A metal rod of length $L$ rotates with a constant angular speed $\omega$ in an anticlockwise sense in a uniform magnetic field $\vec{B}$. The current in the rod has a constant value $I$.

What is the magnitude and direction of the force $\vec{F}$ acting on the current carrying rod?

The rod is now aligned so that it rotated in the plane of the magnetic field.

What is the magnitude and direction of the force $\vec{F}$ acting on the current carrying rod?
Westinghouse and Edison were in competition to supply electricity to cities in the late nineteenth century. This competition led to Edison holding public demonstrations to promote his system of DC generation over Westinghouse’s system of AC generation.

What are some of the arguments that may have been put forward by Edison?

What are some of the arguments that may have been put forward by Westinghouse?

Which system was finally adopted by city authorities and why did they make that choice?

An electron travels at \(2.00 \times 10^7\) m.s\(^{-1}\) in a plane perpendicular to a 0.0178 T magnetic field.

(a) Describe the path of the electron.

(b) Calculate the radius of the circular orbit.

(c) Calculate the period of motion.

(d) Calculate the frequency of the electron.

(e) Calculate the angular frequency of the electron.

(f) If the magnetic field was doubled in strength, how would the above answers change?
A coil of wire ABCD A is placed in a uniform magnetic field $B$. The coil can move freely. An electric current $I$ flows around the coil. In which direction does the coil begin to move as a consequence of the interaction between the external magnetic field and the current? Explain.

An experiment was performed in which the force on a long current-carrying conductor placed perpendicular to an external magnetic field was measured as the current in the conductor was increased. The length of the conductor in the magnetic field was 1.85 m.

The following results were recorded

<table>
<thead>
<tr>
<th>Force (N)</th>
<th>0</th>
<th>15.2</th>
<th>28.6</th>
<th>46.1</th>
<th>59.8</th>
<th>75.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>current (A)</td>
<td>0</td>
<td>1.0</td>
<td>2.0</td>
<td>3.0</td>
<td>4.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Graph the results.

What is the relationship between the force on the conductor in the magnetic field and the current? Is this what you expected?

What was the magnitude of the external magnetic field in this experiment?
An electric motor is connected to a 12 V battery. The motor is used to lift a load vertically by using a pulley attached to the rotating shaft of the motor. As the load is lifted by the motor, weights are continually added to increase the load.

(a) How will the rotation speed of the motor change as the load increases? Explain.

(b) How will the current in the coils change as the load increases? Explain.

(c) Draw a graph of the coil current (y axis) vs rotation speed (x axis) for the increasing load.

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Outline the main physical principles in the operation of a generator.

(b) What is the difference between an ac and a DC generator?

(c) What physical quantities determine the magnitude of the induced emf from a generator? You need to indicate if any of these quantities are increased will the induced emf increase or decrease.
(a) What is Faraday's law of electromagnetic induction?

(b) What is meant by the term induced emf? How can there be an induced current?

(c) What is Lenz’s law?

A copper rod is held in a horizontal position just above the poles of a permanent magnet. It then is released and falls through the magnetic field of the magnet.

(d) How does the motion of the rod differ from its free fall motion?

(e) How is an induced emf created in the rod?

(f) Which end of the rod becomes negative?

(g) Why is no induced current in the rod?

(h) How could the rod be modified so that when it fell through the magnetic field a current would be induced?

(i) How could this experiment be performed to heat the conductor?
(a) A neon sign needs an operating voltage of 5500 V and is to be operated from a 240 V power point. How can this be achieved?

(b) The secondary coil of a step down transformer consists of a larger diameter wire than the primary windings. Explain.

(c) Christmas lights contain a string of 36, 1.5 V lights in series with each other. The resistance of each globe is 2.5 $\Omega$. They are connected to a 240 V power point using a transformer of 500 turns. 

What is the power dissipated by the light globes?

What is the power need to be supplied by the transformer, assuming that the coil is only 95% efficient?

How many turns does the secondary coil have in the transformer?

What is the current in the secondary coil to provide sufficient energy to light the globes?

What is the corresponding primary current?

(d) A transformer is to be designed so that it is efficient, with heating by eddy currents minimised. The designer has some iron and insulating material available to build the transformer core. The windings are to be made with insulated copper wire. 

Draw a design of your transformer to minimise the energy losses in the core? Explain your answer.

P6148

A coil of 1000 turns and an area of 0.125 m$^2$ is located in a uniform magnetic field of strength 5.55 T produced by an electromagnet. The normal to the coil is at 30$^\circ$ to the direction of the magnetic field.

(a) When the electromagnet is switched off, an emf is induced in the coil. Explain.

(b) If the magnetic field dropped to zero is a time interval of 0.200 s, what is the induced emf across the ends of the coil? The coil is now connected to an external circuit of resistance 10.5 $\Omega$. What is the induced current through the external circuit?

(c) If the magnetic field dropped to zero is a time interval of 2.00 ms, what is the induced emf?

(d) Explain why you can get sparking when electrical equipment is switched on or off.
In an evacuated chamber, a pair of parallel metal plates are separated by a distance of \(75.75 \times 10^{-3} \text{ m}\) and have a potential difference of 1.222k V applied to them. A beam of electrons is fired with a velocity of \(6.35 \times 10^{6} \text{ m.s}^{-1}\) between the plates. When the voltage applied to the plates is zero, the electron beam passes un-deflected through the region between the plates.

(a) Calculate the magnitude of the electric field strength between the plates.

(b) Calculate the magnitude of the electrostatic force acting on an electron between the plates.

(c) A magnetic field is applied between the plates, sufficient to cancel the force on the electron beam due to the electric field. Calculate the magnitude of the magnetic field required between the plates to cancel the deflection of the electron beam due to the electric field.

(d) Draw a diagram of the plates showing
- The charge on the plates.
- The electric field and the electric force on an electron.
- The magnetic field and the magnetic force on an electron.
- The trajectory of the electron passing through the plates with zero fields applied.
- The trajectory of the electron if the magnetic field only was set to zero.
- The trajectory of the electron if the electric field only was set to zero.
(a) In a real generator, why does the rotating coil have many turns rather than a single loop of wire? Explain.

(b) When a generator is supplying current to an external circuit, it is found that the force required to keep the coil turning is greater than the force needed to rotate the coil when the external circuit is not connected to the generator. Explain.

(c) The diagram shows two generator coils, one with one loop and the other two loops at right angles to each other.

(i) Describe the commutators that are used for a DC and an AC generator.
(ii) What is the function of the brushes?
(iii) Draw the DC and AC outputs for the two generators.

(d) Discuss the advantages and disadvantages of DC and AC generators.

P6173

You have a task of designing the mechanism for adjusting level of effort required to rotate the spinning wheel of an exercise bike. Explain how this could be achieved using a set of strong permanent magnets.
A simple motor with has an armature of 50 windings and a current of 1.56 A. The area of the coil is 0.0185 m$^2$. The magnetic field has a strength of 0.266 T. The axle of the motor is attached to a pulley of radius 105 mm. A load is attached to the pulley that is to be lifted by the rotation of the motor / pulley system.

(a) What is the maximum load that the motor can just lift?

(b) Sketch a graph of the variation of the torque acting on the coil vs time. On the graph add a line showing the average torque. The average torque is related to the maximum torque by the equation

$$\tau_{\text{avg}} = \left(\frac{2}{\pi}\right)\tau_{\text{max}}$$

(c) By adjusting the current in the coil, a load can be lifted with a constant velocity. Find the coil current for a load of 0.123 kg to be lifted at a constant velocity?
Given:

- Magnetic field $B = 1.25 \, \text{T}$
- $L_{CD} = L_{EF} = 12 \, \text{mm}$
- $L_{DE} = L_{CF} = 6.0 \, \text{mm}$
- Rotation rate $= 20 \, \text{rpm}$ (revolutions per minute)
- Number of turns of coil $N = 100$
- Total resistance of coil $R_{\text{coil}} = 10 \, \Omega$
- Resistance of external load connected between A and B $R_{\text{load}} = 125 \, \Omega$

Calculate:

(a) For the rotation:
   - Angular frequency $\omega = ? \, \text{rad.s}^{-1}$
   - Frequency of rotation $f = ? \, \text{Hz}$
   - Period $T = ? \, \text{s}$

For angles $\alpha = 0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 360 \, \text{deg}$

(b) Magnetic flux $\phi_B = ? \, \text{T.m}^2$
   - Induced polarity of point A with respect to the point B $\text{emf} = ? \, \text{V}$
   - The induced current $I = ?$

(c) Graph the above quantities.

(d) The rotation speed was doubled.

On your graphs add curves to show the resulting changes that would occur.

The generator is now to be used a motor. The coil is no longer rotated by an external mechanical energy supply and the load is removed from between A and B.

The point A was connected to the positive terminal of a 12 V battery and point B was connected to the negative terminal.

(e) Explain why this arrangement does not work as a motor.

(f) The commutator of the slip rings is replaced by a split ring. The motor now works. Why?
Two identical rectangular metal plates are arranged to give a uniform electric field in the region between them when the plates are connected to a battery. This arrangement is known as a parallel plate capacitor. The battery voltage can be changed and the distance between the plates varied.

(a) What is the electric field strength between the plates when the battery voltage is 200 V and the distance of separation of the plates is 40.0 mm?

(b) Draw a graph (to scale) of how the electric field changes as the battery voltages changes from 0 to 600 V when the distance remains constant at 40.0 mm. Mark the point when the voltage is 200 V on your graph. What is the battery voltage if the electric field value from part (a) is doubled? Show this point on your graph.

(c) Draw a graph (to scale) of how the electric field changes as the distance between the plates increases from 20 to 100 mm when the battery voltage remains constant at 200 V. Mark the point when the separation distance is 40 mm on your graph. What is the separation distance if the electric field value from part (a) is halved? Show this point on your graph.

A positively charged rod is fixed above a negatively charged plate.

Sketch the electric field between the rod and the plate.

A proton when located at the point X experiences an acceleration of $8.56 \times 10^{-21}$ m.s$^{-2}$. Calculate the following:

(a) The force on the electron (magnitude and direction).

(b) The electric field at location X (magnitude and direction).

If the electron was located at location Y, would the force on the proton be smaller, larger or the same as location X? Explain.
(a) Can you arrange three parallel wires so that they attract each other?

(b) Can you arrange three parallel wires so that they repel each other?

Explain.

The diagram shows (top view) of a simple DC generator. If the motion of the wires P and Q of the coil are as shown, what are the directions of the induced currents in P and Q?

An electricity substation delivers a current of 10.0 A at a voltage of 11.00 kV to a factory. The factory uses a transformer to provide a current of 205 A at a voltage of 240V.

(a) Explain why AC not DC are used for the primary voltages of transformers.

(b) Outline possible causes of energy loss in the transformer.

(c) Calculate the energy lost by the transformer in eight hours.

(d) If the primary coil had $2.25 \times 10^4$ turns, calculate the number of turns in the secondary windings of the transformer.
A coil is suspended from a support so that it can swing freely.

(a) A magnet is moved towards one end of the coil. As the N pole approaches the end of the coil, what will be the effects upon the coil?

(b) A thick copper wire is now connected between the ends of the coil. As the N pole approaches the end of the coil, what will be the effects upon the coil?

You wanted to design a mechanism to reduce the internal vibrations inside a scientific instrument. The design is based using a coil, strong permanent magnetic and a wire. Explain, how using just the coil, magnet and wire the vibrations can be reduced.
Two parallel wires have currents in the same direction and are separated by a distance of 0.55 m. One wire is 3.60 m in length and has a current of 2.05 A and the other wire can be considered to be infinitely long and carries a current of 5.56 A.

(a) What is the direction of the force that exists between the two wires? Explain.

(b) Sketch a graph that shows how the force between the two wires would vary if the length of the first was increased.

(c) Sketch a graph that shows how the force between the two wires would vary if the distance between the wires was decreased.

(d) Explain the above answers are related to the motor effect.

(a) What is a DC motor? Describe its main features.

(b) What is an AC motor? Describe its main features

(c) Compare the advantages and disadvantages between DC and AC motors.

(d) Which statement correctly describes an AC induction motor?
   (i) An AC or DC motor in which torque is produced by the interaction of a rotating magnetic field in the stator with induced magnetic fields of the induced current in the rotor.
   (ii) An AC only motor in which torque is produced by the interaction of a rotating magnetic field in the stator with induced magnetic fields of the induced current in the rotor.
   (iii) An AC or DC motor in which torque is produced by the interaction of a rotating magnetic field in the stator with induced magnetic fields of the supplied current in the rotor.
   (iv) An AC only motor in which torque is produced by the interaction of a rotating magnetic field in the stator with induced magnetic fields of the supplied current in the rotor.

(e) Which statement about an AC motor is correct?
   (i) It has slip rings and carbon brushes.
   (ii) It has slip rings but no carbon brushes.
   (iii) It has a split ring commutator and carbon brushes.
   (iv) It has a split ring commutator but no carbon brushes.

(f) Which statement about split rings and slip rings is correct?
   (i) Neither are commutators.
   (ii) Only split rings are commutators.
   (iii) Only slip rings are commutators.
   (iv) Both are commutators
What is the magnetic force in each of the following cases for a negative charge moving through a uniform magnetic field?

\[
q = -1.47 \times 10^{-15} \text{ C} \quad v = 7.41 \times 10^5 \text{ m.s}^{-1} \quad B = 2.58 \text{ T}
\]

A generator is made by spinning a magnet near four coils.

(a) Explain why this device would work as a generator.

(b) What would be the advantage of this type of device?

(c) What is a big disadvantage of this device?
A very simple hand generator is shown in the diagram where a conductor in the form of a disc is turned by hand. The bottom portion of the disk is rotated through a region of uniform magnetic field produced by a pair of bar magnets.

(a) Why does the light globe only glow when the wheel is spun rapidly?
(b) Why are brushes used in generators and where are they located in the diagram?
(c) Describe the current through the light globe.

What is the magnetic flux through each of the following circuits:

(a) A square of sides 154 mm with its plane perpendicular to a uniform magnetic field of strength 4.56 T?

(b) A rectangle with sides 154 mm x 258 mm with its normal parallel to a uniform magnetic field of strength 4.56 T?

(c) A circle of radius 154 mm with its normal at an angle of 60° to a uniform magnetic field of strength 4.56 T?

(d) A circle of radius 154 mm with its plane at an angle of 60° to a uniform magnetic field of strength 4.56 T?
A positively charged ion travels at 455 km.s$^{-1}$ through two parallel charged plates, P and Q and a crossed magnetic field directed out of the page. The ion is travelling perpendicular to both the electric and the magnetic fields. The ion has a charge of 12.5 $\mu$C and a mass of 1.85x10$^{-25}$ kg. The electric field between the plates has a magnitude of 15.5 kV.m$^{-1}$. The magnetic field is adjusted so that the ion passes through undisturbed. The separation distance between the plates is 20 mm and the length of the plates are 50 mm.

(a) Calculate the magnitude of the adjusted magnetic field, and the polarity of the P terminal relative to the Q terminal?

(b) Calculate the potential difference between the plates.

(c) If the magnetic field was reduced to zero, what is the vertical deflection of the charged ion?
A conductor of length $L$ is mounted on frictionless rails. The conductor and the rails are connected to a resistor $R$ to form a complete circuit. The arrangement is located in a uniform magnetic field $B$. The conductor is pulled along with a velocity $v$ and it moves in a direction perpendicular to the magnetic field.

(a) Explain why there is a current induced in the circuit.

(b) Show that the magnitude of the induced current is

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

---

An current carrying coil ABCD is to be placed into the magnetic field between the two magnets.

(a) Show how the coil can be placed so that it will not rotate.

(b) Show how the coil can be placed so that the turning effect will be a maximum.
Two conductors 1.65 m in length were supported in a vertical wooden rack. The mass of each conductor was 14 g and they were placed 112 mm apart. The two ends were connected together and then the other two ends were briefly connected to a battery. It was observed that one of the tubes jumped upward as the connection to the battery was made.

(a) Explain why only one tube jumped upward.

(b) What minimum current required for one tube jumps?

(c) What is the implication of this result for power distribution networks?
The two graphs below show the time variation of the magnetic flux through a coil. Draw (show numerical values for each axis) the corresponding graphs for the induced emf.

(a)

(b)
Two conductors are located horizontally, with one conductor a vertical distance of 122 mm above the other. The linear mass of the conductors is 0.154 g.m⁻¹. The top conductors current is \( I_1 = 80.5 \) A. How much current \( I_2 \) does the bottom conductor carry so that it does not fall due to gravity? What are the directions of the currents in the two conductors?

(a)
Explain the physical principles of how an AC motor operates using the diagrams as a basis for your answer.

(b)
Consider the design shown for an induction motor. Explain the operation of this motor and any advantages or disadvantages with the design.
P6506

(a) Identify the two main energy losses in the transmission of electrical energy between power plant and the home.

(b) How are energy losses in transmission lines minimised?

(c) An average of 120 kW of electric power is sent to a small town from a power point 10 km away. The resistance of the transmission lines is \(4.0 \times 10^{-5}\ \Omega \cdot \text{m}^{-1}\). Calculate the power loss and the percentage power loss if the power is transmitted at 240 V and 24 kV.

(d) In the 1880s two systems of power generation were in competition to supply domestic electricity to consumers. Which was the preferred system at that time? What was the deciding factor in the Westinghouse-Edison debate?

(e) In transmission line towers, why are ceramic insulating stacks used?

(f) How are transmission towers protected from lightning strikes?

(g) What stops the current in high voltage overhead transmission lines from running to earth?

(h) You are offered a house plot close to a high-voltage transmission line. The plot has marvellous views and is cheap. Discuss the pros and cons of living on this site. Would you buy the land? Why? What enquiries might you make of the electricity company in arriving at a decision? What measurements would you make to put your mind at rest?

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P6547

(a) Draw a diagram of the main components of a typical galvanometer.

(b) What is the motor effect?

(c) Explain how the galvanometer can measure current in a circuit.

_______________________________
A conductor ABCD is situated in a magnetic field directed out of the page. The conductor has a galvanometer inserted in side BC and a conducting rod XY connects the sides AB and CD. The rod slides 60 mm to the left in one second and then stops for a further one second. Then the rod slides at the same speed, 120 mm to the right of its initial position.

(a) Sketch the possible current changes observed on the galvanometer.

(b) What are the directions of the induced currents?

---

A conductor of length 554 mm was attached to the top an electronic balance. The current in this wire was fixed at 4.59 A. The balanced was adjusted to give a zero reading. A second conductor of the same length was placed directly above the conductor fixed to the top of the balance. The current in the second conductor was varied and the balanced reading was recorded.

<table>
<thead>
<tr>
<th>current #2 (A)</th>
<th>7.5</th>
<th>17.2</th>
<th>28.6</th>
<th>38.5</th>
<th>47.3</th>
<th>57.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>balance (kg)</td>
<td>0.680</td>
<td>0.695</td>
<td>0.702</td>
<td>0.715</td>
<td>0.723</td>
<td>0.735</td>
</tr>
</tbody>
</table>

(a) For a positive reading on the balance, what must be the directions of the two currents?

(b) Plot a graph of the data with the y axis for the balance reading.

(c) Find the mass of the conductor fixed to the top of the balance.

(d) Find the separation distance between the conductors.
A heavy duty electric motor is used to lift heavy loads. The motor is connected to a large battery through a variable resistor. The resistance value $R$ of the resistor can be adjusted from 0 to $R_{\text{max}}$ to control the speed of the motor.

(a) What is the best value of the resistance $R$ when the motor first starts? Explain.

(b) How can the motor speed be varied from slow to high speeds? Explain.

(c) What is the resistance value for the motor to work at its maximum speed? Explain.

A disc magnet has its poles on its opposing flat surfaces. An insulated copper wire was placed on the disc magnet as shown in the diagram. The instant the wire was connected to a DC battery, the wire was observed to move in the direction of the arrow when the current was from X to Y.

What is the direction of the magnetic field and identify the poles of the magnet?

An aeroplane is flying horizontally over the north pole. The diagram shows the plane when viewed from above. How will the plane be charged? Specify the charge at each of the points P, Q, R and S.
(a) What is the role of a transformer at an electrical power station? Explain

(b) Why is it necessary to use transformers with many electrical devices used in the home and not plug them directly into a 240 V power point?

(c) A transformer has 1200 turns in its primary windings and only 12 turns in its secondary. What type of transformer is it? If the transformer primary is connected to a 240 V power point and draws a current of 15 A, what is the secondary voltage and current? Assume an ideal transformer.

(d) A student constructed and tested a model transformer and obtained the results:
\[ V_p = 12.0 \text{ V} \quad I_p = 0.045 \text{ A} \quad V_s = 6.3 \text{ V} \quad I_s = 0.065 \text{ mA} \]

Calculate the power lost from this transformer.

Identify a feature of a real transformer that would reduce this power loss and explain your answer in terms of the key physical principles.

P6655

A magnetic is dropped vertically (N pole lower end) from above a coil connected to a galvanometer.

(a) Sketch a graph of the current through the galvanometer as the magnetic falls through it.

(b) Explain your sketch.
Two conducting coils P and Q are placed near each other.

At time $t = 0$, the switch in the circuit for loop Q is in the open position. At time $t = 2$ s, the switch is closed and then at time $t = 4$ s the switch is open and left in the open position.

(a) Describe the changes if any in the current in loop P.

(b) Sketch a graph of the current in loop P as a function of time from $t = 0$ to $t = 5$ s.

(c) Describe the forces acting on loop P in this 5 s time interval.

(d) Describe the forces acting on loop Q in this 5 s time interval.

(e) Sketch a graph of the force acting on loop P as a function of time from $t = 0$ to $t = 5$ s.
An electron enters a very strong magnetic field.

(a) Sketch the most likely path of the electron.

(b) How does the speed of the electron change?

(c) Explain both your answers.

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An electromagnet is attached to the bottom of a light train which is travelling from left to right. When a large current is passed through the coils of the electromagnet, the train slows down as a direct result of the law of conservation of energy. Explain why the train slowed down.

(b) Explain why it is difficult to move a bar magnet rapidly near a sheet of copper? Why is this effect not so dramatic if an aluminium sheet was used? Why is there no effect whatsoever if the magnet is moved rapidly over a plastic sheet?
A simple generator has a coil of $N$ turns and an area of $A$. It is in a magnetic field of strength $B$. The frequency of the armature rotation is $f$.

The emf of the generator applied to an external circuit is shown in the graph below:

(a) What type of output is shown in the graph?

(b) What type of commutator is used with the generator to produce this emf?

(c) From the graph find the following:
   - maximum emf produced by the generator
   - period of rotation of the coil?
   - frequency of rotation of the coil?
   - angular speed (or angular frequency) of the coil
   - rotation speed of the coil in rpm (revolutions per minute)

(d) If a split ring commutator was used with the generator, draw the graph for the emf produced by the generator.

(e) If the magnetic field was reduced from $B$ to $B/2$, draw the graph for the emf produced by the generator.

(f) If the area of the loop was reduced from $A$ to $A/2.5$, draw the graph for the emf produced by the generator.

(g) If the number of turns of the coil was increased from $N$ to $1.5N$, draw the graph for the emf produced by the generator.

(h) If the frequency of the coil was increased from $f$ to $2f$, draw the graph for the emf produced by the generator.
P6730

A coil containing 150 windings has a coil current of 1.23 A. The coil is suspended in a magnetic field \( B \) and it experiences a torque of 0.185 N.m.

(a) Explain why the coil experiences a torque.

(b) Calculate the strength of the magnetic field if the coil.

(c) How can the turning effect be increased?

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P6754

(a) A copper ring is dropped over a bar magnet.

What are the directions of the induced magnetic field when (i) it approaches the top of the magnet and (ii) when it falls away from the magnet? Explain. Describe the motion of the falling ring. If the ring was cooled to a very low temperature before it was dropped, what difference would it make as it falls through the magnetic field of the magnet?

(b) Four rings (plastic, iron – non-magnetic, copper, copper with slit) are dropped at the same time over four identical magnets. What is the order in which the rings reach the bottom of the magnets? Explain.
A coil is placed into a uniform magnetic field. The normal of the coil is parallel to the magnetic field. The strength of the magnetic field is increasing.

(a) The coil is not connected to an external circuit. What is polarity of the induced emf across the terminals X and Y?

(b) The coil is connected to an external circuit with a resistance $R$. What is the direction of the induced current in the coil and circuit?
A rectangle coil with 1290 turns is in a uniform magnetic field $B = 0.678 \, \text{T}$. The plane of the coil is parallel to the magnetic field. The coil has sides of 400 mm (across $B$) and 160 mm (parallel $B$) and carries a current of 15 A.

(a) Draw a labelled diagram of the coil and magnetic field so that it could act as a DC motor.

(b) Calculate the magnitude of the force on the coil and show the direction of the force on the coil in your diagram.

(c) Calculate is the maximum torque on the coil?

(d) If the plane of the coil was at an angle of $30^\circ$ to the direction of the magnetic field, calculate the force and the torque acting on the coil.

(e) When is the net force and torque on the coil both zero.

(f) The manufacturer of a DC motor made the following claim: “The torque of the DC motor has a constant value of 12 N. Analyse this claim with reference to the accuracy of the statement.

Three wires are laid parallel to each other. Wires 1 and 3 are in fixed positions. Wire 2 can freely move. In what direction will wire 2 move when the currents are simultaneously turned on?

- $I_1 = 2.37 \, \text{A}$
- $I_2 = 5.15 \, \text{A}$
- $I_3 = 1.25 \, \text{A}$
Two types of generators are shown below.

(a) What are the names for the parts of the two generator shown in the diagrams.

(b) What is the difference in the emf produced by the two generators.

(c) Sketch a graph of the emf output from both generators.

(d) If the generator is connected to an external circuit of resistance $R$, what type of current is produced by each generator?

(e) What is the function of the brushes in a generator?

(f) Why are only AC generators used in the generation of electricity by power stations?
(h) If the coil had 500 turns, an area of 0.557 m² and rotation frequency of 60 Hz in a uniform magnetic field of 2.65 T, calculate:

- Maximum emf generated
- Period of rotation
- Draw a diagram of the emf vs time clearly showing numerical values for the scales.

(i) A simple AC generator develops a sinusoidal emf with a maximum value of 46.3 V at a frequency of 50 Hz in a uniform magnetic field of 2.65 T. The area of the coil is 0.557 m².

- What is the rotation speed of the coil in rpm?
- What is the emf produced by a single coil?
- How many turns are in the coil?

(j) The coil of the AC generators rotates at a constant rate in the magnetic field

Draw two graphs of the induced emf as a function of time for both the AC and DC generators. Indicate on your graphs the times 1, 2, 3, 4, and 5 for the different positions of the coil as shown in the diagram.
A beam of electrons are moving in a direction that is parallel to a conductor carrying a current. The electrons are deflected away from the conductor.

(a) What are the possible directions for both the electron beam and the current?

(b) If the current in the conductor was doubled, what can you conclude about the deflection of the electron beam?

(c) If the current in the conductor was reduced to zero, what can you conclude about the deflection of the electron beam?

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What role does a transformer play in an electrical circuit?

Why are transformers so important in the distribution of electrical energy from a power plant to industry and homes?

If a power line has a resistance of $6.2 \times 10^{-4} \, \Omega \cdot m^{-1}$, calculate the power lost over 100 km of line if a current of 50 A is flowing through the line.

A battery charger is used to recharge 1.5 V batteries through a 12 V transformer. The transformer has 2400 turns in the primary coil. Assuming 100% efficiency, calculate: (i) The number of turns in the secondary coil. (ii) The output current if the input current is 10 mA.

What is the reason why heating effects occur in the core of transformers?

Which of the following core designs R, S, T or U would minimise the heating effect due to eddy currents? Explain why each of the designs would work or not work.
Electric power generators are much harder to turn when current is drawn from the generator. Explain.

Power stations need to burn much coal to supply power during times of peak demand. Explain.

Access the impacts of the development of AC generators on today’s society and the environment.

What principle was the deciding factor in the AC/DC competition?

Westinghouse created opportunities for his AC distribution system at the right time by underbidding Edison on two extremely important projects. What were the projects? Why were the projects important? If Edison had one of these projects – would it have made a difference? How would our electricity supply system be different if DC transmission was used today instead of AC? What are the limitations of DC transmission?

Thomas Edison was a great scientist. He had over 150 inventions and held over 1900 scientific patents. However, his tactics in the competition against Westinghouse seem to be a bit unethical. What were three of his possible motives? Critically evaluate each motive. Assess the fairness of Edison’s tactics. Was Edison justified at his win at all costs attitude?
An electric DC motor consists of 1500 turns of wire formed into a rectangular coil of area $25 \times 10^{-6} \text{ m}^2$. The coil is in a uniform magnetic field of $5.12 \times 10^{-3} \text{ T}$. A current of 3.42 A flows through the coil.

(a) Draw a diagram showing the forces acting on the coil and the resultant torque on the coil when the angle $\theta$ between the normal to the area of the coil and magnet field is $30^\circ$. Calculate the torque acting on the coil.

(b) Draw a diagram showing the orientation of the coil when the torque acting on the coil is zero.

(c) Draw a diagram showing the orientation of the coil when the torque acting on it is a maximum. Calculate the maximum torque acting on the coil.

(d) If the rotational speed of the coil was 30 rpm, calculate the rate of change of the magnetic flux and the back emf of the motor. The motor is run from a 12.0 V battery and the resistance of the coil windings plus the series resistance between the coil and battery is 10.0 $\Omega$, what is the maximum current through the coil?
A rectangular loop of mass 2.456 g is suspended vertically from a spring balance in a uniform magnetic field which is directed out of the page as shown. The width of the conductor in the magnetic field is 120 mm. The top portion of the loop is free of the magnetic field. The spring balance reading is $4.896 \times 10^{-3}$ N when the conducting loop carries a current of 0.451 A. What is the magnitude of the uniform magnetic field? (This technique is a highly accurate means of measuring the strength of magnetic fields).

(a) Suppose that a square loop of wire is moved through a uniform magnetic field in a direction at right angles to the field. Will there be an induced current around the loop? Consider different orientations of the loop. Explain your answers.

A flat horizontal metal plate is perpendicular to a magnetic field. The plate is moved at a constant speed through the magnetic field. As the metal plate is moved out of the magnetic field:

(b) Draw a diagram showing the eddy current (include direction) induced in the metal plate.

(c) Explain why the eddy current is induced and how does this affect the motion of the plate through the magnetic field?

(d) Give one practical example of this phenomenon.

(a) A motor operating at maximum has an armature resistance of 5.5 Ω and a coil current of 12.5 A when connected to a 240 V power supply. What is the back emf? If the motor jammed and stopped rotating, what would be the coil current. Why would this be a problem?

(b) The back emf in a motor is 75.4 V when operating at a rotation speed of 1200 rpm. What would be the back emf at 1800 rpm if the magnetic field does not change?
A magnetic moving near a loop induces a current in the circuit.

(a) What will the direction of the current when the magnetic enters the loop?

(b) What will the direction of the current when the magnetic exits the loop?

Explain your answers.

A rectangular loop is rotating about the y axis in a uniform magnetic field \( B = 1.0 \text{ T} \) that is directed in the +x direction with a constant angular frequency (speed) \( \omega = 20 \text{ rad.s}^{-1} \). The dimensions of the loop are 40 mm x 50 mm. At time \( t = 0 \text{ s} \) the plane of the loop is perpendicular to the magnetic field (in the yz plane).

(a) Sketch the loop in the magnetic field, showing the x,y and z axes.

(b) Graph the variation of the magnetic flux through the loop with time for three complete rotations of the loop (include the scales for the magnetic flux and time)?