top of the page.
   d) No resultant force – charges are moving parallel with the field.

9. a) When the doorbell's switch is closed, the current-carrying solenoid produces a magnetic field. This field magnetises the soft iron rod which is, therefore, attracted to the bell (which must be made of a ferromagnetic material). This force of attraction causes the rod to accelerate to the left. Even though the iron rod's acceleration drops to zero when it is in the centre of the solenoid, its momentum continues its motion towards the left and, eventually, the rod strikes the bell.

   b) The bell will ring louder if the iron rod strikes it with a greater force. The attractive force acting on the piece of soft iron can be increased by:
   - increasing the number of turns in the solenoid (increases 'B');
   - increasing the amount of current that is flowing in the wire (also increases 'B').

   (there may be others)

10. Assume n = 1:
    $F = nIlB$
    $F = 1 \times 10.0 \times 0.12 \times 2.00$
    $F = 2.40$ N

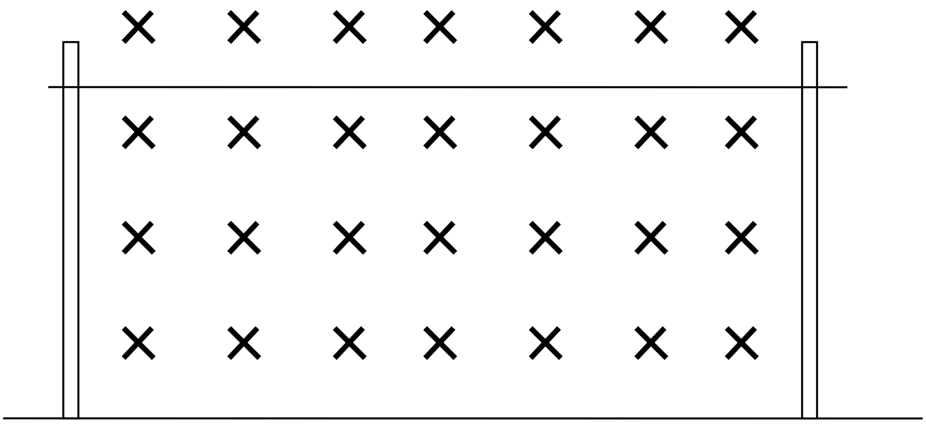
11. The windings (armatures) experience the most torque when they are parallel to the magnetic field (the magnetic force experienced by the coil is at its maximum distance from the pivot of the coil in this position).

This torque reduces to zero as a winding rotates to a perpendicular position relative to the field (r = 0). In other words, the torque experienced by a single winding varies according to a sinusoidal function as it rotates – from a maximum to zero, and so on.

The 12 windings in a commercial motor are arranged at angles to each other within a 360º arc. A winding is only connected to the DC power supply when it is parallel to the magnetic field and experiencing maximum torque. Hence, at any given time, the motor is mostly experiencing maximum torque.

This means the torque produced by the motor remains relatively constant instead of varying between a maximum and zero torque as would be the case for a single armature.

12.



Viewed from the south looking north. X represents Earth external magnetic field.

F= IlB
$F = 40 \times 75 \times 5 \times 10^{-5}$
F = 0.150 N

The direction of the force depends on the direction of the current:

- If conventional current flows to the west, then the magnetic force acts towards the bottom of the page.
- If conventional current flows to the east, then the magnetic force acts towards the top of the page.

13. a) Out of the page.
b) Due to Newton's third law, into the page.
c) The rails is in a fixed positon on the earth, the train is not. Therefore, because the magnet is attached to the train, the train will move into the page.
d) Armature, magnetic field and commutator.

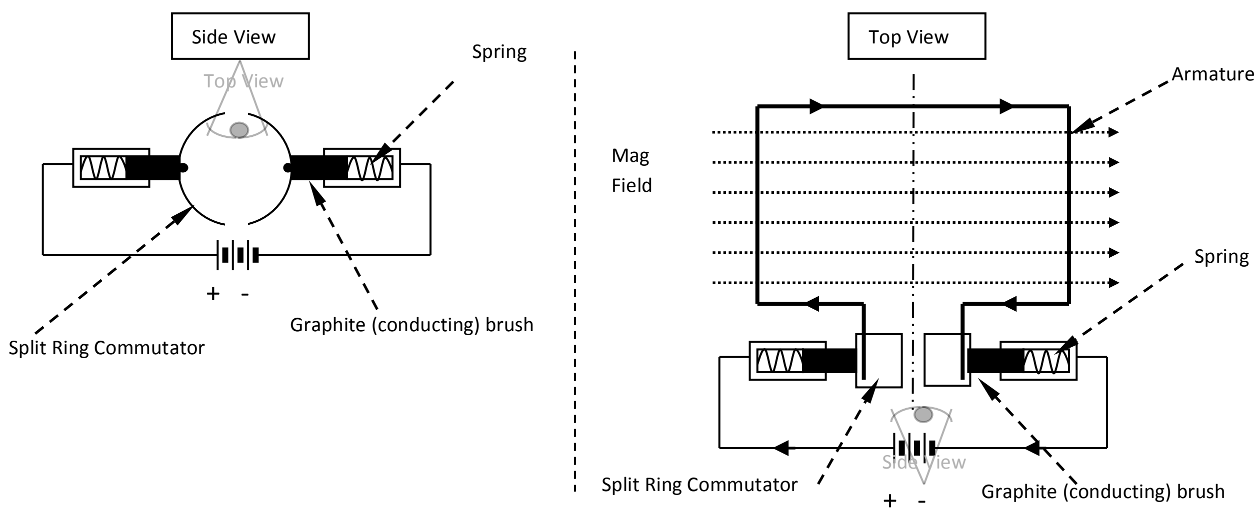
e) The construction of each is very similar. There is, however, a difference in the inputs and outputs.

	Input	Construction	Output
Generator	Motion	Slip rings	Electricity
Motor	Electricity	Commutator	Motion

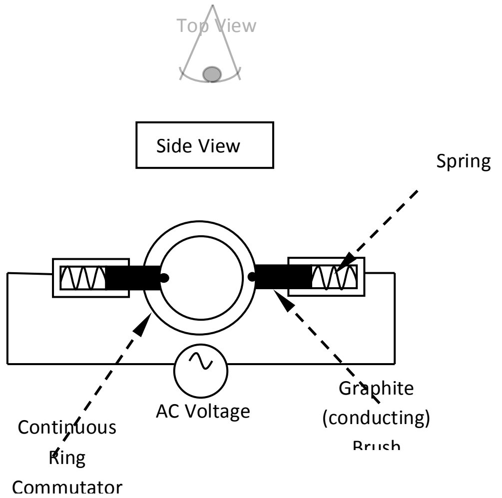
f) Applying the brakes would switch off the electric current that is supplied to the rail. The movement of the magnet past the charges in the rail induces an emf and an electric current in the rail. According to Lenz's Law, the direction of this induced emf and current will oppose the change that produced it (ie – the motion of the train). Hence, the train slows down.

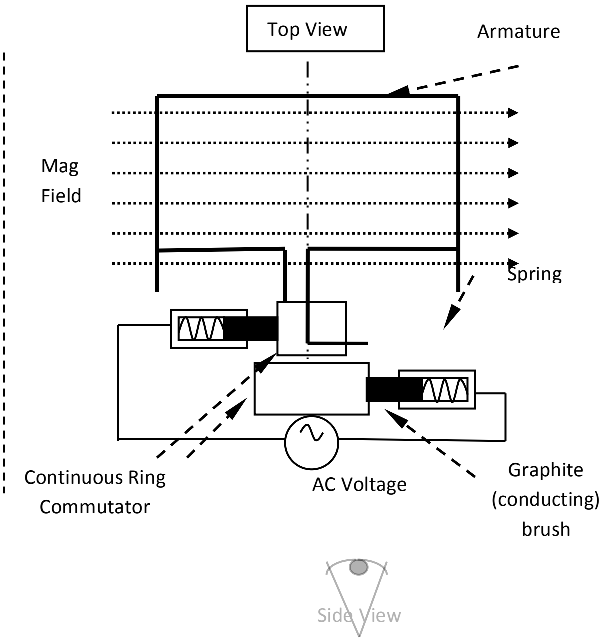
14.

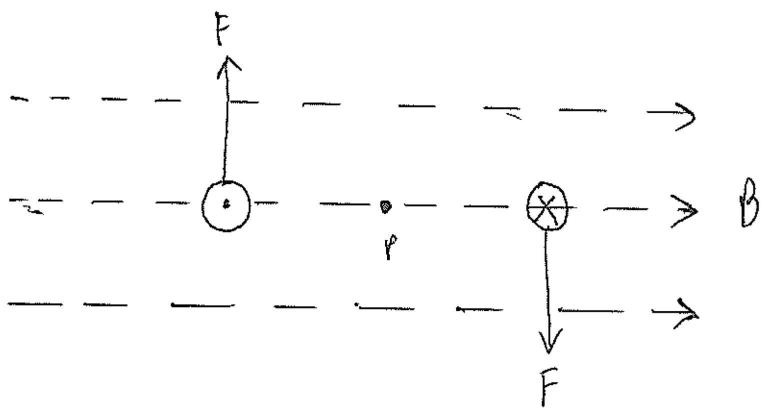
Split Ring Commutator - Direct Current Motor



Continuous Ring Commutator - Alternating Current Motor







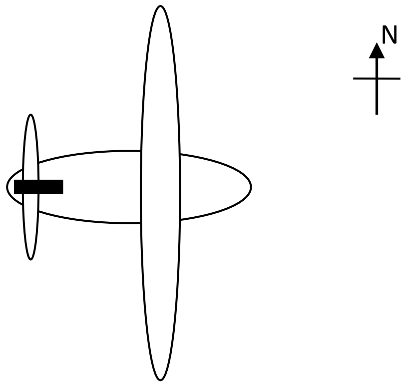
Problem Set 7: Magnetic Induction

1. emf = nlvB

v = 980 km h^{-1} × 1000/3600 = 272.22 m s^{-1}

emf = 1 × 60.0 × (980 / 3.6) × 3.50 × 10^{-5}

emf = 0.572 V



2. a) % efficiency = $\frac{P_{out}}{P_{in}} \times 100$

90 = $\frac{50}{P_{in}} \times 100$

P_{in} = $\frac{50 \times 100}{90}$

P_{in} = 55.6 W

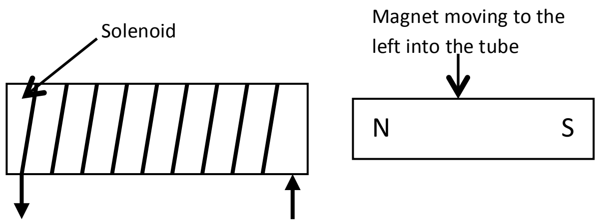
P = VI

55.56 = 240 × I

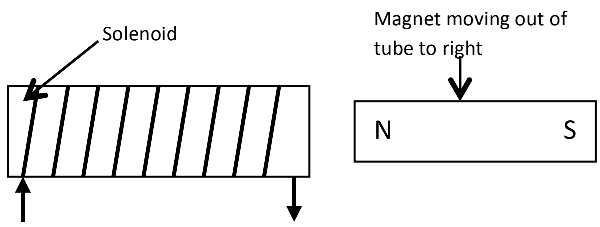
I = 0.231 A

b) The television set is not 100 % efficient. Much of the energy that is lost is converted to heat. This heat must be vented to the surrounding or it will cause the internal components of the television to over heat.

3. Lenz's Law. When the magnet is inserted a current is induced by the increasing field strength. The current is induced in such a direction as to oppose the field that created it. This means that the current that is induced creates its own magnetic field that repels (opposes) the increasing magnetic field strength.



When the magnet is withdrawn a current is induced in the opposite direction to that above. This is because the external magnetic field is weakening. The current induced creates a magnetic field that attempts to attract the external magnet back.



4. a) When the primary circuit closes, a current flows. The change from no current to a steady current, induces a magnetic field for that very short period of time. That magnetic field induces a current in the secondary. Since turning the switch on is a very quick change, the current noted in the secondary coil will only be induced for a very short time hence "transitory".

b) Increase the voltage supplied to the primary.
Decrease the switching time (difficult!).
Increase the ratio of the coils in the secondary to that in the primary.
Link the primary and secondary coils using a hoop of soft iron.

c) Applying Lenz's law, the current in the secondary is opposite that of the current in the primary when the switch is closed and the current increases. As the current is shown travelling from left to right through the primary coil in the diagram, the current through the secondary coil will be right to left.

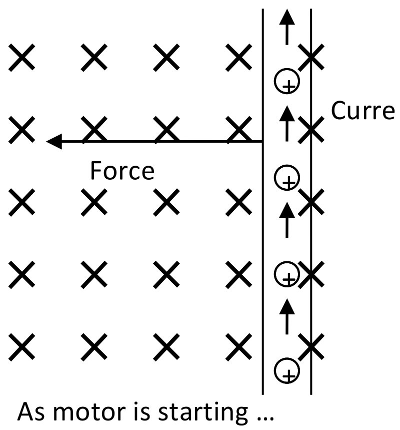
5. a) By moving in an easterly direction, the aerial will be cutting across the field at 90^0 and so an EMF will be induced.

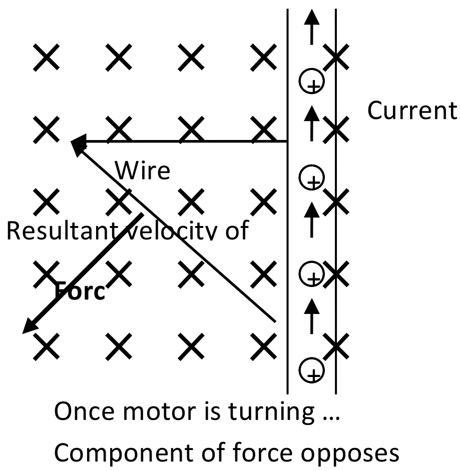
EMF = nlvB
v = 60.0 km h^{-1} = 60.0 x 1000/3600 = 16.67 m s^{-1}
EMF = 1 x 0.500 x 16.67 x 2.50 x 10^{-5}
EMF = 2.08 x 10^{-4} V or 0.208 mV

b) Same answer as part a. The alternative unit is **2.08 x 10^{-4} Wb s^{-1}**

c) The current will change. The aerial is no longer cutting across flux lines but running parallel to the Earth's magnetic field so no current will be induced.

6. Lenz's law. Current induces a force. The force induces a current in opposite direction. This current opposes the original current and shows up as an increased resistance on the coil as the speed increases. This is also known as a back-emf. If as the motor spins the current induced was in the same direction as the original current, too much current would flow and this would result in the motor burning out. This would violate the law of conservation of energy.

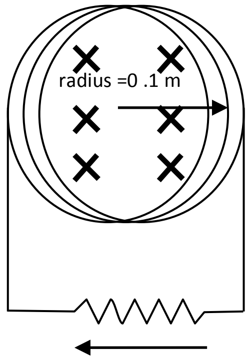




7. emf = n Δ (BA) / t = n (BA – BA) / t
area of a coil = π r^2
emf = 200 (0.5 x π x 0.015^2 – 0) / 10
emf = 20 (0.5 x π 0.015^2 – 0) / 1

emf = 7.07 x 10^{-3} V

8. a) emf = n (BA – BA) / t
emf = 1 (0.25 x π 0.1^2 – 0) / 0.2
emf = 3.92 x 10^{-2} V



b), c)
Based on this diagram the direction of the current is right to left through the resistor.

d) V = IR
3.92 x 10^{-2} = I x 5
I = 7.84 x 10^{-3} A

9. a) emf = nlvB
v = 80 km h^{-1} x 1000/3600 = 22.2 m s^{-1}
emf = 1 x 1.00 x 22.2 x 36.0 x 10^{-6}
emf = 7.99 x 10^{-4} V

b) If the earth's magnetic field is out of the earth the force on the electrons will be south east. If the earth's magnetic field is into the earth the force on the electrons will be north west.

10 . Lenz's law. As the plate approaches the magnet the field strength increases. This induces a current (eddy current) in the plate. The eddy current creates its own magnetic field in opposition to the strengthening original external magnetic field. This causes repulsion and slows the approach of the plate.

As the plate passes out the other side the external magnetic field experienced by the plate is decreasing in strength. This induces a current in the plate. The current creates its own magnetic field in support of the weakening external magnetic field. This attracts the plate and slows its movement away from the magnet.

The slowing on approach and slowing on exit causes the swing of the plate to be damped and so the pendulum comes to a stop sooner.

11. Assuming that 180 V is the average voltage (RMS)
T = 1 / 50
T = 0.02 s
Change in flux will happen over a quarter of a turn so t = ¼ T = 0.005s

emf = nΔBA / t
emf = n (BA – BA) / t
180 = n (0.200 x 2.00 x 10^{-2} – 0) / 0.005
n = 225 turns

12.a) l = 20.0 mm = 0.0200 m
IR = nlvB
10.0 x 10^{-3} x 2.50 = 1 x 0.0200 x v x 0.500
v = 2.50 m s^{-1}

b) F = IlB
F = 10.0 x 10^{-3} x 0.0200 x 0.500
F = 1.00 x 10^{-4} N

13.a) T = 1 / 60.0

T = 0.0167 s

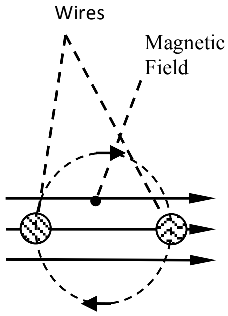
t = ¼ T = 0.00417 s

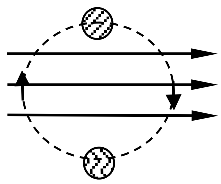
emf = n (BA – BA) / t

240 = 300 (B x 0.2 x 0.2 – 0) / 0.00417 s

B = 8.33 x 10^{-2} T

b)





Maximum Voltage
Wires cut across flux

Minimum Voltage
Wires move parallel with flux

14. The metal will usually be of a ferromagnetic type. The current through the coil magnetises the iron, and the field of the magnetised material will add to the field produced by the coil. The core can increase the magnetic field of a coil by many times over what it would be without the core, resulting in a larger deflection for any given current.

15. Need to make an assumption regarding the direction the plane is flying in respect to the Earth's magnetic field.

Assuming the plane's wing is at right angles to the Earth's magnetic field, then the EMF induced will be at a maximum and

From question:

l = 64.0

v = 920 km h^{-1} x 1000/3600 = 255.6 m s^{-1}

B = 1.02 x 10^{-5} T

Induced EMF, ε = l v B   ε = 64.0 x 255.6 x 1.02 x 10^{-5} = **0.167 V**

16. a)

$$\varepsilon = N\frac{(\phi_2 - \phi_1)}{t}\sin\theta$$

$$\varepsilon = N\times\frac{(B_2A - B_1A)}{t}\sin\theta$$

$$\varepsilon = N\times\frac{(B_2 - B_1)A}{t}\sin\theta$$

Area of the coil, A = Πr^2 = 3.1416 x 0.0800^2 = 20.11 x 10^{-3} m^2

B_2 = 3.95

$B_1 = 0.850$

N= 45.0

$\theta = 300\text{-}270 = 30^0$

$$\varepsilon = 45.0 \times \frac{(3.95 - 0.850) \times 20.11 \times 10^{-3}}{450 \times 10^{-3}} \times \sin 30$$

$$\varepsilon = 3.117 = 3.12V$$

b) V = IR or I = V/R

R = 12.8 Ω

$$I = \frac{V}{R}$$

$$I = \frac{3.117}{12.8} = 0.2435 = 0.244\,A$$

17.

$$\varepsilon = N \times \frac{\Delta(BA_\perp)}{t}$$

Area of the coil, A = Πr^2

Diameter of the coil = 6.80 cm = 0.0680 m and r = 0.0680/2 = 0.0340

A = 3.1416 x 0.0340^2 = 3.632 x 10^{-3} m^2

ΔB = 250 mT = 250 x 10^{-3} T

N = 60.0 turns

t = 3.50 s; and so

$$\varepsilon = 60.0 \times \frac{(250 \times 10^{-3} \times 3.632 \times 10^{-3})}{3.50}$$

$$\varepsilon = 15.6 \times 10^{-3} V$$

18. a)

$$\varepsilon = N \times \frac{\Delta(BA_\perp)}{t}$$

Area of the coil, A = l x w = 0.0500 x 0.0180 = 900 x 10^{-6} m^2

N = 300 turns

B = 0.180 T

t = ¼ T = ¼ x 1/f = ¼ x 1/60 = 4.167 x 10^{-3} s

$$\varepsilon = 300 \times \frac{(0.180 \times 900 \times 10^{-6})}{4.167 \times 10^{-3}}$$
$$\varepsilon = 11.663 = 11.7V$$

b)

$$\varepsilon_{rms} = \frac{\varepsilon_{max}}{\sqrt{2}} = \frac{11.663}{\sqrt{2}} = 8.247 = 8.25V$$

c) Curved poles keeps more of the coil more perpendicular to the magnetic field for a greater amount of time.

19.

Emf (max) = 2x pi x85 x 0.25 x 0.031 x 60
= 248 V

Emf Rms = 175 V

6 s

20.

$$\varepsilon = N \times \frac{\Delta(BA_{\perp})}{t}$$

N= 240 turns

B = 0.860 T

Area of the coil, A = Πr^2

Diameter of the coil = 12.0 cm = 0.120 m and r = 0.120/2 = 0.060

A = 3.1416 x 0.060^2 = 11.310 x 10^{-3} m^2

t = ¼ T = ¼ x 1/f = ¼ x 1/2400 = 104.17 x 10^{-6} s

$$\varepsilon = 240 \times \frac{(0.860 \times 11.310 \times 10^{-3})}{104.17 \times 10^{-6}}$$

$$\varepsilon = 22.409 \times 10^{3} = 22.4 kV$$

$$\varepsilon_{rms} = \frac{\varepsilon_{max}}{\sqrt{2}} = \frac{22.409 \times 10^{3}}{\sqrt{2}} = 15.846 \times 10^{3} = 15.8 kV$$

21.

$$\varepsilon = N \times \frac{\Delta(BA_{\perp})}{t}$$

N= 1500 turns

B = 51.0 μ T = 51.0 x 10^{-6} T

Area of the coil, A = Πr^2

Diameter of the coil = 0.240 m and r = 0.240/2 = 0.120

A = 3.1416 x 0.120^2 = 0.04524 m^2

t = 1/2 T since the coil is rotated through only 180^0 = 1/2 x 2.50 x 10^{-3} = 1.25 x 10^{-3} s

$$\varepsilon = 1500 \times \frac{(51.0 \times 10^{-6} \times 0.04524)}{1.25 \times 10^{-3}}$$

$$\varepsilon = 2.769 = 2.77 V$$

22.

$$\varepsilon = N \times \frac{\Delta(BA_{\perp})}{t}$$

Rearranging for N

$$N = \frac{\varepsilon \times t}{\Delta(BA_{\perp})}$$

ε = 240 RMS = 240 x √2 = 339.41 V peak

Diameter of the coil = 7.60 cm = 0.0760 and r = 0.0760/2 = 0.0380

A = 3.1416 x 0.0380^2 = 0.00454 m^2

B = 300 mT = 300 x 10^{-3} T

t = ¼ T = ¼ x 1/f = ¼ x 1/50 = 0.005 s

$$N = \frac{339.41 \times 0.005}{(300 \times 10^{-3} \times 0.00454)}$$

$$N = 1246 turns, say 1250 turns$$

23. Note incorrect wording in question. Coils are rectangular hence can not have a diameter – assume 6.00 cm long, 8.00 cm *wide*

$$\varepsilon = N \times \frac{\Delta(BA_{\perp})}{t}$$

Rearranging for B

$$B = \frac{\varepsilon \times t}{NA}$$

ε = 20.0 V peak

N = 400 turns

Area of each coil = 0.0600 x 0.0800 = 0.00480 m^2

t = ¼ T = ¼ x 1/f

f = 400 rpm = 400 / 60 = 6.667 Hz

so t = 0.0375 s

$$B = \frac{20.0 \times 0.0375}{400 \times 0.00480}$$

$$B = 0.391 T$$

Problem Set 8: Electrical energy and power

1a) $P = V \times I$
$P = 3000 \times 20$
$\mathbf{P = 60\ 000\ W = 60.0\ kW}$

b) $E = P \times t$
$E = 60\ 000 \times 5 \times 10^{-3}$
$\mathbf{E = 300\ J}$

c) $V = IR$
$3000 = 20 \times R$
$R = \frac{3000}{20}$
$\mathbf{R = 150\ \Omega}$

2a) $P_{total} = P_{per\ meter\ on\ panel} \times 10/100 \times n_{metres\ square}$
$2000 = 1373 \times 0.1 \times n_{metres\ square}$
$\mathbf{n = 14.6\ m^2}$

b) $P = V^2 / R$
$2000 = 50^2 / R$
$\mathbf{R = 1.25\ \Omega}$

3a) $P = V \times I$
$125\ 000 = 1500 \times I$
$\mathbf{I = 83.3333\ A = 83.3\ A}$

b) $V = IR$
$1500 = 83.3333 \times R$
$\mathbf{R = 18.0\ \Omega}$

4 The thicker wire is on the low voltage side of the transformer. In a step down transformer this is on the secondary side. If the power out of the transformer is similar to the power in, then based on P = VI, if the voltage drops on the secondary side then the current must increase. This increase of current flow results in a heating effect in the secondary wire due to the resistance of the wire. If the wire is made thicker then the resistance of the wire is reduced based on the resistivity formula
$R = \rho l / A$

5 Current in the outer coil is anti-clockwise and increasing at a constant rate. By Lenz's Law the current on the inner coil is clockwise and steady.
Primary current created a strengthening field. Strengthening field induces current in the secondary. The magnetic field created by the secondary current is in such a direction as to oppose the change that created it.

6a) $\frac{V_p}{V_s} = \frac{I_s}{I_p}$

$\frac{240}{12\,000} = \frac{I_s}{I_p}$

$\frac{I_s}{I_p} = \frac{240}{12\,000}$

$I_s = I_p$
1 : 50
0.02 : 1 times

b) $\frac{V_p}{V_s} = \frac{N_p}{N_s}$

$\frac{240}{12\,000} = \frac{200}{x}$

N_s = 10 000 turns

c) 98% of your answer to part a). No power is quoted.
Ratio = 0.02 × 98/100 = 0.0196 : 1

7a) $P = V^2 / R$
$2500 = 240^2 / R$
$R = = 240^2 / 2500$
R = 23.0 Ω

b) V = I R
240 = I × 23
I = 10.43 A = 10.4 A

I = q / t
q = **10.43 × 2 × 60**
q = 1.25 × 10^3 C

8a) We assume that the energy is lost before arriving in the motor.

$\% \text{ efficiency} = \frac{\text{out}}{\text{in}} \times 100$

$80 = \frac{1000}{\text{in}} \times 100$

in = 100 000 / 80

in = 1250 W

P = VI
1250 = 12 × I

I = 104.17 A = 104 A

b) The wires connecting the battery to the starter motor are thicker than the other wires. This is because the current supplied to the starter motor is large Since $P_{loss} = I^2 R_{wire}$ when the resistance in the wire is large, the power loss will be large. By using a thicker wire, the resistance of the wire is decreased and hence the power losses are decreased.

9a) An electricity sub-station is a transformer converting the higher voltages from direct supply from the power station to lower voltage in preparation for distributing out to the local area. Power from the power station is supplied at high voltages to reduce the supply current and hence power losses. Typical voltage drop is from 250 kV initially to 66kV or 33 kV and then to 340 V

b) i) Train systems operate at higher voltages than neighbourhood houses.
ii) The power demand of a train is near zero when stationary, very large when accelerating and medium when running at a constant velocity. These fluctuations in demand will result in fluctuations in the amount of power available to houses also connected to the substation.

c) The voltage is stepped up in order to minimise the current flowing in the high tension (high voltage) wires. By decreasing the current, it decreases the power loss in the transmission line.
$P_{loss} = I^2R_{lines}$

10a) Assume that the transformers are 100% efficient, power losses are only in the transmission lines.

$P = VI$
$500\,000 = 2000 \times I$
$I = 250$ A

$P_{loss} = I^2 R$
$P_{loss} = 250^2 \times 0.500$
$P_{loss} = 31\,250$ W = 31.2 kW

b) $P = VI$
$500\,000 = 20000 \times I$
$I = 25.0$ A

$P_{loss} = I^2 R$
$P_{loss} = 25^2 \times 0.500$
$P_{loss} = 312.5$ W = 312 W

c) Increase voltage, decrease current, decease power loss by $P_{loss} = I^2R_{lines}$.

11 Transmisson pylons have to be high enough above the ground to reduce the effect of the magnetic field induced by the power lines. These would otherwise induce currents in metallic objects in the surroundings (houses, cars etc). Eventually the cost of the larger pylons outweighs the cost associated with the power loss.

12a) $P_{loss\ in\ cable} = V_{loss\ in\ cable} \times I$
$P_{loss\ in\ cable} = (415 - 405) \times 200$
$P_{loss\ in\ cable} = 10 \times 200$
$P_{loss\ in\ cable} = 2000$ W

b) $P_{loss\ in\ cable} = I^2 R$
$2000 = 200^2 R$
$R = 0.05\ \Omega$

R = length × Resistance per metre
0.05 = length × 0.40
Length = 0.05 / 0.40 = 0.125 m

c) The power loss can be reduced by reducing the current in the wire. Changing the transformer ratios to increase output voltage will decrease the output current and allow the motor to work at a larger distance.

13a) % efficiency = $\frac{out}{in} \times 100$

$80 = \frac{5000}{in} \times 100$

in = 500 000 / 80 **input from motor = 6250 W = 6.25 kW**

b) Heat losses in converting the chemical potential energy in the fuel to mechanical energy in the generator, heat energy losses due to friction in bearings, resistance in the windings of the armature. Sound.

14a) The voltage available to other devices should remain at 240 V. If a lot of current is supplied to one device, for example the electric motors or arc welding equipment, the mains may difficulty supplying sufficient power so some dimming of lights or reduction in speed of the motor may occur. (brown out)

b) As more power is supplied to a house an increasing amount of current has to flow in the supply lines to the house. This will cause heating of the supply lines according to the power loss formula ($P_{loss} = I^2R_{lines}$)

c) If excessive current is drawn by one device, insufficient power may be available for the other appliances running including the lights. The lights may dim.

15 Train runs away from the transformer along the lines until the voltage available = 20.0 kV

Current provided by transformer.
P = VI
$3 \times 10^6 = 25\,000 \times I$
I = 120 A

Voltage drop along line is from 25.0 kV to 20.0 kV.

Voltage drop = 25.0 kV – 20.0 kV = 5 kV = 5 000 V.

$P_{loss} = V \times I$
$P_{loss} = 5000 \times 120$
P_{loss} = 600 000 W = 600 kW

$P_{loss} = I^2 R$ 600 000 W
600 000 = $120^2 \times R$
R = 41.67 Ω

R_{line} = (R per km) × (distance in km)
41.67 = 1.2 × (distance in km)
(distance in km) = 34.7 km or approximately 35 km.

16. a) There are four main causes of inefficiency in transformers. List any two:

Resistance of the windings

Flux leakage – i.e. poor design may mean not all of the flux from the primary coil is linked to the secondary coil.

Eddy currents in the iron core

Hysteresis – Constant reversing of the magnetic field in the core expends energy.

All but flux leakage lead to energy losses due to heating.

b) V_p = 240 V rms

V_s = ?

N_p = 300 turns

N_s = 4800 turns

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

$$V_s = \frac{V_p \times N_s}{N_p} = \frac{240 \times 4800}{300} = 3840 Vrms$$

$$V_s peak = V_s rms \times \sqrt{2} \times \% efficiency$$

$$V_s peak = 3840 \times \sqrt{2} \times \frac{92}{100} = 4996 = 5.00 kV$$

c) $I_s$peak = $I_s$rms x √2= 40 x 10^{-3} x √2= 0.05657 A

P_s peak = 4996 x 0.05657 = 282.62 W

Based on efficiency losses P_p peak = P_s peak x 100/92 = 307.20 W

$V_p$peak = $V_p$rms x √2= 240 x √2 = 339.41

$$P = VI$$

$$I = \frac{P}{V} = \frac{307.20}{339.41} = 0.905 A$$

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17. $V_p = 240$ V

Step down: $V_s = 6.30$ V, $I_s = 8.00$ A, $P_s = VI = 6.30 \times 8.00 = 50.4$ W, $N_s = 84.0$ turns

Step up: $V_s = 35000$ V, $I_s = 15.0 \times 10^{-3}$ A, $P_s = VI = 35000 \times 15.0 \times 10^{-3} = 525$ W

a)

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

$$N_p = \frac{V_p \times N_s}{V_s}$$

$$N_p = \frac{240 \times 84.0}{6.30} = 3200 turns$$

b)

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

$$N_s = \frac{V_s \times N_p}{V_p}$$

$$N_s = \frac{35000 \times 3200}{240} = 466667 turns$$

c) Total power drawn in the primary coil = sum of the secondaries

$P_p = 50.4 + 525 = 575.4$ W

$$P = VI$$

$$I = \frac{P}{V}$$

$$I = \frac{575.4}{240} = 2.3975 = 2.40 A$$

d) The coils in the step up transformer would use considerably finer wire than the step down. As the current is comparably smaller, power losses are minimised. The step down transformer should have thicker wire in order to minimise resistive power losses with a higher current.

18.a) Back emf ε = I R = 9.00 x 20.0 = 180 V

Operating voltage across the coil = V – ε = 414 – 180 = 234 V

b) At switch on, the motor is not turning so there is no back emf

$$R_T = \frac{V}{I} = \frac{414}{12} = 34.5\Omega$$
$$R_s = R_T - R_m$$
$$R_s = 34.5 - 20.0 = 14.5\Omega$$

19.a) Initially the motor is not turning so there is no back emf, and

$$I = \frac{V}{R} = \frac{240}{6.30} = 38.095 = 38.1A$$

b) At full speed, the back emf opposes the exterior source, and

$$V - \varepsilon = IR$$
$$240 - 212 = I \times 6.30$$
$$I = \frac{240 - 212}{6.30} = 4.44A$$

20.

At start up, there is no back emf so

$$R_{motor} = \frac{V}{I} = \frac{12}{5.00} = 2.40\Omega$$

At full speed, there is a back emf and

$$V - \varepsilon = IR$$
$$\varepsilon = V - IR$$
$$\varepsilon = 12 - 1.20 \times 2.40 = 9.12V$$

21. Initially, the motor is not turning and there is no induced back emf. The current is very high. As the motor spins up to operating speed, the back emf increases and the current being drawn reduces.

Problem Set 9: Charged particles in an electric field

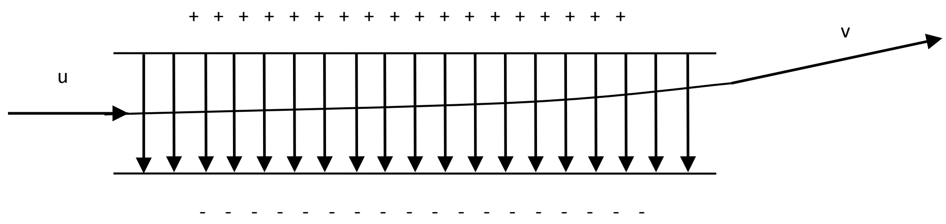
1. $F = q E$
   $7.20 \times 10^{-13} = 1.60 \times 10^{-19} \times \mathbf{E}$
   $\mathbf{E = 4.50 \times 10^{6}\ N\ C^{-1}}$

2. By the square rule …
   $F = q \times E$ so $E = F / q = E$, hence E is measured in N/C

   By the square rule …
   $V = E\ s$ so $E = V / s$, hence E is measured in V / m.

   As both can be used to calculate E then the units are equivalent.

3a)



b) initial velocity (u) is purely to the right
Final velocity (v) is the same to the right but also contains a component towards the top of the page. This component has been provided by the electric field.

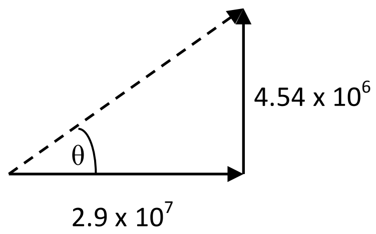
Time for which the electric field acts = the time for which the charge is between the plates.

$v = s / t$
$t = s / v$
$t = 0.03 / 2.9 \times 10^{7}$
$\mathbf{t = 1.0344 \times 10^{-9}\ s}$

The force provided by the field causes the electron to accelerate towards the positive plate.

$qE = m (v – u) / t$
$1.6 \text{ x } 10^{-19} \times 2.5 \times 10^{4} = 9.11 \times 10^{-31} (v – 0) / 1.0344 \times 10^{-9}$
$\mathbf{v = 4.54 \times 10^{6}\ m/s}$ **parallel to the field**

Combine the horizontal and the vertical velocities to find the angle.



Magnitude
$R = \sqrt{([2.9 \times 10^{7}]^2 + [4.54 \times 10^{6}]^2}$
$\mathbf{R = 2.94 \times 10^{7}\ m/s}$

Angle
$\tan \theta = 4.54 \times 10^{6} / 2.9 \times 10^{7}$
$\mathbf{\theta = 8.90^{0}}$
Answer **= 2.94×10^{7} m/s at 8.90^{0} to the original direction.**

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3c) The electron experiences a force which causes an acceleration towards the positive plate (i.e. towards the top of the page as shown in the diagram).

d) Electrons are deflected toward a particular point on the screen. The electrons on striking the screen cause a chemical on the screen to fluoresce. This creates an image on the screen.

e) $W = qV$
$W = 1.6 \times 10^{-19} \times 1.80 \times 10^{3}$
$\mathbf{W = 2.88 \times 10^{-16}\ J}$

f) $V = E\ s$
$E = V / s$

$E = 1.80 \times 10^{3} / 30.0 \times 10^{-3}$
$\mathbf{E = 6.00 \times 10^{4}\ N\ C^{-1}}$

4. This is done to remove the interference of external (unwanted) radio signals and other EMR. The box acts as a faraday cage. The only signal that can get into the box is the one that is passed down the TV aerial and is able to pass through the circuitry that selects the radio or TV channel. All other signals are excluded.

5a) $F = q \times E$

$F = 5.00 \times 10^{-9} \times 2.20 \times 10^{4}$
$\mathbf{F = 1.10 \times 10^{-4}\ N}$

$W = F \times s$
$W = 1.10 \times 10^{-4} \times 3.00 \times 10^{-3}$
$\mathbf{W = 3.30 \times 10^{-7}\ J}$

b) $W = q \times V$
$V = W / q$
$V = 3.30 \times 10^{-7} / 5.00 \times 10^{-9}$
$\mathbf{V = 66.0\ V}$

6. $V = E\ s$
$E = V / s$
$E = 12 / 120 \times 10^{-3}$
$\mathbf{E = 1.00 \times 10^{2}\ N\ C^{-1}}$ **or** $\mathbf{1.00 \times 10^{2}\ V\ m^{-1}}$ **(these are equivalent units)**

7a) $W(eV) = q\ V / e$
$W(eV) = e\ V / e$
$W(eV) = V$
$W(eV) = 5.00 \times 10^{3}\ eV$

b) $W = q\ V$
$W = 1.6 \times 10^{-19} \times 5.00 \times 10^{3}$
$W = 8.00 \times 10^{-16}\ J$

8a) $W(eV) = q\ V / e$
$W(eV) = 2e\ V / e$

$W(eV) = 2V$
$W(eV) = 2 \times 5.00 \times 10^3$ V
$W(eV) = 1.00 \times 10^4$ eV

8b) $W = q\,V$
$W = 2 \times 1.6 \times 10^{-19} \times 5.00 \times 10^3$
$\mathbf{W = 1.60 \times 10^{-15}}$ **J**

9a) $V = E\,s$
$E = V / s$
$E = 1.50 \times 10^4 / 2.70 \times 10^{-4}$
$\mathbf{E = 5.55 \times 10^7}$ **N C^{-1}**

b) $W = q \times V$
$W = 1.6 \times 10^{-19} \times 1.50 \times 10^4$
$\mathbf{W = 2.4 \times 10^{-15}}$ **J**

10a) The shirt has a static charge on it from the outer surface of the car. The dust particles became charged by induction and, hence, were opposite that of those on the shirt and so the dust was attracted.

b) $F = qE$
$F = 4 \times 10^{-6} \times 9$
$\mathbf{F = 3.60 \times 10^{-5}}$ **N**

c) Assuming that the electric field is uniform:

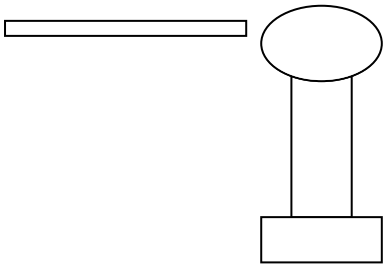
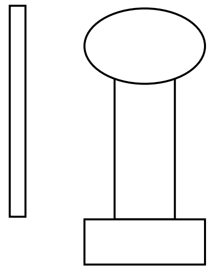
$W = F \times s$
$3.6 \times 10^{-7} = 3.6 \times 10^{-5}$ x s
s = 0.01 m

$W = q \times V$
$3.6 \times 10^{-7} = 4$ x $10^{-6} \times V$
$\mathbf{V = 9 \times 10^{-2}}$ **V**

11a) An electrostatic precipitator uses a static charge to attract the dust and soot out of the smoke and gasses passing up a chimney or smoke stack. This leave gases that come out the end of the chimney clear of dust and soot.

b) A power company would install one to meet pollution regulations governing the type of waste that it can pollute the environment with.

12.

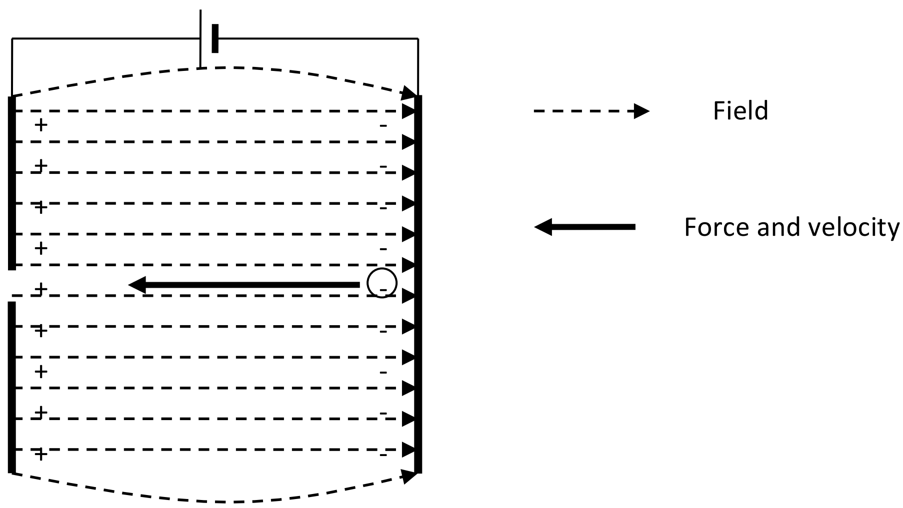
Light Produced	No Light produced
 The tube is in line with the electric field lines which accelerate charged particles (electrons) along the tube causing the light to work.	 The tube is parallel line with the electric field lines which accelerate charged particles (electrons) along the tube causing the light to work.

13. $qV = ½ m v^2$

$1.6 \text{ x } 10^{-19} \times 800 = 0.5 \text{ x } 1.67 \times 10^{-27} \times v^2$

$\mathbf{v = 3.92 \times 10^5 \text{ m s}^{-1}}$

14a)



b)

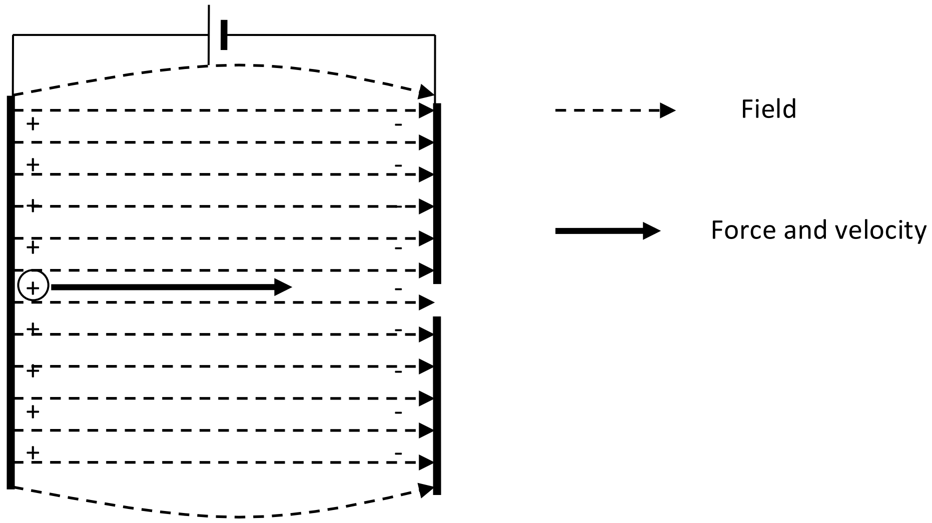
Method 1	Method 2
$F = qE$ $F = 1.6 \times 10^{-19} \times 2.5 \times 10^4$ $\mathbf{F = 4.00 \times 10^{-15} \text{ N}}$ $W = F \times s$ $W = 4 \times 10^{-15} \text{ x } 10 \times 10^{-2}$ $\mathbf{W = 4 \times 10^{-16} \text{ J}}$	$V = E \times s$ $V = 2.5 \times 10^4 \times 0.1$ $\mathbf{V = 2.5 \times 10^3 \text{ V}}$ $W = q \times V$ $W = 1.6 \times 10^{-19} \times 2.5 \times 10^3$ $\mathbf{W = 4 \times 10^{-16} \text{ J}}$

14c) $W = \frac{1}{2} m v^2$

$4 \times 10^{-16} = 0.5 \times 9.11 \times 10^{-31} \times v^2$

$v = 2.96 \times 10^7$ m s^{-1} **This is less than the speed of light so probably ok.**

d)



e) Same kinetic energy or work as before because charge has not changed magnitude

$W = 4 \times 10^{-16}$ J

f) Final velocity of proton will be less than that of the electron because it has more mass. As m increases v^2 decreases.

$W = \frac{1}{2} m v^2$

$4 \times 10^{-16} = 0.5 \times 1.67 \times 10^{-27} \times v^2$

$v = 6.92 \times 10^5$ m s^{-1}

15a) $W = q \times V$

$W = 1.6 \times 10^{-19} \times 4000$

$W = 6.4 \times 10^{-16}$ J (4000 eV)

$W = \frac{1}{2} m v^2$

$6.4 \times 10^{-16} = \frac{1}{2} \times 9.11 \times 10^{-31} \times v^2$

$v = 3.75 \times 10^7$ m s^{-1}

b) $V = E s$

$E = V / s$

$E = 200 / 10.0 \times 10^{-2}$

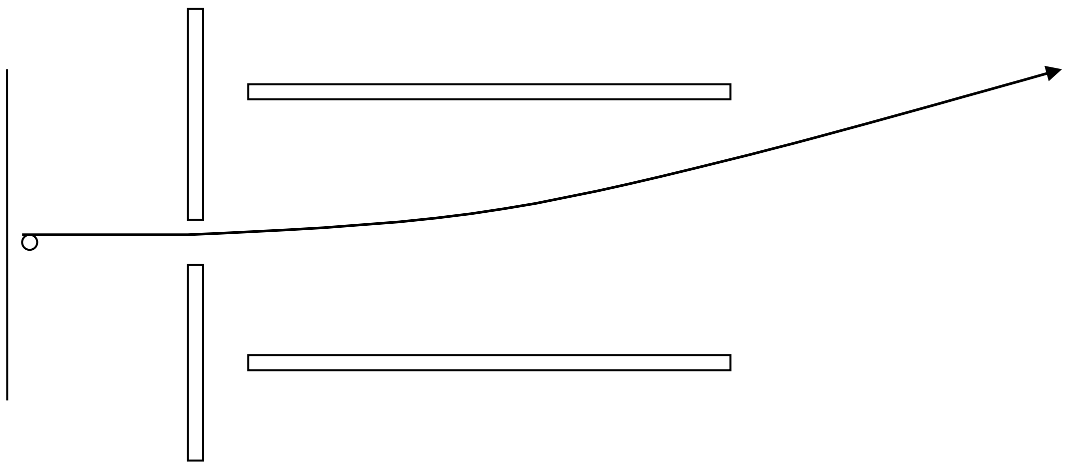
$E = 2000$ N C^{-1} or 2000 V m^{-1}

$F = q \times E$

$F = 1.6 \times 10^{-19} \times 2000$

$F = 3.20 \times 10^{-16}$ N

15c)



16a) If this were not done in a vacuum the accelerating electron would collide with the air gas molecules in the air and the electrons would be deflected or would be lost via ionisation with the molecules.

b) $W = q \times V$

$W = 1.6 \times 10^{-19} \times 2000$

$\mathbf{W = 3.20 \times 10^{-16}\ J}$

$W = F \times s$

$F = W / s$

$F = 3.2 \times 10^{-16} / 5 \times 10^{-2}$

$\mathbf{F = 6.4 \times 10^{-15}\ N}$

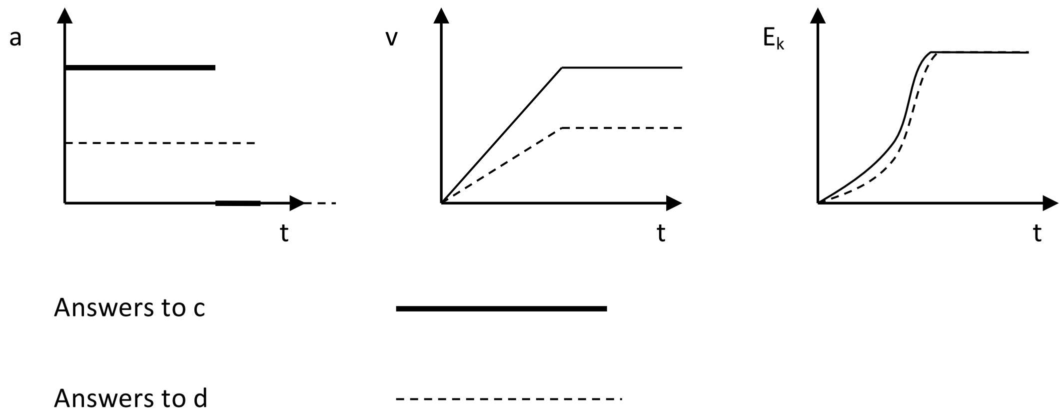
$F = ma$

$6.4 \times 10^{-15} = 9.11 \times 10^{-31}$ x a

$\mathbf{a = 7.03 \times 10^{15}\ m\ s^{-2}}$

16c) and d)

i) ii) iii)



17. $q_1 = q_2 = 1.60 \times 10^{-19}$ C
$\epsilon = 8.84 \times 10^{-12}$ $C^2N^{-1}m^{-2}$
$r = 5.30 \times 10^{-11}$ m

$$F = \frac{1}{4\pi\varepsilon}\frac{q_1 q_2}{r^2}$$

$$F = \frac{1}{4\pi \times 8.84 \times 10^{-12}}\frac{(1.60 \times 10^{-19})^2}{(5.30 \times 10^{-11})^2}$$

$$F = 9.002 \times 10^9 \times 9.114 \times 10^{-18}$$

$$F = 8.20 \times 10^{-8} N$$

18. $q_1 = 7.00 \times 10^{-9}$ C
$q_2 = 9.00 \times 10^{-9}$ C
$\epsilon = 4.18 \times 10^{-11}$ $C^2N^{-1}m^{-2}$
r = 25.0 cm = 0.250 m

$$F = \frac{1}{4\pi\varepsilon}\frac{q_1 q_2}{r^2}$$

$$F = \frac{1}{4\pi \times 4.18 \times 10^{-11}}\frac{7.00 \times 10^{-9} \times 9.00 \times 10^{-9}}{0.250^2}$$

$$F = 1.904 \times 10^9 \times 1.008 \times 10^{-15}$$

$$F = 1.92 \times 10^{-6} N$$

19. $q_1 = q_2 = 1.20 \times 10^{-6}$ C
ϵ = ?
r = 68.4 cm = 0.684 m
F = 1.86 N

$$F = \frac{1}{4\pi\varepsilon}\frac{q_1 q_2}{r^2}$$

$$1.86 = \frac{1}{4\pi \times \varepsilon}\frac{(1.20 \times 10^{-6})^2}{0.684^2}$$

$$1.86 = \frac{1}{4\pi \times \varepsilon} \times 3.078 \times 10^{-12}$$

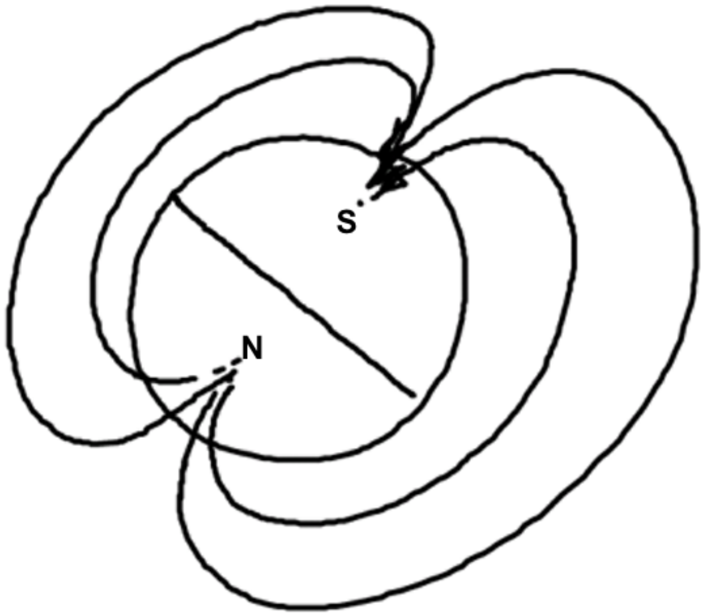
$$\varepsilon = \frac{1}{4\pi \times 1.86} \times 3.078 \times 10^{-12}$$

$$\varepsilon = 1.32 \times 10^{-13} C^2 N^{-1} m^{-2}$$

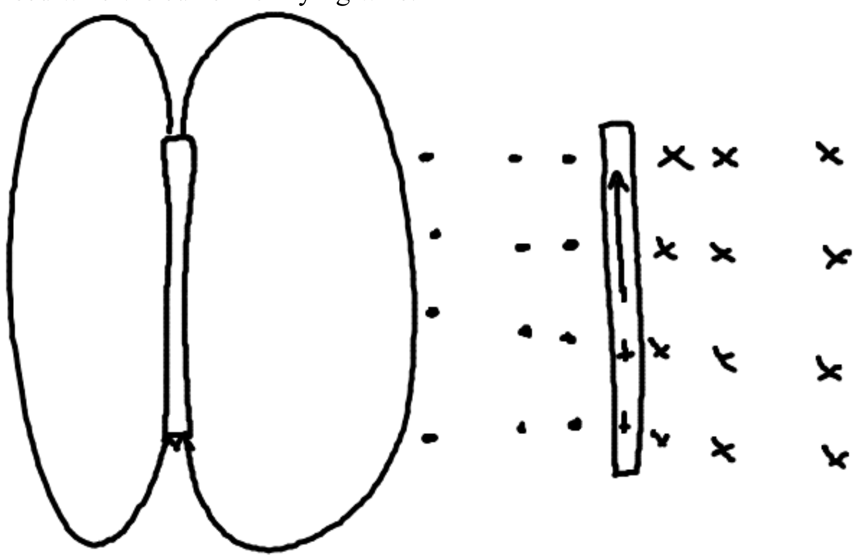
Problem Set 10: Charged particles in a magnetic field

1.a) The space or region around a magnet or moving electric charge within which the magnetic force operates.

b) Sketch magnetic field of earth. Note that magnetic north roughly corresponds with geographic south, magnetic south with geographic north

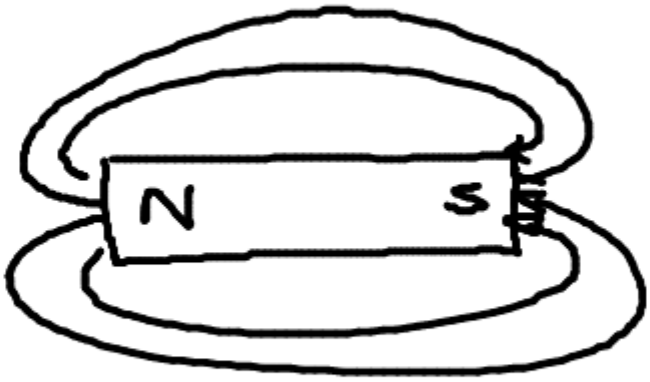


c) magnetised wire v's current carrying wire.

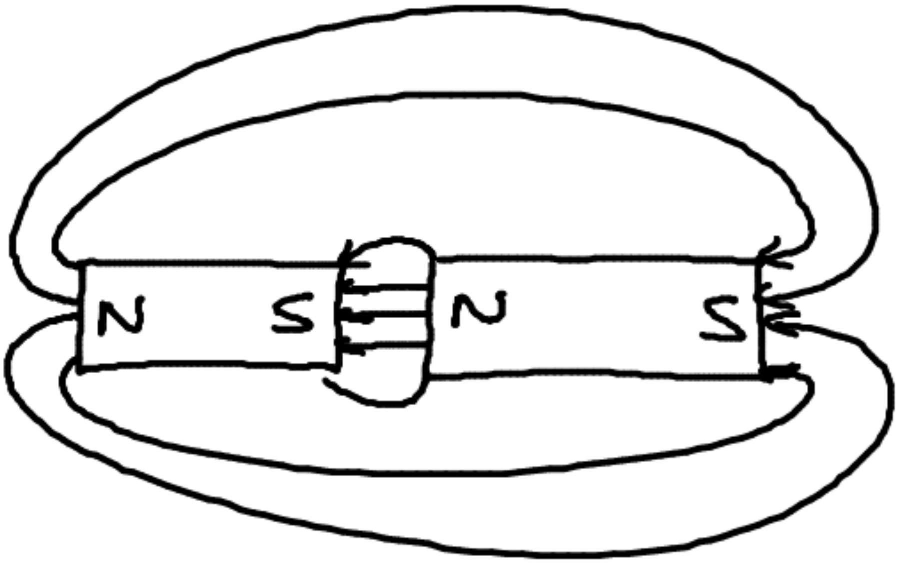


d) Coil the wire into a solenoid

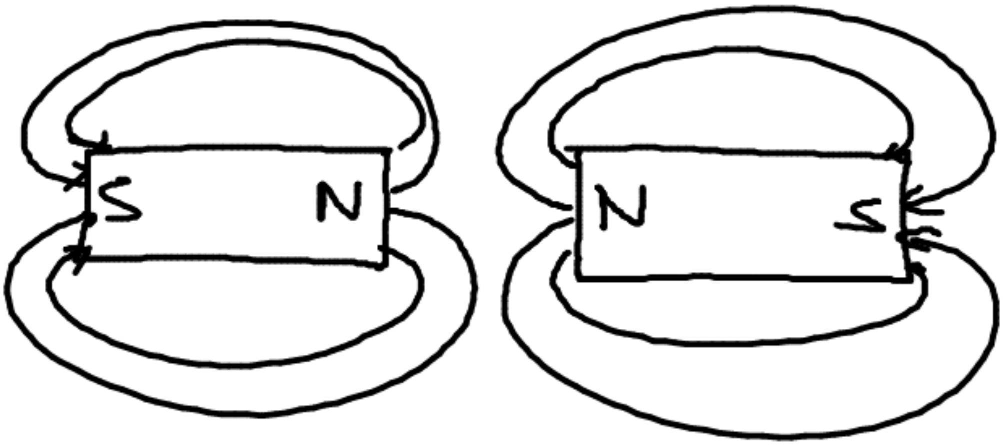
2.a) Bar magnet



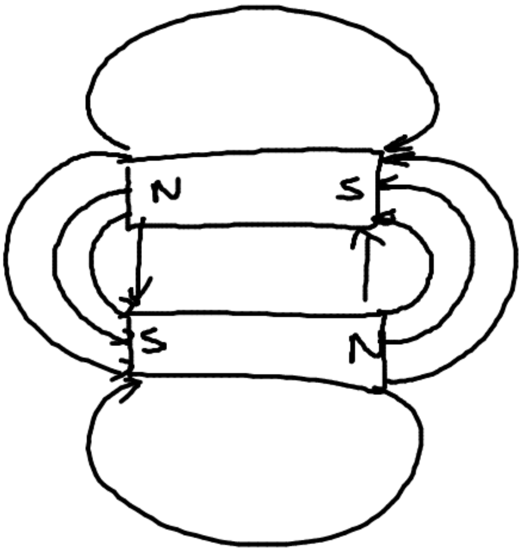
b) 2 bar magnets in line north to south



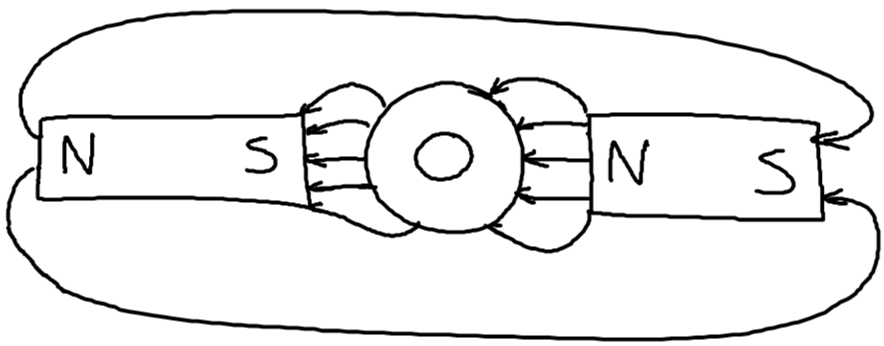
c) 2 bar magnets in line north to north



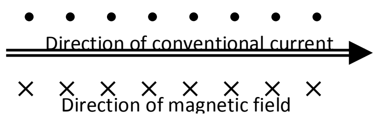
d) 2 bar magnets side by side



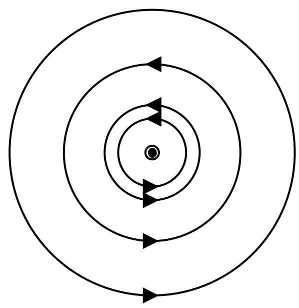
e) 2 bar magnets north to south with washer in between.



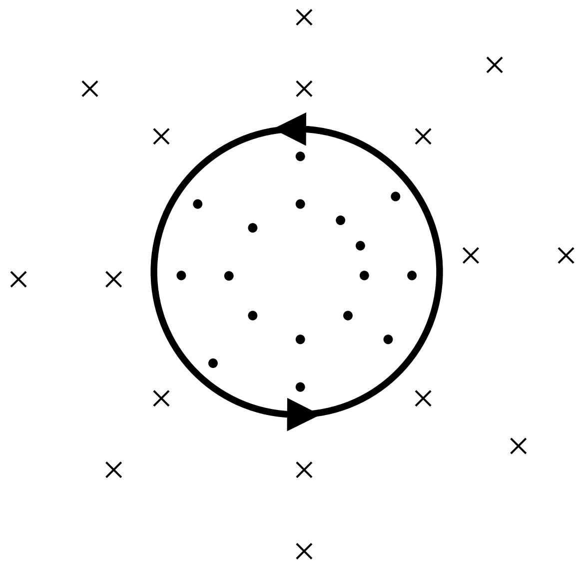
3.a) Current carrying conductor.



Conventional current flowing out of the



b) Current carrying coil of wire



4.a) No change in direction. Velocity is parallel with field.
b) Electron will change direction because of a force according to the right hand rule.

5. A is positive B is uncharged, C is negative

6.a) F = qvB
b) Spiral with a radius dependent upon the proton's initial velocity $mv^2/r = qvB$ r = mv / qB
c) v = 2πr / T v= 2πrf
d) Sub v= 2πrf formula into r = mv / qB
rqB = m(2πrf)
qB = m(2πf)

$f = \frac{qB}{2\pi m}$

f is proportional to B
$f = \frac{qB}{2\pi m}$

f is proportional to v
v= 2πrf

7. Min radius = diameter/2 = 0.0990/2 = 0-0495 m
Max radius = diameter/2 + width of the slit = 0.0495+0.002 = 0.0515

r = 0.0495 m (minimum radius)	r = 0.0515 m (maximum radius
r = mv / qB m = rqB / v $m = 0.0495 \times 1.6 \text{ x } 10^{-19} \times 10.0 / 5.00 \times 10^6$ **$m = 1.58 \times 10^{-26}$ kg**	r = mv / qB m = rqB / v $m = 0.0515 \times 1.6 \times 10^{-19} \times 10.0 / 5.00 \times 10^6$ **$m = 1.65 \times 10^{-26}$ kg**

8.a) r = mv / qB

$r = 1.67 \times 10^{-27} \times 1 \times 10^{4} / 1.6 \times 10^{-19} \times 2.50 \times 10^{-6}$
r = 41.75 m
r = 41.8 m (3 sig fig)

b) $v = 2\pi r / T$
$T = 2\pi r / v$
$T = 2\pi \times 41.75 / 1 \times 10^{4}$
$T = 2.62 \times 10^{-2}$ s

c) As B increases T decreases

$r = mv / qB$
but…
$v = 2\pi r / T$
substituting we get
$r = m\, 2\pi r / qBT$
Re arranging for T we get
$T = m2\pi / qB$
Hence as B increases T decreases

d) As the v increases the radius of the circle increases according to $r = mv / qB$
If the radius of the circle increase the circumference increases by the formula $2\pi\ (mv / qB)$
Hence the time taken is constant. by the formula $\mathbf{v} = 2\pi\ (m\mathbf{v} / qB) / T$.

9.a) B_1 = into the page, B_2 = out of the page.

b) $F = qvB$
$F = 1.6 \times 10^{-19} \times 1.50 \text{ x } 10^{6} \times 0.1$
$F = 2.40 \times 10^{-14}$ N

c) The electrons are in the field for longer. The causes them to experience a force for longer and increases the amount of deflection they experience.

d) Make the field non uniform so that the field is stronger at the top and bottom edges of the rectangle. The direction of the field will reverse half way down the triangle.

10.a) $qvB = mv^2 / r$

$r = mv / qB$

$q / m = v / rB$

b) i) $q / m = v / rB$
$q / m = 2.20 \times 10^5 / 2.9 \times 10^{-2} \times 0.120$
$q / m = 6.32 \times 10^7$ C / kg (6.3 × 10^7 C / kg)

ii) $q / m = v / rB$
$q / m = 2.20 \times 10^5 / 3.8 \times 10^{-2} \times 0.120$
$q / m = 4.82 \times 10^7$ C / kg (4.8 × 10^7 C / kg)

Ratio = 6.52 / 4.82 = **1.35 : 1**

c) Yes. The radius are in a 1/3 : 1/4 ratio based on reciprocal of mass.

d) Solve for mass using $m = qrB / v$

Divided the mass found by the mass of a proton or neutron (1.67 × 10^{-27}) to discover the number of nucleons.

Oxygen - 16, Oxygen - 17 and Oxygen – 18 (in order from smallest radius to largest).

11. $v = 0.5c = 0.5(3.00 \times 10^8)$ m s^{-1} = 1.50×10^8 m s^{-1}
r = 4 cm = 0.04 m

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

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

$B = 37.5 \times 10^8$ m/q $= 3.75 \times 10^9$ m/q

where m = mass of the positively charged ion
and q = charge on the ion
The field strength can be found once the postively charged ion is identified.

Problem Set 11: Charged particles in combined electric and magnetic fields

1.a) Proton accelerates parallel with field. Proton may accelerate positively or negatively depending on the direction of the field and sign convention.

b) No force on charged particle moving parallel with field lines.

c) Proton accelerates parallel with field. Proton may accelerate positively or negatively depending on the direction of the field and sign convention. proton is deflected sideways relative to original line of motion.

d) Proton begins to move in a circle because it is experiencing a force as it cuts across magnetic field lines.

2. As seen from a top view looking down, electric field is west to east. The magnetic field will need to be North to South.

3.a) $qvB = qE$
$4.5 \times 10^{6} \times 24.5 \times 10^{-3} = E$
$\mathbf{E = 1.10 \times 10^{5}\ N\ C^{-1}}$

b) Yes - the forces are independent of mass

4.a) The field has a turning effect on the electron.

b) The electron passes straight through un-deviated. There is no force on the electrons when travelling parallel to the magnetic field.

c) Electron decelerates linearly and bounces back in the same direction for which it came.

$ma = qE$
$a = qE / m$
$a = 1.6 \times 10^{-19} \times 1.00 \times 10^{3} / 9.11 \times 10^{-31}$
$\mathbf{a = 1.76 \times 10^{14}\ m\ s^{-2}}$ **in the opposite direction to the field**

5.a) $qV = ½\ m\ v^{2}$
$v^{2} = 2 \times 1.6 \times 10^{-9} \times 10.0 \times 10^{3}/9.11 \times 10^{-31}$
$v^{2}= 5.27 \times 10^{15}$
$\mathbf{v = 7.26 \times 10^{7}\ m/s}$

b) $r = mv / qB$
$r = 9.11 \times 10^{-31} \times \mathbf{7.26 \times 10^{7} / 1.6 \times 10^{-19} \times 2.35}$
$\mathbf{r = 1.76 \times 10^{-4}\ m}$ **or 0.176 mm**

c) $v = 2\pi r / T$
$T = 2\pi r / v$
$T = 2\pi \times 1.76 \times 10^{-4} / 7.26 \times 10^{7}$
$\mathbf{T = 1.52 \times 10^{-11}\ s}$

6.a) r = mv / qB
v = rqB / m
$v = 0.05 \times 1.6 \times 10^{-19} \times 1.50 / 1.67 \times 10^{-27}$
$v = 7.19 \times 10^{6}$ m/s

b) v = 2πr / T
T = 2πr / v
$T = 4.37 \times 10^{-8}$ s

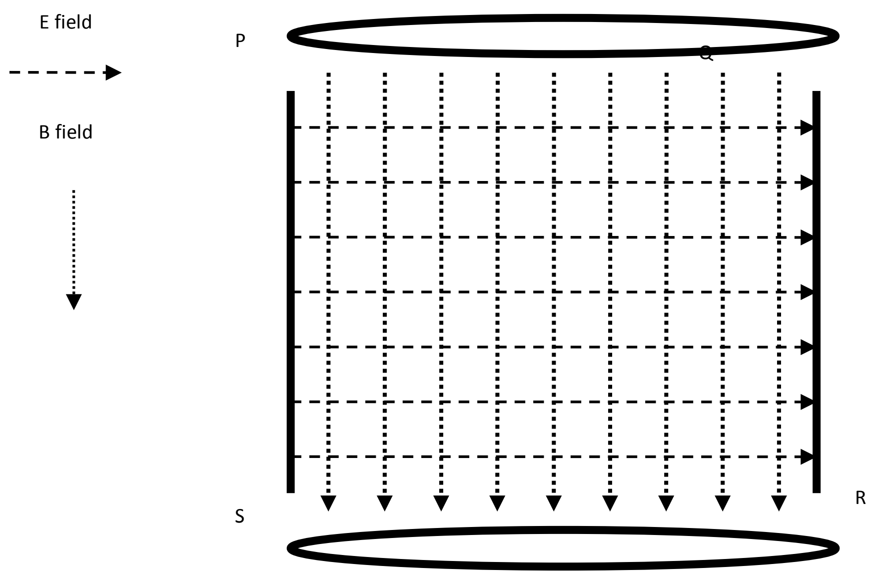
f = 1 / T
$f = 2.29 \times 10^{7}$ Hz

c) $qV = \frac{1}{2} m v^2$
$1.6 \times 10^{-19} \times V = \frac{1}{2}\, 1.67 \times 10^{-27} \times (\mathbf{7.19 \times 10^{6}})^{2}$
$V = 2.70 \times 10^{5}$ V or 270 kV

7.a)

	E field	B field
Deflection direction (positive charge)	Deflected with field	If at right angles to field deflected at right angles to velocity and field according to the right hand rule.
Effect of velocity	Does not affect the magnitude (force) of deflection (F = qE) (no v term)	Does effect the force of deflection (F = qvB) (Contains v term)

b)



c) F = q E
F = qvB

E = vB
E / B = v
$1.00 \times 10^{4} / 0.100 = v$

$v = 1.00 \times 10^{5}$ m/s

8.a) $qV = \frac{1}{2} m v^2$
$v^2 = 2 q V / m$
$v^2 = 2 \times 1.6 \times 10^{-19} \times 20.0 \times 10^3 / 1.67 \times 10^{-27}$
$\mathbf{v = 1.96 \times 10^6}$ **m/s**

$F = qvB$
$F = ma$
$a = qvB / m$
$a = 1.6 \times 10^{-19} \times \mathbf{1.96 \times 10^6 \times 0.200 / 1.67 \times 10^{-27}}$
$\mathbf{a = 3.76 \times 10^{13}}$ **m s^{-2} at right angles to the field**

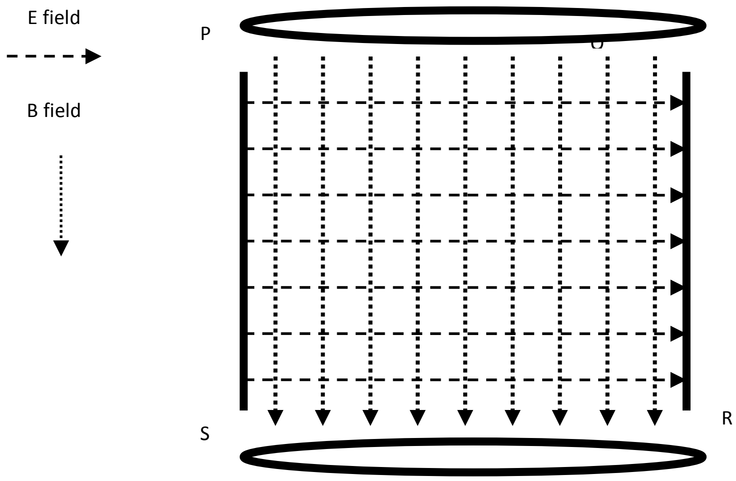
b) The force is a centripetal force, acting at right angles to the particles velocity toward the centre of the circular path.

c) $qE = qvB$
$E = vB$
$E = 1.96 \times 10^6 \times 0.200$
$\mathbf{E = 3.92 \times 10^5}$ **N C^{-1}**

9.a) $r = mv / qB$
$r = 9.11 \times 10^{-31} \times 1.6 \times 10^4 / 1.6 \times 10^{-19} \times 3.00 \times 10^{-2}$
$\mathbf{r = 3.04 \times 10^{-6}}$ **m**

b) $E = vB$
$E = 1.6 \times 10^4 \times 3.00 \times 10^{-2}$
E = 480 N C^{-1}

c)



Electron is fired into the page.

d) Original electron travelling at 1.6×10^4 m/s passes through un-deviated: faster electron is bent more by the magnetic field and so in the above diagram, bents to the right.

10 Figures partly obscured in the diagram. Larger radius should read 0.40 m not 40 m

a) The radius increases because the velocity of the charged particle increases as it moves from one D to the next. As v increases r increases.

b) i)

$r = mv / qB$

$v = rqB / m$

$v = 0.20 \times 1.6 \times 10^{-19} \times 1.50 / 1.67 \times 10^{-27}$

$\mathbf{v = 2.87 \times 10^{7}}$ **m/s**

ii)

$r = mv / qB$

$v = rqB / m$

$v = 0.40 \times 1.6 \times 10^{-19} \times 1.50 / 1.67 \times 10^{-27}$

$\mathbf{v = 5.75 \times 10^{7}}$ **m/s**