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Physics Module 6

Electromagnetism
WORKSHEETS

Worksheet 1 Electric Charges in Electric Fields
Concepts & Basic Calculations

Student Name.....................................

1.
a) How is the magnitude of an electric field defined? (answer in words AND in mathematical symbols)

b) How is the direction of an electric field defined?

2.
Mathematically define "potential difference" (voltage) in terms of:
a) potential energy.

b) electric field.

3.
a) What is an "equipotential line" in an electric field?

b) How much work must be done on a charge to move it (at constant velocity) along an equipotential line?

4. Compare the trajectories of a mass in a gravitational field to a charge in an electric field if:
a) both are released from rest inside the field.

b) both are "fired" into the field with a velocity at right angles to the field.

Practice Problems

5.
Two parallel charged plates are separated by 10.0cm in vacuum and have a potential difference of 2,000V.
a) What is the strength of the electric field?

b) How much energy would be gained by a single proton which accelerated from one plate to the other?

c) Starting from rest, what velocity would it achieve as it stikes the negative plate?

d) What force acts on the proton due to the field?

e) Calculate its rate of acceleration.

6.
A speck of dust carrying a static electric charge, experiences a force of 2.29×10^{-12}N in a field produced by 2 plates 5.00cm apart. A 200V potential difference is applied across the plates.
a) Find the strength of the field between the plates.

b) What is the magnitude of the charge carried by the speck of dust?

c) The static charge was created when some electrons were either removed from, or added to, the speck of dust. How many electrons were added or removed?

d) The speck of dust was observed to move toward the negative plate. Did the speck lose or gain electrons?

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Worksheet 2 Force on Moving Charge in Mag.Field Practice Problems

Student Name.....................................

1.
An electron ($q = -1.60 \times 10^{-19}$C) is travelling horizontally north at $3.00 \times 10^{7}ms^{-1}$ in a cathode ray tube when it enters a magnetic field of strength 4.96×10^{-2}T. The field is directed vertically upwards through the CRT. Find the magnitude and direction of the force experienced by the electron.

2.
In a nuclear accelerator, a charged ion has been accelerated up to a velocity of $2.90 \times 10^{8}ms^{-1}$. As it enters a magnetic field of strength 8.05T (field is perpendicular to ion's velocity vector) it experiences a force of magnitude 3.75×10^{-9}N.
What is the magnitude of the charge on the ion?

3.
A particle of the solar wind with charge of (+)1.60×10^{-19}C (it is in fact a proton) encounters the Earth's magnetic field at an angle of 25^{o} to the field lines. At this point the field has a strength of 5.48×10^{-4}T. The proton experiences a force of 7.40×10^{-15}N. Find the velocity of the proton.

4.
In an experiment, a stream of electrons in a CRT are each experiencing a force of magnitude 4.06×10^{-15}N due to a perpendicular magnetic field. The velocity of the electrons is $7.80 \times 10^{6}ms^{-1}$.

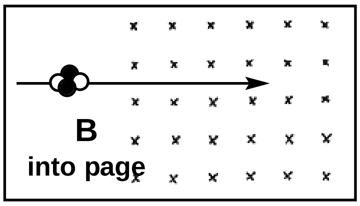
a) What is the strength of the magnetic field?

The magnetic force on the electrons is exactly counteracted by an electric field produced by a pair of charged plates.

b) What is the strength of the electric field?

c) What is the voltage being applied across the plates if they are 8.00mm apart.?

5.
An alpha particle ($q = + 3.20 \times 10^{-19}$ C) is about to enter a magnetic field of strength 5.22T at a velocity of $2.95 \times 10^{3}ms^{-1}$as shown in the diagram.



a) Find the magnitude and (initial) direction of the force due to the magnetic field it will experience.

b) A pair of electrically charged plates (not shown in the diagram) are arranged so that the force due to the magnetic field will be exactly cancelled out by the force due to the electric field.
Sketch where the plates need to be to do this, and indicate the type of charge on each plate.

c) If these electric plates are 10.0cm apart, what voltage must be applied to exactly cancel the magnetic deflection?

6.
a) Describe the trajectory of a charged particle which is moving at constant velocity through a magnetic field perpendicular to its velocity vector.

b) Prove algebraically that the radius of its motion is given by r = m.v / q.B

c) A proton has a positive charge of the same magnitude as an electron's negative charge, but is much more massive. Compare (in general terms) the trajectories of a proton & an electron which enter the same magnetic field at the same velocity.

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Worksheet 3 Force Between 2 Wires Carrying Current
Practice Problems

Student Name.....................................

1.
Calculate the force per unit of length between 2 long, parallel wires carrying 15.3A and 12.7A and separated by 1.00cm. State the direction of the force, given that the currents are in opposite directions.

2.
Two long, parallel wires are carrying equal currents. The wires are 10.0cm apart. The force between them is found to be 8.25×10^{-5} N per metre of length, attracting each other. Find the magnitude, and relative direction, of the currents in the wires.

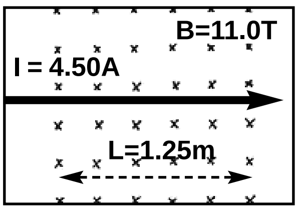
3.
Two wires run parallel for a length of 1.48m. The total force acting between them over this length is 6.44×10^{-4}N when they are carrying currents of 8.90A and 14.5A. How far apart are they?

4.
Two power cables, both carrying 30.0A of current in the same direction, are separated by a distance of 8.00cm. The cables run parallel over a distance of 25.0m. What is the total force (including relative direction) acting between them?

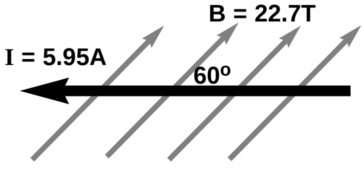
Worksheet 4 Force on a Wire Carrying Current in a Field
Practice Problems

Student Name.....................................

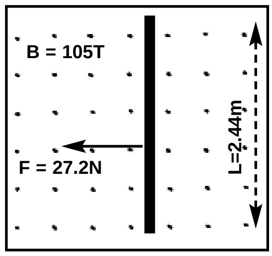
1.
A wire is carrying 4.50A of current through a 11.0T field, directed as shown. The length of wire in the field is 1.25m. Find the magnitude and direction of the force on the wire.



2.
Find the magnitude & direction of the force which would act on the wire shown. The length of wire within the field is 0.385m.



3.
The vertical wire runs for 2.44m through a 105T field directed out of the page. The force on the wire is 27.2N left. Find the magnitude and direction of the current in the wire.



4.
A wire is carrying 8.00A of current over a length of 0.287m through a magnetic field of 7.50T. A force of 3.72N acts on the wire. Find the angle between the wire and the field lines.

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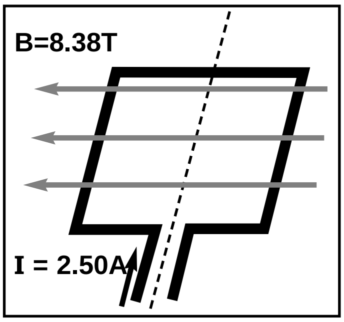
Worksheet 5 Torque on a Coil in a Field
Practice Problems

Student Name....................................

1. Calculate the amount of torque on a coil of 200 turns of wire carrying 1.50A in a field of strength 5.25T. The area of the coil is $1.20 \times 10^{-3} m^2$. Assume that the field is radial, so that the torque is always at a maximum. (i.e. $\theta = 90^o$)

2.
The coil shown is 20cm square and composed of 35 turns of wire.

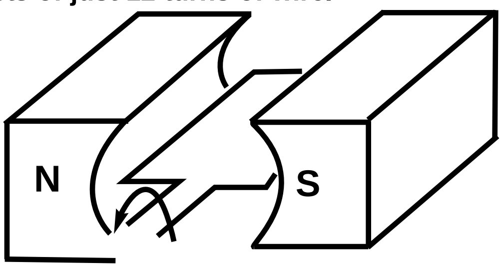


a) Find the torque on the coil when it lies "flat" in the field (i.e. $\theta = 90^o$).

b) Will the coil rotate clockwise or anti-clockwise as viewed from the lower end?

3.The torque achieved by a small electric motor is found to be 3.86Nm, when a current of 3.20A flows through the rotor coil which has an area of $0.00262m^2$. The stator provides a <u>radial</u> field of 4.60T. (assume $\theta = 90^o$)
How many turns of wire in the coil?

4.The rectangular coil shown is 8.00cm x 5.00cm and is rotating anti-clockwise due to the torque on it. The magnetic field of 22.3T gives maximum torque of 12.3Nm at the position shown. The coil consists of just 12 turns of wire.



a) What is the current in the coil?

b) Determine the direction of conventional current flow (clockwise or anti-clockwise around the coil diagram?)

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Worksheet 6 Electromagnetic Forces & Motors

Fill in the blank spaces.

Student Name.....................................

Two parallel wires, both carrying a)................................... will exert a b)........................... on each other. The reason is because each wire will produce a c)......................... .... around itself, and these 2 fields interact with each other. If the wires carry current in the same direction, the force will d)........................ the wires. If the current flow e)................................., the force will f).................................... the wires. The magnitude of the force per unit of g)........................... is proportional to h).................................. in the wires, and i)............................... proportional to the distance between them.

If a wire is carrying current through a j)............................ field, it will experience a k)........................ The magnitude of the force depends upon 4 factors:

- The strength of the Magnetic field, measured in l)....................
- The m)....................... flowing in the wire
- The n)........................... of the wire that is within the o)................................, and
- The p)........................... between wire & field.

This force on a wire is the basis of electric motors and is called the “q)....................... Effect”. The directions of current, field & force are all at r).................................... to each other, and can be determined by the “s).................................. .... Rule”.

“Torque” is a measure of the t).................................... effect of a pair of forces which cause something to u)........................... around a pivot point or axle. A loop or coil of wire, carrying current within a v)................................. ...., will experience a torque, because the force acting on the opposite sides of the coil will be w)..

The size of the torque depends on 5 factors:

- The x)...................................... in the coil.
- The strength of the y)................................. ....
- The z).......................... flowing in the coil.
- The aa)..................................... of the coil, and
- The angle between the ab)...................... to the plane of the coil, and the field.

Maximum torque occurs when the angle is ac)..................... Zero torque occurs at an angle of ad).................. degrees.

A simple DC motor has just 4 main parts:

- The Rotor, made up of a ae)................................ mounted on an axle to allow it to af)...
- The ag)...................................... which provides the magnetic field, from either a ah).............................. magnet, or an ai)..
- The Brushes, which maintain aj)................................ contact between the electricity supply and the rotating coil.
- The ak)..................................., which causes the current to al)............................... every half-turn.

The Motor Effect is also involved in the operation of a am).................................... ...., and a moving-coil loudspeaker. In an electric meter, the needle moves along a calibrated scale because of the an).............................. on a coil inside a ao)................................ (shape) magnetic field. In a loudspeaker, the sound is produced by ap).................................. of a speaker cone. In turn, this is made to vibrate by a coil’s magnetic field aq)... with a permanent magnet.

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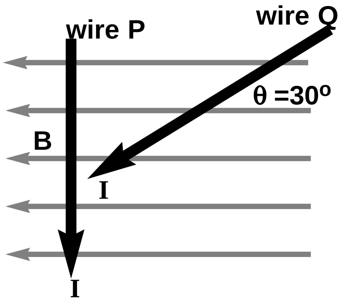
Worksheet 7 Test-Style Questions

Student Name.....................................

Multiple Choice



The diagram is used for questions 1 and 2.

It shows 2 wires P & Q both carrying the same current through the same magnetic field. The length of each wire within the field is the same.

1.
The force experienced by wire P would be directed:
A. to the right
B. to the left
C. out of the page
D. into the page

2.
Compared to the force acting on P, the force on wire Q would be:
A. exactly the same.
B. about 87% as strong.
C. exactly half as strong.
D. zero.

3.
A "torque" is produced when:
A. a force causes circular motion.
B. a force acts on a pivot point, causing acceleration.
C. a pair of separated forces act in opposite directions.
D. a pair of forces act in the same direction.

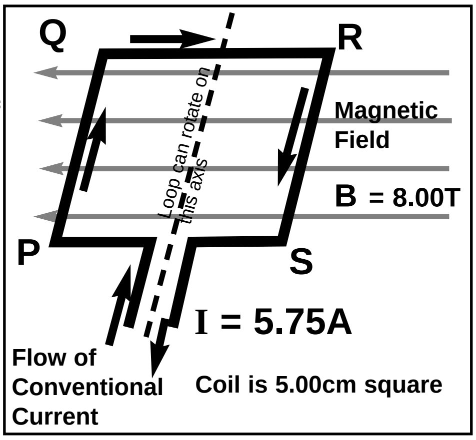
4.
Electric motors often have a curved stator structure to give a "radial magnetic field". The benefit of this field is that it:
A. gives a more constant torque as the coil rotates.
B. reverses the current each half-revolution.
C. intensifies the field in the centre of the coil for increased torque.
D. reverses the field so the coil will turn the other way.

Longer Response Questions

5.
Two parallel wires are carrying 12.0A and 7.50A of current in opposite directions. The parallel section of the wires is 1.85m long, and the wires are 1.00cm apart. Calculate the total force (including direction) which will act between these wires.

6.
A wire is carrying 9.00A of current in a direction due north. 0.750m of the wire is within a vertical magnetic field, which causes a force of 3.25N to push the wire due east.
Find the magnitude and direction of the magnetic field.

7.
The rectangular coil PQRS is made of a single strand of wire. It is carrying current through a field as shown.



a) Find the force acting on side RS, including direction.

b) What force acts on side QR? Explain your answer.

c) Find the torque on the coil at the moment when the "normal" to the plane of the coil is inclined at an angle of 10° to the field lines.

8.
a) In a simple DC motor, describe the <u>role</u> of:
i) the commutator

ii) the stator

b) Explain what is meant by a "radial magnetic field", and describe the advantage it gives in a rotating-coil motor.

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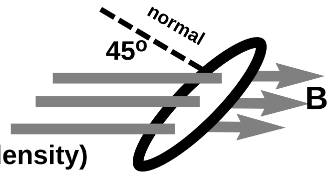
Worksheet 8 Electromagnetic Induction
Practice Problems

Student Name....................................

1.
a) If a magnetic field of 7.5×10^{-3}T passes through an area of 1.5 m^2, perpendicular to the plane of the field, what is the magnetic flux through that area?

b) A magnetic field passes through a circular area of 0.25m^2 as shown.This produces a flux of 0.85 Wb. What is the intensity (flux density) of the field B?



c) When a 0.025T magnetic field passes at right angles (ie down the normal line) through the plane of a coil, it results in a magnetic flux of 6.50 Wb. What is the area of the coil?

2.
a) If the flux through a single conducting wire changes by 0.085 Wb in 0.25s, what EMF is induced in the wire?

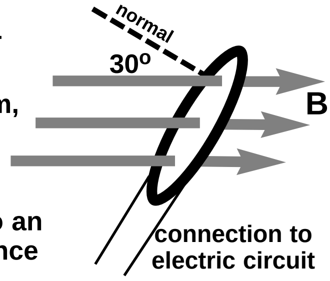
b) In a coil containing 200 turns of wire, an EMF of 60V magnitude was induced in a time of 0.045s. What was the flux change?

c) Over what time period could a flux change of 73 Wb induce an EMF of magnitude 24V in a coil containing 50 turns of wire?

3.
Refer to Q1 (c).
a) If the magnetic field increased to 0.075T, what is the new value of the flux?

b) If this change occurred in 12.0s, and the coil contains 75 turns of wire, calculate the magnitude of the EMF induced.

4.
A magnetic field of 0.0575T passes through a circular wire coil with radius 5.00cm, as shown in this diagram.



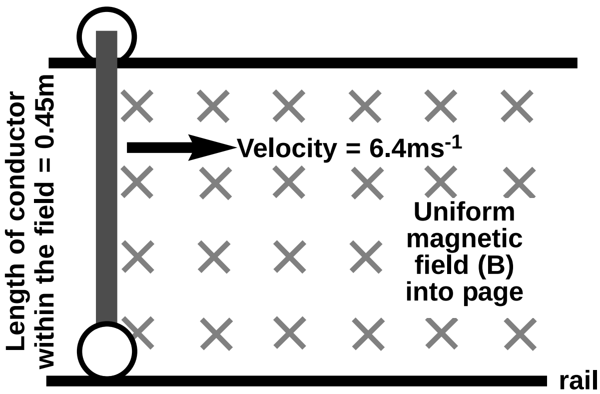
The coil contains 80 turns of wire and is connected to an electric circuit with resistance of 6.0Ω.

a) What is the magnetic flux through the coil?

b) Over a time of 0.02s the field intensity (flux density, B) increases to 0.755T. Calculate the EMF induced in the coil.

c) What current would flow through the circuit?

5.
A conducting rod is pushed along a set of rails through a magnetic field which has a flux density of B = 2.25 T.



Calculate the magnitude of the induced EMF in the conducting rod.

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Worksheet 9 Lenz's Law & Generators

Guided Notes.
(Make your own summary)

Student Name.....................................

1.
a) State Lenz's Law.

b) Explain how this law is really (yet another) aspect of the Law of Conservation of Energy.

2.
An electric motor was being driven from a 12V battery. During operation, the actual voltage across the motor terminals was found to be only 9.5V. Suggest why this might be.

3.
Why might a small, powerful magnet defy gravity and fall very slowly through a hollow aluminium tube?

4.
a) Explain the basic principle of all electrical generators.

4.
b) What device is usually involved in forcing the generator rotor to spin?

c) Outline the main methods used to spin this device.

5.
A simple "alternator" generator produces AC electricity.

a) Explain what this means.

b) Sketch a graph of the generated EMF voltage against time.

c) What additional component is needed to turn an "alternator" into a DC "dynamo"? Explain this.

d) Sketch a graph of the generated EMF voltage against time for a simple 1-coil dynamo.

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Worksheet 10 Transformers

Fill in the blanks

Student Name......................................

The purpose and function of a transformer is to a)..
This allows electricity to be stepped-up to b)...................... voltages for efficient, long-distance c)............................, and then d)..................................
again for convenient safe use by consumers.

The basic structure of a transformer is simple: it consists of e)....... coils, called the f)........................ and .... The coils are arranged one inside the other, with a core of g).......................... in the centre. If h).................... electricity flows in the i)............................... coil, it creates a j)...................... magnetic field. This, in turn, k)............................... an EMF in the secondary coil, at a l)............................ voltage.

A "step-up" transformer has more turns of wire in its m)............................ coil, and its output voltage is n)............................ than the input. A "step-down" transformer has more turns in its o)............................ coil and its output voltage is p)............................

In a perfect transformer, the input and output q).................. will be equal, because of the Law of r)................................ of ....
This means that if voltage is stepped up, then s).......................... will be lower.

In reality, there are t)... in any transformer, mainly due to u)........................ ....

This is partly due to resistance in the coils, but mainly because of resistance to v)...................... currents induced in the iron core. Once some heat is produced, the resistance w)................................ at higher temperatures. To minimise these energy losses:
- transformers are designed to x)............................... heat.
- thicker wires in coils reduce y)............................
- the iron core is made from z)...................... sheets of iron, aa)............................. together to minimise the ab)......................... currents.

The electricity generated at a power station is usually stepped ac)................ to at least ad)........................ volts for long-distance transmission. It will then be stepped-ae).................... in 4 or 5 separate transformers at district, suburb and af)............................. levels, before entering your home at ag)................. volts.

Worksheet 11 Transformer Calculations

Practice Problems

Student Name......................................

1.
A step-up transformer inputs 240V AC and outputs 11,000V AC. If it has 24,000 turns in its primary coil and the maximum input current is 30A:

a) how many turns of wire are in its secondary coil?

b) What max. current flows in its secondary coil? (assume no energy losses)

2.
A household mini-transformer is designed to output 6.0V from its 50-turns secondary coil when connected to 240V AC mains supply.
a) How many turns are in the primary coil?

b) The maximum output of current is 0.5A. It should be designed for what max. input current?

3.
An industrial transformer is designed for an output of 2,000 watts of power at 800V AC, when connected to an input supply of 4,000V AC.

a) What is the max.current flowing in the secondary coil?

b) What is the ratio $n_p : n_s$ of turns of wire in its coils?

c) The wire used in the secondary coil is thicker than that used in the primary coil. Explain why.

d) This transformer is quite large and is equipped with a system to pump a cooling fluid around its core. Explain why.

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Answer Section

Worksheet 1

1.
a) It is the force per unit of charge experienced by a charge placed within the field. ie $E = F/q$
b) The vector direction of the field is defined as the direction of the force experienced by a positive charge.

2.
a) $V = \Delta U / q$
(Voltage is the difference in potential energy (per unit of charge) between 2 points in an electric field.
b) $V = E.d$
(Voltage between 2 points is the electric field strength multiplied by the distance between the points.)

3.
a) Equipotential lines join 2 or more points which have the same potential energy value within a field.
b) Zero, because there is no difference in electrical potential energy along an equipotential.

4.
a) Similar: both examples will accelerate uniformly parallel to the field lines.
Different: all masses accelerate at same rate in the direction of the grav. field.
+ve & -ve charges will accelerate in opposite directions. Different masses will accelerate at different rates.

b) Similar: both examples will follow parabolic curves while in a uniform field.
Different: In grav.field, all masses follow the same curve if initial velocity is the same.
In elect.field, +ve & -ve charges curve in opposite directions. Exact curve will vary according to velocity, charge and mass.

5.
a) $E = V/d = 2000 / 0.010 = 2.0\text{x}10^5\ Vm^{-1}$ (or NC^{-1})

b) $\Delta U = V.q = 2000 \text{ x } 1.602\text{x}10^{-19} = 3.20\text{x}10^{-16}J$

c) Gain of $E_k = 1/2.m.v^2 = 3.20\text{x}10^{-16}$
$\therefore v^2 = 2 \text{ x } 3.20\text{x}10^{-16} / 1.673\text{x}10^{-27}$ (mass kg)
$\therefore v = 6.19 \text{ x}10^5\ ms^{-1}$.
(equal to about 600 km per sec !!
Not bad over 10 cm distance)

d) $F = E.q = 2.0\text{x}10^5 \text{ x } 1.602\text{x}10^{-19} = 3.20\text{x}10\text{-}14$ N

e) $F = m.a$, so $a = F/m = 3.20\text{x}10^{-14} / 1.673\text{x}10^{-27}$
$= 1.92\text{x}10^{13}\ ms^{-2}$.

6.
a) $E = V / d = 200 / .0500 = 4000\ Vm^{-1}$ (or NC^{-1})

b) $E = F / q$ so $q = F / E = 2.29\text{x}10^{-12} / 4000$
$= 5.73 \text{ x } 10^{-16}$ C

6.
c) No. electron charges = q / q_e
$= 5.73 \text{ x } 10^{-16} / 1.602\text{x}10^{-19}$
$= 3.58 \text{ x } 10^3$ electrons
d) Charge is attracted to -ve plate, so must have +ve charge. Therefore, it has lost electrons.

Worksheet 2

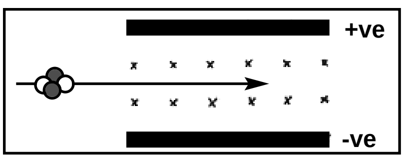
1.
$F = q.v.B.\sin\theta$
$= -1.60\text{x}10^{-19}\text{x}3.00\text{x}10^7\text{x}4.96\text{x}10^{-2}\text{x}\sin 90^o$
$= -2.38\text{x}10^{-13}$N.
(Negative sign indicates direction is opposite to whatever the RH Palm rule tells us)
RH Palm rule: if vel. vector is north, and B vector vertically up, then F vector is east for a +ve charge. Therefore, for -ve electron, is west.
Force = $2.38\text{x}10^{-13}$ N, west.

2.
$F = q.v.B.\sin\theta$, so $q = F / v.B.\sin\theta$
$= 3.75\text{x}10^{-9}/(2.90\text{x}10^8\text{x}8.05\text{x}\sin 90^o)$
$= 1.61\text{x}10^{-18}$C.

3.
$F = q.v.B.\sin\theta$,
so $v = F / q.B.\sin\theta$
$= 7.40\text{x}10^{-15} / (1.60\text{x}10^{-19}\text{x}5.48\text{x}10^{-4}\text{x}\sin 25^o)$
$= 2.00\text{x}10^8 ms^{-1}$. (2/3 light speed!)

4.
a) $F = q.v.B.\sin\theta$,
so $B = F / q.v.\sin\theta$
$= 4.06\text{x}10^{-15} / (1.602\text{x}10^{-19}\text{x}7.80\text{x}10^6\text{x}\sin 90^o)$
$= 3.25\text{x}10^{-3}$T.
b) The force due to the electric field must be equal to the force due to the mag.field,
so F = $4.06\text{x}10^{-15}$N. (on each electron)
$E = F / q = 4.06\text{x}10^{-15} / 1.602\text{x}10^{-19}$
$= 2.54\text{x}10^4\ NC^{-1}$.
c) $E = V / d$, so $V = E.d = 2.54\text{x}10^4 \text{ x } 0.00800$
= 203 V.

5.
a) $F = q.v.B.\sin\theta$
$= 3.20\text{x}10^{-19}\text{x}2.95\text{x}10^3\text{x}5.22\text{x}\sin 90^o$
$= 4.93\text{x}10^{-15}$N. Initial direction up the page.
b) Plates need to be as shown in diagram.



c) Elect.force must be equal to mag.force, so
F = $4.93\text{x}10^{-15}$N.

$E = F/q = 4.93\text{x}10^{-15}/3.20\text{x}10^{-19} = 1.54\text{x}10^4\ NC^{-1}$

and $V = E.d = 1.54\text{x}10^4\text{x}0.100 = 1.54\text{x}10^3$V.

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Answer Section

Worksheet 2 (cont.)

6.
a) Circular motion.

b) Magnetic force = Centripital force
and so $q.v.B = \frac{m.v^2}{r}$

cancelling v's & re-arranging: $r = \frac{m.v}{q.B}$

c) They will both take up circular motion, but in opposite directions.
The proton orbit will be very much larger radius than the electron due to the mass difference.

Worksheet 3

1.
$\frac{F}{L} = \frac{\mu_0 .I_1.I_2}{2\pi \quad d}$
$= 2.00\text{x}10^{-7}\text{x}15.3\text{x}12.7 / 0.0100 = 3.89\text{x}10^{-3}\ \text{Nm}^{-1}$.
The force will repel the wires.

2.
$\frac{F}{L} = \frac{\mu_0 .I_1.I_2}{2\pi \quad d}$ and $I_1 = I_2 = I$

$8.25\text{x}10^{-5} = 2.00\text{x}10^{-7} \text{ x } I^2 / 0.100$
$\therefore I = \sqrt{8.25\text{x}10^{-5}\text{x}0.100/2.00\text{x}10^{-7}}$
$= 6.42$ A.
Since force is attracting, the currents must be in same direction.

3.
$F = \frac{\mu_0 .I_1.I_2.L}{2\pi \quad d}$
so $d = \frac{\mu_0 .I_1.I_2.L}{2\pi \quad F}$

$= 2.00\text{x}10^{-7} \text{ x } 8.90 \text{ x } 14.5 \text{ x } 1.48 / 6.44\text{x}10^{-4}$
$= 0.0593$ m (= 5.93 cm).

4.
$F = \frac{\mu_0 .I_1.I_2.L}{2\pi \quad d}$
$= 2.00\text{x}10^{-7} \text{ x } 30.0 \text{ x } 30.0 \text{ x } 25.0 / 0.0800$
$= 5.63\text{x}10^{-2}$ N, attraction.

Worksheet 4

1.
F = B.I.L.sinθ
= 11.0 x 4.50 x 1.25 x sin90°
= 61.9N.
RH palm rule shows force is directed up the page.

2.
F = B.I.L.sinθ
= 22.7 x 5.95 x 0.385 x sin60°
= 45.0N, directed vertically into the page.

3.
F = B.I.L.sinθ, So I = F / B.L.sinθ
= 27.2 / 105 x 2.44 x sin90°
= 0.106A. ($1.06\text{x}10^{-1}$A)
RH palm rule shows current flows down the page.

4.
F = B.I.L.sinθ, So Sinθ = F / B.I.L
= 3.72 / 7.50 x 8.00 x 0.287
= 0.2160
∴ θ = 12.5°

Worksheet 5

1.
τ = n.I.A.B.sinθ
= 200 x 1.50 x $1.20\text{x}10^{-3}$ x 5.25 x sin90°
= 1.89 N.m.

2.
a) τ = n.I.A.B.sinθ
= 35 x 2.50 x (0.20x0.20) x 8.38 x sin90°
= 29.3 N.m.
b) RH Palm rule shows left side force is up, right side force down, therefore coil will rotate clockwise.

3.
τ = n.I.A.B.sinθ
so, n = τ / I.A.B.sinθ
= 3.86 / 3.20 x 0.00262 x 4.60 x sin90°
= 100 turns.

4.
a) τ = n.I.A.B.sinθ
so, I = τ / n.A.B.sinθ
= 12.3 / 12 x (0.0800x0.0500) x 22.3 x sin90°
= 11.5A.
b) To rotate as shown, the force on left side of coil must be downward. RH Palm Rule indicates current must flow clockwise around coil.

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Answer Section

Worksheet 6

a) electric current
b) force
c) magnetic field
d) attract
e) is in opposite direction
f) repel
g) length
h) the product of the currents
i) inversely
j) magnetic
k) force
l) teslas (T)
m) current
n) length
o) magnetic field
p) (sine ratio of) angle
q) Motor
r) right angles
s) Right Hand Palm
t) turning
u) rotate
v) magnetic field
w) equal but opposite
x) no. of turns of wire
y) magnetic field
z) current
aa) area
ab) "normal"
ac) 90°
ad) 0°
ae) coil of wire
af) rotate
ag) stator
ah) permanent
ai) electromagnet
aj) electrical
ak) commutator
al) reverse direction
am) galvanometer
an) torque
ao) radial
ap) vibration
aq) inter-acting

Worksheet 7

1. D 2. C 3. C 4. A

5.
$F = \frac{\mu_0 \; .I_1.I_2.L}{2\pi \quad d}$
$= 2.00 \times 10^{-7} \times 12.0 \times 7.50 \times 1.85 / 0.0100$
$= 3.33 \times 10^{-3}$ N.
Force will repel the wires, since currents opposite.

6.
$F = B.I.L.\sin\theta$, so, $B = F / I.L.\sin\theta$
$= 3.25 / 9.00 \times 0.750 \times \sin 90$
$= 0.481$T.
RH Palm Rule shows field is vertically upwards.

7.
a) $F = B.I.L.\sin\theta$,
$= 8.00 \times 5.75 \times 0.0500 \times \sin 90$
$= 2.30$N.
RH Palm Rule shows force is into page.
b) Zero, because current flows parallel to field lines.
c) $\tau = n.I.A.B.\sin\theta$
$= 1 \times 5.75 \times (0.0500)^2 \times 8.00 \times \sin 10^o$
$= 2.00 \times 10^{-2}$ N.m.

8.
a) i) It reverses the direction of current flow every half revolution. This ensures that the torque remains in the same direction even when the coil has turned over.

8. a)
ii) In a moving-coil motor, the "stator" surrounds the coil & provides a magnetic field, either from a permanent magnet, or electromagnet.
b) The magnetic poles are curved into semi-circles so the mag.field lines are approx. like the spokes of a wheel. This means that at all rotor positions torque is constant and close to maximum.

Worksheet 8

1.
a) $\Phi = B.A.\cos\theta$
$= 7.5 \times 10^{-3} \times 1.5 \times \cos 0$
$= 1.13\ 10^{-2}$ Wb
b) $B = \Phi \ / A.\cos\theta$
$= 0.85 / 0.25 \times \cos 45$
$= 4.81$ T.
c) $A = \Phi \ / B.\cos\theta$
$= 6.5 / 0.025 \times \cos 0$
$= 260\ m^2$.

2.
a) $\varepsilon = -\frac{N.\Delta\Phi}{\Delta t} = -1 \times 0.085 / 0.25 = -0.34$ V
(the negative sign arises from Lenz's Law & may be ignored in simple questions like this)

b) $\varepsilon = N.\Delta\Phi / \Delta t$ so $\Delta\Phi = \varepsilon.\Delta t / N$
$= 60 \times 0.045 / 200$
$= 1.35 \times 10^{-2}$ Wb

c) $\varepsilon = N.\Delta\Phi / \Delta t$ so $\Delta t = N.\Delta\Phi / \varepsilon$
$= 50 \times 73 / 24$
$= 152$ s.

3.
a) $\Phi = B.A.\cos\theta$
$= 0.075 \times 260 \times \cos 0 = 19.5$ Wb

b) $\varepsilon = N.\Delta\Phi / \Delta t = 75 \times 19.5 / 12.0 = 122$ V

4.
a) $\Phi = B.A.\cos\theta$
$= 5.75 \times 10^{-2} \times (\pi \times 0.05^2) \times \cos 30$
$= 3.91 \times 10^{-4}$ Wb
b) Later flux: $\Phi = B.A.\cos\theta$
$= 0.755 \times (\pi \times 0.05^2) \times \cos 30$
$= 5.14 \times 10^{-3}$ Wb
Flux change $= 5.14 \times 10^{-3} - 3.91 \times 10^{-4} = 4.74 \times 10^{-3}$ Wb

$\varepsilon = N.\Delta\Phi / \Delta t = 80 \times 4.74 \times 10^{-3} / 0.02$
$= 19.0$ V

c) $V = I.R$ so $I = V / R = 19.0 / 6.0 = 3.17$ A

5.
$\varepsilon = B.L.v = 2.25 \times 0.45 \times 6.4 = 6.5$ V

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Answer Section

Worksheet 9

1.

a) The direction of an induced EMF (and current) is such that it produces a magnetic field <u>opposing</u> the change that produced the EMF.

b) If this was NOT the case, the result would be a gain of energy from nothing. Lenz's Law is not only consistent with energy conservation, but can readily be verified by observation & experiment.

2.

This is due to "back-EMF".
When the coil begins to turn, an EMF is induced in the conductor. This EMF must oppose the driving force by Lenz's Law. In effect, the final voltage across the coil is the driving voltage <u>minus</u> the induced EMF.

3.

This is due to eddy currents induced in the aluminium tube. By Lenz's Law the EMF induced by the moving magnet will create a force opposing the motion causing the induction.

The resulting eddy currents create a magnetic force which pushes against the falling magnet and slows it down.

4.

a) All generators involve 1 or more coils of wire which are forced to rotate within a magnetic field. (or vice-versa... magnets rotate inside the coils) This creates flux change which induces EMF in the wires.

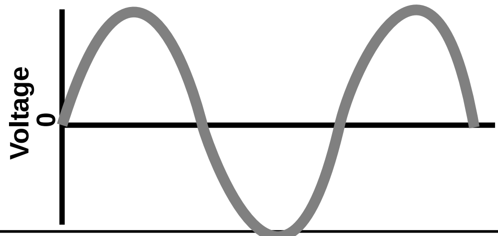
b) The generator rotor is attached to a <u>turbine</u>. When air, water or steam flow through the turbine blades the turbine spins.

c) "Conventional" or "thermal" power stations burn fuel (coal, gas, etc.) to make steam to spin the turbines.
Hydroelectric stations use flowing water.
Wind "farms" have turbines turned by wind.

5.

a) As the coil turns over within the field, the induced EMF and current reverses its direction. This is Alternating Current (AC).

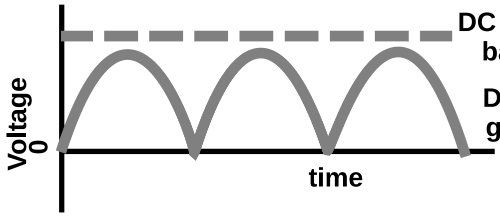
b)



5.

c) Add a commutator which will reverse the current direction each half-revolution so it always flows in the same direction (although it will vary a lot in value as shown by the graph).

d)



Worksheet 10

a) change the voltage	b) higher
c) transmission/distribution	
d) stepped-down	e) two
f) primary & secondary	g) iron
h) AC	i) primary
j) fluctuating	k) induces
l) different	m) secondary
n) higher	o) primary
p) lower	q) power/energy
r) Conservation of Energy	s) current
t) energy losses	u) resistance heating
v) eddy	w) increases
x) lose/radiate	y) resistance
z) (many) thin	aa) laminated
ab) eddy	ac) up
ad) 250,000	ae) down
af) neighbourhood	ag) 240

Worksheet 11

1. a) $V_p / V_s = n_p / n_s$

so $n_s = n_p.V_s / V_p = 24{,}000 \times 240 / 11{,}000$
$= 524$ turns

b) $V_pI_p = V_sI_s$ so $I_s = V_pI_p / V_s$
$= 240 \times 30 / 11{,}000 = 0.65$ A

2.

a) $n_p = n_s.V_p / V_s = 50 \times 240 / 6.0 = 2{,}000$ turns

b) $V_pI_p = V_sI_s$ so $I_p = V_sI_s / V_p$
$= 6.0 \times 0.5 / 240 = 0.0125$ A

3. a) $P_s = V_s.I_s$ so $Is = Ps / Vs = 2000 / 800 = 2.5$ A

b) $V_p / V_s = n_p / n_s$ and $V_p / V_s = 4{,}000 / 800 = 5$.
Therefore, $n_p : n_s = 5 : 1$

c) The secondary coil has to carry a higher current (because of step-down in voltage). Thicker wires reduce resistance & energy losses.

d) Resistance heating (especially from eddy currents in core) increases resistance & wastes more energy. Cooling system reduces resistance & energy loss, plus it prevents over-heating & core melt-down.