CHAPTER 13

Magnetic Effects of Ele

DISCLAIMER: This material is prepared for educational reference only. All questions are from NCERT Exemplar Problems, Class 10 Science, Chapter 13. Attempt questions independently before consulting solutions.

KEY TERMS & GLOSSARY

Term	Definition
Magnetic Field	Region around magnet/conductor where magnetic force acts; has direction and magnitude
Magnetic Field Line	Closed curve showing direction of field; tangent at any point gives field direction
Solenoid	Helical coil of insulated wire; acts like a bar magnet when current flows through it
Electromagnet	Temporary magnet made by passing DC through coil wound on soft iron core
Right-Hand Thumb Rule	Thumb = current direction; curled fingers = direction of magnetic field around conductor
Fleming's Left-Hand Rule	Forefinger=B, Middle finger=I, Thumb=Force (motion); used for MOTORS
Fleming's Right-Hand Rule	Thumb=conductor motion, Forefinger=B, Middle finger=Induced I; used for GENERATORS
Electromagnetic Induction	Inducing current in closed loop by changing magnetic flux (Faraday's law)
AC Generator	Converts mechanical energy to alternating current using slip rings
DC Generator	Converts mechanical energy to direct current using split-ring commutator
Commutator	Split ring that reverses current every half cycle to maintain one-way rotation in motors
Direct Current (DC)	Current that always flows in one direction; source: battery, DC generator
Alternating Current (AC)	Current that reverses direction periodically; 50 Hz in India (100 changes/sec)
Fuse	Safety device in series; thin wire melts on excess current, breaking the circuit
Earthing	Green wire connecting metal body to earth; protects users from electric shock

KEY FORMULAE & RULES

Rule / Formula	Description	Application
Right-Hand Thumb Rule	Thumb = current direction; curled fingers = field direction	Straight conductors, solenoids
Fleming's Left-Hand Rule	Forefinger=B, Middle=I, Thumb=Force	Electric motors
Fleming's Right-Hand Rule	Thumb=motion, Forefinger=B, Middle=induced I	Generators/dynamos
Force on conductor	F = BIL sin(theta) (Force = B x I x Length)	Perpendicular when theta=90 deg
AC frequency India	f = 50 Hz; T = 1/50 s; 100 direction changes/second	Household supply 220V
Power (motor)	P = V x I = I<super rise='4' size='8'>2</super> x R	Electrical power consumed
Magnetic field (wire)	B proportional to I/r (field decreases with distance r)	Straight conductor

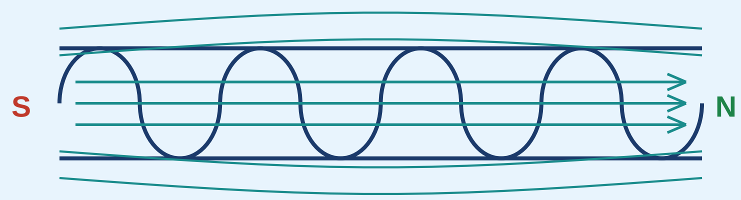
COMPARISON: DC vs AC \| Motor vs Generator \| Slip Ring vs Commutator

Property	Direct Current (DC)	Alternating Current (AC)
Direction	Always same direction	Reverses periodically

Frequency	0 Hz (constant)	50 Hz in India
Direction changes	Never	100 times per second (2 x 50)
Source	Battery, DC generator	AC generator (alternator)
Generator component	Split-ring commutator	Slip rings (continuous)
Usage	Electronics, charging	Household supply

Aspect	Electric Motor	Electric Generator
Energy conversion	Electrical -> Mechanical	Mechanical -> Electrical
Input	Current + Voltage	Rotational mechanical energy
Output	Rotational motion	Current + Voltage
Key component	Commutator reverses current	Slip rings / commutator output
Principle	Force on current in B field	EMI - changing flux induces current
Examples	Fan, mixer, pump, drill	Power station, bicycle dynamo

Solenoid -- Magnetic Field Pattern (Current carrying coil)



Uniform straight field lines inside | Curved field lines outside | Resembles bar magnet

Magnetic Field Lines Around Straight Conductor (Cross-section view)

Anticlockwise circles for current out of page | Clockwise circles for current into page | Right-hand thumb rule

SECTION A: MULTIPLE CHOICE QUESTIONS (18 MCQs -- All Solved)

Exam Strategy: For 'INCORRECT statement' questions, verify each option carefully. Apply rules: Right-hand = field direction; Left-hand = motor force; Right-hand (generator) = induced current.

Q1. Choose the INCORRECT statement from the following regarding magnetic lines of field:

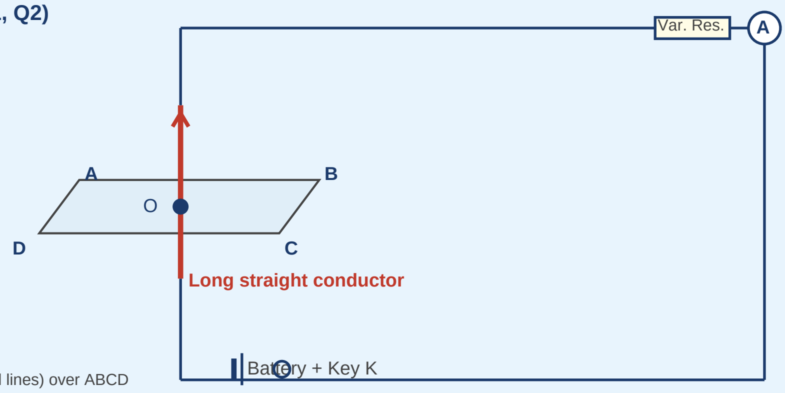
(a) Direction of magnetic field at a point is taken to be direction in which N-pole of compass needle points

(b) Magnetic field lines are closed curves

(c) If magnetic field lines are parallel and equidistant, they represent ZERO field strength [CORRECT]

(d) Relative strength of magnetic field is shown by degree of closeness of the field lines

Fig 13.1 -- Long straight conductor circuit (Q1, Q2)



Key K removed -> no current -> only Earth's field (straight parallel lines) over ABCD

Answer: (c)

Parallel and equidistant magnetic field lines represent a UNIFORM (constant) field strength -- NOT zero field strength. Zero field would mean no field at all, shown by absence of lines. Options (a), (b), (d) are all correct statements.

Tip: Uniform field = parallel equidistant lines (constant magnitude). Zero field = no lines at all. Do not confuse the two.

Q2. If the key in the arrangement (Fig 13.1) is taken out (circuit open) and magnetic field lines are drawn over the horizontal plane ABCD, the lines are:

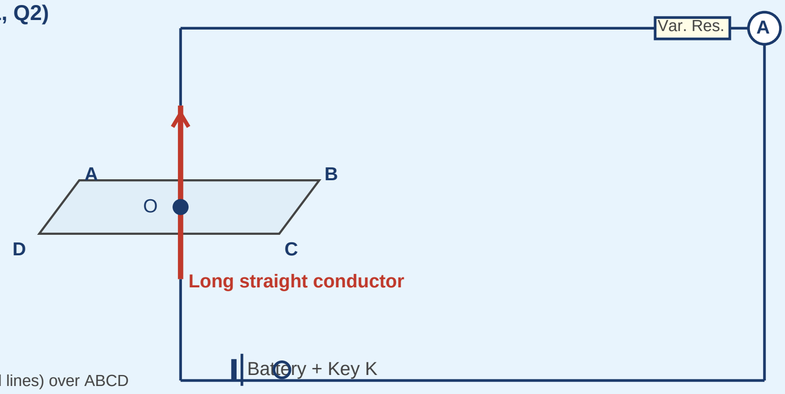
(a) Concentric circles

(b) Elliptical in shape

(c) Straight lines parallel to each other [CORRECT]

(d) Concentric circles near O but elliptical as we go away

Fig 13.1 -- Long straight conductor circuit (Q1, Q2)



Key K removed -> no current -> only Earth's field (straight parallel lines) over ABCD

Answer: (c)

When key is removed, NO current flows in the conductor. Without current there is NO magnetic field from the conductor. The only field present is Earth's magnetic field, which produces straight parallel lines across the horizontal plane.

Tip: No current = no circular field from conductor. Only Earth's uniform field remains = straight parallel lines.

Q3. A circular loop carries current. Seen from A: anticlockwise; seen from B: clockwise. Field lines point from B to A. N-pole of resultant magnet is on face close to:

(a) A [CORRECT]

(b) B

(c) A if current small, B if current large

(d) B if current small, A if current large

Answer: (a)

By right-hand rule for circular loop: if current appears ANTICLOCKWISE viewed from a face, that face is the N-POLE. Current from A is anticlockwise -> face A is N-pole. Field lines go from B to A (i.e., from S to N outside magnet) confirming A is N-pole. N/S pole position is independent of current magnitude.

Tip: Anticlockwise current view = N-pole face. This never changes with current magnitude -- so options (c) and (d) are wrong.

Q4. For current in a long straight solenoid, N and S poles are created at ends. The INCORRECT statement is:

(a) Field lines inside solenoid are straight lines -- field same at all points inside

(b) Strong field inside can magnetise soft iron placed inside

(c) Pattern of field of solenoid is DIFFERENT from pattern around a bar magnet [CORRECT]

(d) N and S poles exchange position when direction of current is reversed

Answer: (c)

The field pattern of a solenoid is IDENTICAL to that of a bar magnet -- both have N and S poles, same curved external field pattern, and uniform internal field. Option (c) says 'different' which is the INCORRECT statement. (a), (b), (d) are all correct.

Tip: Solenoid = equivalent bar magnet in field pattern. The only difference: solenoid needs current, bar magnet is permanent.

Q5. Uniform magnetic field pointing left to right. Electron moves upward, proton moves downward (Fig 13.3). They experience:

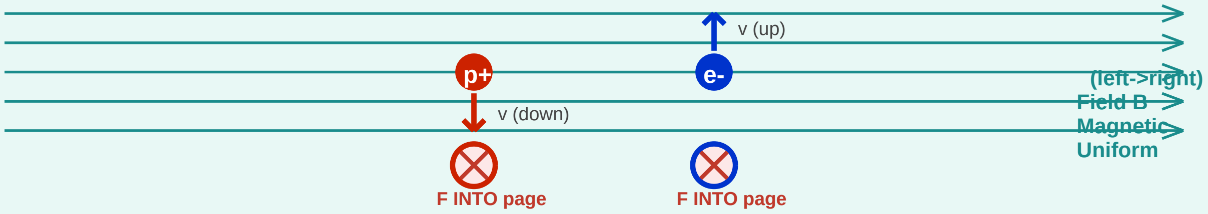
(a) Forces both pointing INTO the plane of paper [CORRECT]

(b) Forces both pointing OUT OF the plane of paper

(c) Forces pointing into and out of plane respectively

(d) Force pointing opposite and along direction of field respectively

Fig 13.3 -- Electron (up) & Proton (down) in uniform B field (left to right) [Q5]



X = Force INTO page   BOTH forces point into plane of paper   Answer: (a)

Answer: (a)

For ELECTRON (negative charge q = -e, velocity upward, B = rightward): F = qv x B. v(up) x B(right) = out of page. But q is negative -> F is INTO page. For PROTON (positive charge, velocity downward, B = rightward): v(down) x B(right) = into page. q positive -> F is INTO page. Both forces are INTO the plane of paper.

Tip: For opposite charges moving in opposite directions: F = qv x B gives same force direction since both q and v are reversed.

Q6. Commercial electric motors do NOT use:

(a) An electromagnet to rotate the armature

(b) Effectively large number of turns of conducting wire in the coil

(c) A permanent magnet to rotate the armature [CORRECT]

(d) A soft iron core on which the coil is wound

Answer: (c)

Commercial motors use ELECTROMAGNETS (not permanent magnets) for much stronger magnetic fields. They also use many turns of wire (b) and soft iron core (d). PERMANENT MAGNETS are used only in simple/school-level motors, not commercial ones.

Tip: Simple motor: permanent magnet. Commercial motor: electromagnet + many coil turns + soft iron core. Three key differences.

Q7. Two coils on a rod (Fig 13.4). Key not inserted, then inserted, then removed. Galvanometer:

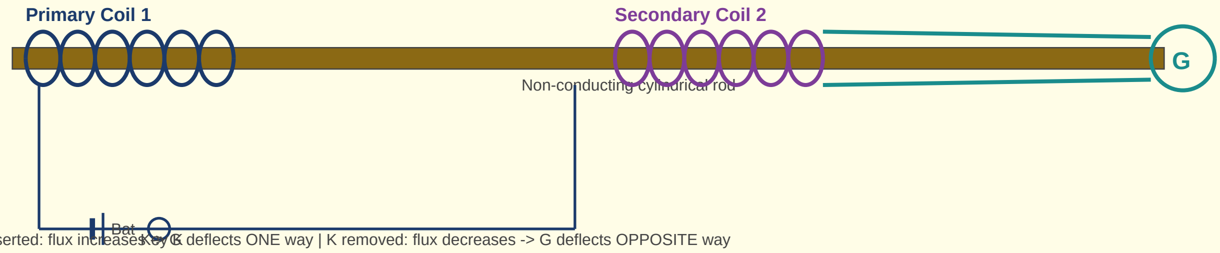
(a) Deflection remains zero throughout

(b) Momentary deflection when key inserted; dies out; no effect when removed

(c) Momentary deflections; both in SAME direction

(d) Momentary deflections that die out; deflections in OPPOSITE directions [CORRECT]

Fig 13.4 -- Two coils on rod: EMI demonstration [Q7]



K inserted: flux increases -> G deflects ONE way | K removed: flux decreases -> G deflects OPPOSITE way

Answer: (d)

When key INSERTED: current in primary increases from 0 -> flux increases -> EMI induces current in secondary -> galvanometer deflects in ONE direction momentarily. When key REMOVED: current decreases to 0 -> flux decreases -> induced current REVERSES direction -> galvanometer deflects in OPPOSITE direction. Steady current = no deflection. Both deflections are momentary.

Tip: EMI occurs only when flux CHANGES. Increasing flux -> one direction; decreasing flux -> opposite direction.

Q8. Choose the INCORRECT statement:

(a) Fleming's right-hand rule gives direction of induced current

(b) Right-hand thumb rule finds direction of magnetic field due to current-carrying conductors

(c) DC always flows in one direction; AC reverses direction periodically

(d) In India, AC changes direction after every 1/50 second [CORRECT]

Answer: (d)

AC in India has frequency 50 Hz (50 complete cycles per second). In EACH cycle, current changes direction TWICE. Therefore it changes direction 2 x 50 = 100 times per second, i.e., after every 1/100 second -- NOT after every 1/50 second. Option (d) is INCORRECT.

Tip: Period T = 1/50 s (time for 1 full cycle). But direction changes TWICE per cycle -> every 1/100 s.

Q9. Constant current flows horizontally East to West (in plane of paper). Direction of magnetic field is North to South at:

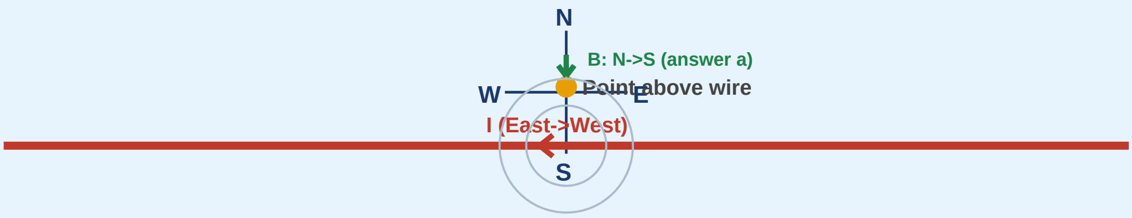
(a) Directly above the wire [CORRECT]

(b) Directly below the wire

(c) At a point in plane of paper on NORTH side of wire

(d) At a point in plane of paper on SOUTH side of wire

Fig 13.5 -- Current East->West, find B direction [Q9]



Apply right-hand thumb rule: thumb West (current dir) -> above wire: field points South (N->S)

Answer: (a)

Current direction: East to West (leftward). Apply right-hand thumb rule: thumb points West. Directly ABOVE the wire: fingers come from East side curling through North direction toward West. At a point directly above, field direction is from North to South (pointing South). This matches option (a).

Tip: Always draw a diagram and apply right-hand thumb rule carefully for direction questions.

Q10. Strength of magnetic field inside a long current-carrying straight solenoid is:

(a) More at ends than at centre

(b) Minimum in the middle

(c) Same at all points [CORRECT]

(d) Increases from one end to the other

Answer: (c)

Inside a long solenoid the magnetic field is UNIFORM -- same magnitude and direction at ALL interior points. This is shown by straight, parallel, equally-spaced field lines inside. The field is weaker outside (especially near ends) but uniform throughout the interior.

Tip: Inside solenoid = uniform field. Same as inside a bar magnet conceptually. Uniform spacing of lines.

Q11. To convert an AC generator into a DC generator:

(a) Split-ring type commutator must be used [CORRECT]

(b) Slip rings and brushes must be used

(c) A stronger magnetic field has to be used

(d) A rectangular wire loop has to be used

Answer: (a)

AC generator uses SLIP RINGS (two complete rings) -> output alternates direction -> AC. To get DC: replace slip rings with SPLIT-RING COMMUTATOR. The split ring reverses the external connections every half cycle, compensating for the current reversal in the coil. Result: output always flows in same direction -> DC.

Tip: Memory: AC = Slip rings (both have 'continuous'). DC = split-ring commutator (both have 'broken/split').

Q12. The most important safety method for protecting home appliances from short circuiting or overloading:

(a) Earthing

(b) Use of fuse [CORRECT]

(c) Use of stabilizers

(d) Use of electric meter

Answer: (b)

FUSE is the primary safety device against excess current due to short circuits and overloading. It melts and breaks the circuit when current exceeds rated value. EARTHING protects against electric shock (not overloading). Stabilizers protect against voltage fluctuation, not excess current.

Tip: Fuse: protects circuit/appliances from excess current. Earthing: protects user from electric shock. Different purposes.

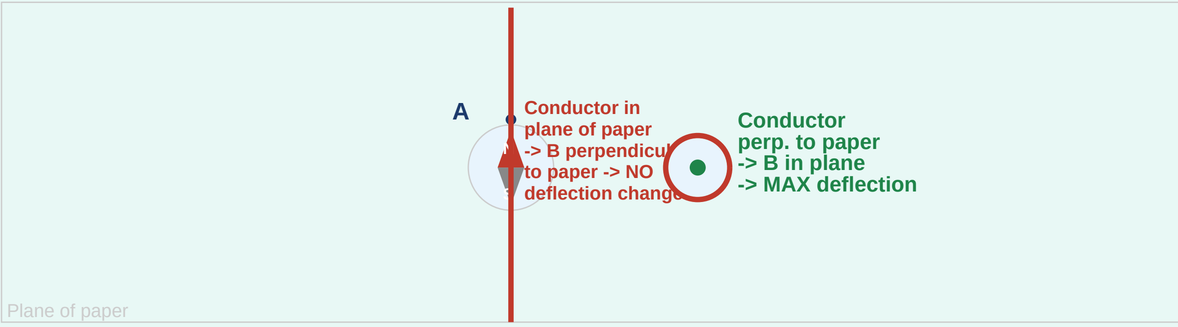
MCQ ANSWER KEY (Quick Reference)

1	**(c)**	2	**(c)**	3	**(a)**
4	**(c)**	5	**(a)**	6	**(c)**
7	**(d)**	8	**(d)**	9	**(a)**
10	**(c)**	11	**(a)**	12	**(b)**

SECTION B: SHORT ANSWER QUESTIONS (Q13 to Q24)

Q13. A magnetic compass needle is placed near point A (Fig 13.6). In which plane should a straight current carrying conductor be placed through A so there is NO change in compass deflection? Under what condition is deflection MAXIMUM?

Fig 13.6 -- Compass needle at point A [Q13]



Left: conductor in plane of paper (no deflection change). Right (dot): conductor perp. to paper (max deflection)

No change in deflection:

Place the conductor in the PLANE OF THE PAPER (vertical plane containing the compass). The magnetic field produced by this conductor is perpendicular to the plane of paper (either into or out of paper). The compass needle lies horizontal in the plane of paper and responds only to horizontal field components. A perpendicular (vertical) field has no deflecting effect on the horizontal needle. Hence no change in deflection.

Condition for MAXIMUM deflection:

Deflection is maximum when the conductor is placed PERPENDICULAR TO THE PLANE OF PAPER passing through A (i.e., conductor axis vertical, entering/leaving the paper at A). Then the field produced is entirely horizontal in the plane of paper, acting directly on the compass needle. This maximum field produces maximum torque on the needle, giving maximum deflection.

Tip: Compass responds to horizontal components of field. Perpendicular field = no deflection. In-plane circular field = maximum deflection.

Q14. Under what conditions is a PERMANENT electromagnet obtained using a current carrying solenoid? Give a labelled circuit diagram.

Conditions:

1. The solenoid must carry DIRECT CURRENT (DC) -- not AC. 2. The material of the core placed inside must be STEEL (hard magnetic material). Steel has HIGH RETENTIVITY -- it retains magnetism after current is switched off. 3. The DC current magnetises the steel rod permanently along the solenoid axis. N-pole forms at the end from which field lines emerge (anticlockwise current face).

Why NOT soft iron:

Soft iron has LOW RETENTIVITY -- loses magnetism immediately when current stops. Soft iron core gives a TEMPORARY ELECTROMAGNET (used in electric bells, cranes). For permanent magnets: steel, alnico, or ferrite cores are used.

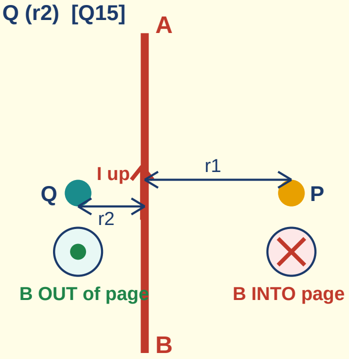
Circuit diagram (description):

Components: DC battery -> Switch K -> Variable resistor -> Solenoid coil wound around STEEL rod. The steel rod becomes a permanent magnet with poles at its two ends. Direction of poles determined by right-hand rule applied to coil current direction.

Tip: Steel = permanent magnet (high retentivity). Soft iron = temporary electromagnet (low retentivity). Always DC for solenoid magnets.

Q15. AB is a current carrying conductor in plane of paper (Fig 13.7). Directions of magnetic fields at P and Q? Given r1 > r2, where is field larger?

Fig 13.7 -- Conductor AB with points P (r1) and Q (r2) [Q15]



r1 > r2 -> B at Q (closer) is LARGER than B at P | B proportional to 1/r | Q has stronger field

Direction at P (right of conductor):

Current flows UPWARD in conductor AB. Using right-hand thumb rule: thumb points UP. On the RIGHT side of conductor (at P): fingers come FROM the right side going AWAY from viewer. Magnetic field at P is directed INTO the plane of paper.

Direction at Q (left of conductor):

On the LEFT side of conductor (at Q): fingers come FROM the left side coming TOWARD viewer. Magnetic field at Q is directed OUT OF the plane of paper.

Where is field larger:

Since r1 > r2 (P is farther, Q is closer), the field at Q is LARGER. For a straight conductor: B is proportional to 1/r (inversely proportional to distance). Closer distance r2 -> stronger field at Q.

Tip: B proportional to I/r for straight conductor. Closer point = stronger field. Opposite sides of conductor = opposite field directions.

Q16. How does the deflection of a compass get affected when current in a nearby wire is increased?

Effect:

The deflection of the compass needle will INCREASE when the current in the wire is increased.

Reason:

The magnetic field produced by a current-carrying conductor is DIRECTLY PROPORTIONAL to the magnitude of the current (B proportional to I for a straight conductor). Greater current -> stronger magnetic field around wire -> greater resultant field on compass -> greater torque on the magnetic needle -> needle deflects more from its original N-S position. If current is doubled, field doubles, causing greater deflection.

Tip: B proportional to I. More current = stronger field = compass needle deflects more. Reverse current = needle deflects opposite way.

Q17. Is there a magnetic field around a thin beam of moving (i) alpha particles, (ii) neutrons? Justify.

(i) Alpha particles -- YES:

Alpha particles are positively charged (charge = +2e). A beam of moving alpha particles constitutes an ELECTRIC CURRENT in the direction of motion (positive charge moving = conventional current). By Oersted's discovery, any electric current produces a magnetic field around it. Therefore, YES, a magnetic field is produced around a beam of moving alpha particles.

(ii) Neutrons -- NO:

Neutrons are electrically NEUTRAL (zero charge). A beam of moving neutrons does NOT constitute an electric current (no charge is flowing). Without an electric current, no magnetic field is produced (by classical electromagnetism). Therefore, NO magnetic field is produced around a beam of moving neutrons.

Tip: Current = flow of charges. Charged particles (alpha) -> current -> magnetic field. Neutral particles (neutrons) -> no current -> no field.

Q18. What does the direction of thumb indicate in the right-hand thumb rule? How is this rule different from Fleming's left-hand rule?

Right-Hand Thumb Rule:

In the right-hand thumb rule, hold a straight current-carrying conductor in the right hand with the THUMB pointing in the direction of ELECTRIC CURRENT. The curled fingers indicate the direction of the CIRCULAR MAGNETIC FIELD LINES around the conductor. Thumb = current direction. Fingers = magnetic field direction around conductor.

Difference from Fleming's Left-Hand Rule:

RIGHT-HAND THUMB RULE: Finds direction of MAGNETIC FIELD produced around a current-carrying conductor. Uses right hand; thumb = current. No external field involved. Applicable to all current-carrying conductors. FLEMING'S LEFT-HAND RULE: Finds direction of FORCE (mechanical motion) on a current-carrying conductor already placed in an EXTERNAL magnetic field. Uses left hand with three fingers mutually perpendicular: forefinger = external field B, middle finger = current I, thumb = force/motion direction. Used specifically for electric motors (force on conductor in external field).

Tip: Right-hand thumb: field AROUND conductor. Fleming's left-hand: force ON conductor in external field. Two completely different applications.

Q19. Meena observes that magnetic field lines near the axis of a current-carrying circular loop keep diverging as she moves away from centre. Explain.

Explanation:

Near the CENTRE of the circular loop, the field lines are closely packed and nearly parallel, indicating a strong, nearly uniform field. As we move AWAY from the centre along the axis, the magnetic field becomes progressively WEAKER with increasing distance from the current-carrying loop. DIVERGING field lines are a visual representation of DECREASING field strength -- the more the lines spread apart, the weaker the field. At very large distances, the field becomes negligible. This is analogous to field lines spreading from a bar magnet pole as distance increases. Conclusion: Divergence = field lines spreading = field getting weaker with distance.

Tip: Field line density = field strength. Close together = strong. Spreading apart (diverging) = weakening field with distance.

Q20. What does the divergence of magnetic field lines near the ENDS of a current-carrying straight solenoid indicate?

Inside the solenoid:

Field lines are straight, parallel, and uniformly spaced, indicating UNIFORM and STRONG magnetic field inside. This is the region of maximum field strength.

At and beyond the ends -- divergence indicates:

1. The magnetic field is becoming WEAKER near and beyond the ends of the solenoid. 2. The field is NO LONGER UNIFORM in this region. 3. The solenoid ends behave like POLES of a bar magnet: N-pole end: field lines emerge and spread out (diverge). S-pole end: field lines converge and enter. 4. The diverging lines eventually curve around externally from N to S, just like the external field of a bar magnet. 5. Overall, the solenoid field pattern RESEMBLES a bar magnet -- uniform inside, curved and diverging outside.

Tip: Divergence at solenoid ends = solenoid acts as bar magnet. Internal uniform field + external bar-magnet-like field.

Q21. Name four appliances using an electric motor. How are motors different from generators?

Four appliances using electric motors:

1. Electric fan 2. Mixer/grinder 3. Washing machine 4. Electric water pump. (Also: refrigerator compressor, electric drill, hair dryer, computer cooling fan)

Motors vs Generators (key difference):

ELECTRIC MOTOR: Input = ELECTRICAL ENERGY; Output = MECHANICAL ENERGY (rotation). Principle: A current-carrying conductor in a magnetic field experiences force (motor effect). ELECTRIC GENERATOR: Input = MECHANICAL ENERGY (rotation); Output = ELECTRICAL ENERGY. Principle: A conductor moving in a magnetic field has an EMF induced (electromagnetic induction). They are REVERSE processes of each other, both using the relationship between electricity and magnetism, but in opposite directions.

Tip: Motors: electrical to mechanical. Generators: mechanical to electrical. Based on same electromagnetic principle but in reverse.

Q22. What is the role of the two conducting stationary brushes in a simple electric motor?

Role of brushes:

The two conducting STATIONARY BRUSHES (usually made of carbon or copper) serve as ELECTRICAL CONTACTS between the EXTERNAL STATIONARY CIRCUIT (battery/power supply) and the ROTATING SPLIT-RING COMMUTATOR attached to the coil. Specifically: 1. They maintain continuous electrical contact with the split rings as the commutator rotates. 2. They ensure current from the battery flows into the rotating coil without tangling. 3. In combination with the split ring, they REVERSE the direction of current in the coil every half rotation, ensuring the coil always experiences force in the same direction (necessary for continuous rotation). 4. Without brushes, no current could be supplied to the rotating coil.

Tip: Brushes = interface between stationary circuit and rotating commutator. They enable current reversal every half turn via the split ring.

Q23. Difference between direct current and alternating current? How many times does AC in India change direction in one second?

Direct Current (DC):

DC flows continuously in ONE FIXED DIRECTION only. The magnitude may vary but direction never reverses. Sources: electrochemical cell/battery, DC generator, rectifier. Examples: current in torch, car battery, electronic devices.

Alternating Current (AC):

AC REVERSES its direction PERIODICALLY at regular time intervals. It follows a sinusoidal pattern: flows in one direction, reverses, flows back, reverses again. Sources: AC generator (alternator), power stations. Examples: household supply at 220V, 50 Hz.

Direction changes in India:

In India, AC frequency = 50 Hz = 50 complete cycles per second. In each cycle: current changes direction TWICE (once in first half, once in second half). Total direction changes per second = 2 x 50 = 100 TIMES PER SECOND. Time between each direction change = 1/100 = 0.01 second.

Tip: 50 Hz means 50 cycles/second. 2 direction changes per cycle. Total = 100 changes/second. Every 0.01 s.

Q24. What is the role of fuse used in series? Why should a fuse with defined rating not be replaced by one with larger rating?

Role of fuse:

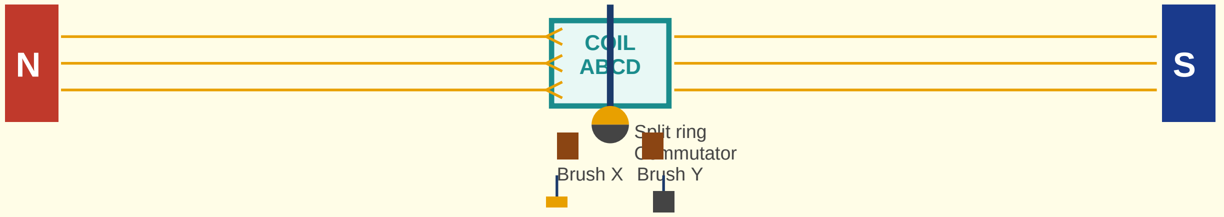
A fuse is connected in SERIES with electrical appliances/circuits as a safety device. It contains a thin wire of LOW MELTING POINT alloy (tin-lead or similar). When EXCESS CURRENT flows (due to short circuit or overloading), the fuse wire heats up rapidly due to Joule heating ($H = I^2 Rt$), reaches its melting point, MELTS, and BREAKS the circuit. This stops current flow and PROTECTS appliances and wiring from damage. The fuse 'sacrifices' itself to protect the more expensive equipment.

Why NOT a larger rated fuse:

A larger-rated fuse requires MORE current to melt than the circuit can safely handle. If excess current flows (fault condition): - The larger fuse will NOT melt at the dangerous current level. - The excess current continues flowing through the circuit and appliances. - This causes overheating of wires (potential fire hazard). - Appliances get damaged or destroyed. - Risk of electric shock to users. The original fuse rating is chosen to match the MAXIMUM SAFE CURRENT of that specific circuit. Replacing with higher rating removes the protection entirely.

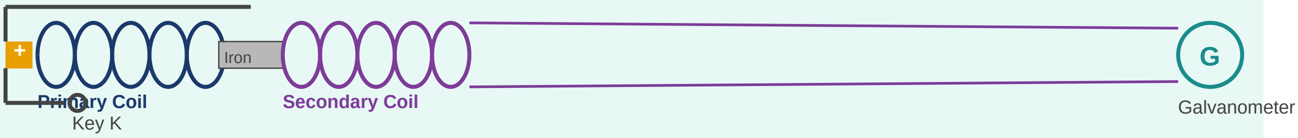
Tip: Fuse rating = maximum safe current for circuit. Higher rating fuse = no protection. Always use IDENTICAL rating fuse.

Simple Electric Motor -- Schematic



Battery (+/-) -> Brushes -> Commutator -> Coil | Fleming's LHR determines force on AB and CD

Electromagnetic Induction Experiment (Faraday)



Key ON->increasing flux->deflection 1 direction | Key OFF->decreasing flux->deflection OPPOSITE direction

SECTION C: LONG ANSWER QUESTIONS (Q25 to Q32)

Q25. Why does a magnetic compass get deflected when a bar magnet or current carrying loop is brought near it? Describe salient features of magnetic lines of field.

Why compass deflects:

A compass needle is a small bar magnet that aligns with Earth's magnetic field (pointing approximately N-S). When a bar magnet or current-carrying loop (which also behaves like a bar magnet) is brought near, it creates an additional magnetic field in the region. The compass needle now experiences the VECTOR SUM (resultant) of Earth's field and the external field. This resultant points in a different direction, causing the needle to rotate and align with the new resultant direction -- hence deflection. Stronger external field = greater deflection from N-S.

Salient features of magnetic field lines:

1. DIRECTION: Tangent to a field line at any point gives the direction of the magnetic field at that point. 2. CLOSED CURVES: Field lines are closed, continuous curves -- they emerge from N-pole, curve around outside, enter at S-pole, and continue through the magnet from S to N forming closed loops. 3. FIELD STRENGTH: Degree of closeness (density) of field lines represents field strength. Closely packed lines = strong field; widely spaced lines = weak field. 4. NON-INTERSECTING: Two field lines can NEVER cross or intersect. At any point, field has only ONE direction. If lines crossed, field would have two directions at that point -- impossible. 5. UNIFORM FIELD: Parallel, equally-spaced field lines represent a uniform (constant) magnetic field (e.g., inside a solenoid or between poles of a horseshoe magnet).

Tip: Compass needle = small magnet. External field changes resultant -> deflection. 5 properties: direction, closed curves, density=strength, non-intersecting, uniform=parallel.

Q26. With a labelled circuit diagram illustrate pattern of field lines around a current-carrying straight long wire. How is the right-hand thumb rule useful?

Circuit diagram and field pattern:

SETUP: Battery connected to a long vertical wire passing through a horizontal cardboard. Iron filings sprinkled on cardboard, or compass needles placed at various points. OBSERVATION: When current flows, iron filings arrange themselves in CONCENTRIC CIRCLES centered on the wire in planes perpendicular to the conductor. PATTERN FEATURES: (i) Field lines are concentric circles around the wire (closed loops with wire at centre). (ii) Circles become LARGER and MORE WIDELY SPACED with increasing distance -- field weakens. (iii) Field B is proportional to 1/r (inversely proportional to distance r from wire). (iv) Direction of circles: ANTICLOCKWISE when current comes out of paper; CLOCKWISE when into paper. (v) Reversing current reverses all field directions.

Right-Hand Thumb Rule:

Imagine holding the current-carrying wire in the RIGHT HAND with the THUMB pointing in the direction of ELECTRIC CURRENT. The CURLED FINGERS around the wire indicate the direction of CIRCULAR MAGNETIC FIELD LINES at any point around the conductor. APPLICATION: If current is upward (thumb up), fingers curl: front of wire = leftward, right of wire = forward, back = rightward, left = backward. This allows determination of field direction at any point around any straight conductor.

Tip: Concentric circles centered on wire = field lines. Density decreases with distance. Right-hand thumb rule gives field direction.

Q27. Explain with a labelled diagram the distribution of magnetic field due to current through a circular loop. Why does a coil of n turns produce n times the field of one turn?

Field distribution of circular loop:

For a current-carrying circular loop, the magnetic field varies with position: AT THE CENTRE: Field lines are nearly straight, perpendicular to the plane of loop. Field is strongest here. All parts of the loop contribute field in the same direction at centre. ALONG THE AXIS (away from centre): Field lines curve outward and diverge. Field weakens progressively. FAR FROM LOOP: Field pattern resembles that of a bar magnet (dipole field). INSIDE LOOP (non-axis): Complex curved field lines. DIRECTION AT CENTRE: Right-hand rule for loop -- curl fingers in direction of current, thumb points toward the N-face (field direction at centre points from S to N face through loop centre).

Why n turns give n times the field:

Each individual turn of wire carries the SAME current I and is wound in the SAME direction. Each turn independently produces a magnetic field at any given point. Since all turns have current in the same direction, the fields from ALL turns at any given point are in the SAME DIRECTION (they add constructively -- not cancel). By the principle of SUPERPOSITION, the total field = sum of fields from all turns. B(n turns) = n x B(1 turn). This is why increasing number of turns dramatically increases field strength in solenoids and electromagnets.

Tip: More turns = same direction fields add up. B is proportional to n. This is the key advantage of using coils over single loops.

Q28. Describe the activity showing a current-carrying conductor experiences a force perpendicular to its length and the external field. How does Fleming's left-hand rule help?

Activity/Experiment:

APPARATUS: Two strong horseshoe magnets (or C-shaped magnets) facing each other to create a horizontal magnetic field between their poles, a straight aluminium rod AB suspended horizontally by flexible wires so it can move, battery, rheostat, switch. PROCEDURE: Step 1: Place rod AB horizontally between the poles (perpendicular to field B). Step 2: Connect to battery and close switch to pass current through AB. OBSERVATION: Rod AB immediately experiences a force and JUMPS UP or DOWN (perpendicular to both AB and field B). VARIATIONS: (a) Reverse current direction -> force reverses (rod jumps opposite way). (b) Reverse magnet poles -> force reverses. (c) Increase current -> greater force. CONCLUSION: Force is perpendicular to both current direction and field direction. F = BIL.

Fleming's Left-Hand Rule:

Stretch THUMB, FOREFINGER, and MIDDLE FINGER of LEFT hand mutually perpendicular (90 deg to each other). FOREFINGER: points in direction of MAGNETIC FIELD B (from N to S). MIDDLE FINGER: points in direction of CONVENTIONAL CURRENT I in conductor. THUMB: points in direction of FORCE (mechanical motion) on the conductor. EXAMPLE: B pointing North, I flowing East -> Thumb points Upward. This rule allows us to PREDICT the direction of force without doing the experiment. This is the exact principle used in electric motors to produce rotation.

Tip: F = BIL, perpendicular to both I and B. Fleming's LHR: left hand, 3 perpendicular fingers, forefinger=B, middle=I, thumb=force.

Q29. Draw a labelled circuit diagram of a simple electric motor and explain its working. How are simple motors different from commercial motors?

Labelled diagram -- components:

COMPONENTS: Two permanent magnets (N and S poles facing each other), rectangular coil ABCD (wound on soft iron core), split-ring commutator (two half-rings P and Q, insulated from each other, attached to the coil ends), two carbon brushes (X and Y, stationary, pressing against P and Q), battery (DC source), switch.

Working principle:

1. Current enters via brush X, flows through commutator P -> arm AB -> arm CD -> commutator Q -> brush Y -> battery. 2. Arm AB (current in one direction in field B): by Fleming's LHR, experiences UPWARD force. 3. Arm CD (current in opposite direction): experiences DOWNWARD force. 4. These two forces create a TORQUE, rotating the coil. 5. After HALF ROTATION: commutator halves P and Q swap contact with brushes X and Y. 6. Current direction in coil REVERSES. 7. Now AB has downward force and CD has upward force -- but since they have also changed position, the coil CONTINUES to rotate in the SAME direction. 8. This process repeats, maintaining continuous rotation. Result: Electrical energy -> Continuous mechanical (rotational) energy.

Simple motor vs Commercial motor:

SIMPLE MOTOR: Permanent magnets (weak field), few turns in coil, no iron core, low power. COMMERCIAL MOTOR: (1) Uses ELECTROMAGNETS instead of permanent magnets -> much stronger adjustable field. (2) Uses LARGE NUMBER OF TURNS of copper wire in coil -> much greater force/torque. (3) Uses SOFT IRON CORE inside the coil -> concentrates and increases the magnetic field. Result: Commercial motors are far more powerful, efficient, and suitable for industrial use.

Tip: Three differences: electromagnet vs permanent magnet; many turns vs few; soft iron core vs no core. All three increase motor power.

Q30. Explain electromagnetic induction. Describe an experiment to show that current is set up in a closed loop when external magnetic field increases or decreases.

Electromagnetic Induction:

ELECTROMAGNETIC INDUCTION (EMI) is the phenomenon by which an ELECTROMOTIVE FORCE (EMF) and hence an electric current is INDUCED (generated) in a closed conducting loop whenever the MAGNETIC FLUX through the loop CHANGES. Discovered by Michael Faraday (1831). KEY PRINCIPLE (Faraday's Law): Induced EMF = rate of change of magnetic flux = d(phi)/dt. LENZ'S LAW: The direction of induced current is such that it OPPOSES the change in flux that caused it. Important: It is the CHANGE in flux that matters, not the flux itself. Steady flux = zero EMF.

Experiment:

SETUP: Primary coil (P) connected to battery and switch K. Secondary coil (S) wound on same iron rod, connected to a sensitive galvanometer G. OBSERVATIONS: 1. Switch K OPEN (no current): Galvanometer reads ZERO -- no flux, no change. 2. Switch K CLOSED (current builds up, flux INCREASES): Galvanometer deflects momentarily in ONE direction (say right) then returns to zero. Induced current flows briefly as flux rises to steady value. 3. Current STEADY (constant flux): Galvanometer reads ZERO -- no change in flux. 4. Switch K OPENED (current drops to zero, flux DECREASES): Galvanometer deflects momentarily in OPPOSITE direction (left) then returns to zero. CONCLUSION: Current is induced only during CHANGE in flux (increase or decrease). Increasing flux -> induced current in one direction; decreasing flux -> opposite direction.

Tip: EMI: changing flux -> induced current. Key: CHANGE needed (not just large flux). Lenz's law: induced current opposes the change.

Q31. Describe the working of an AC generator with a labelled circuit diagram. What changes convert it to a DC generator?

AC Generator -- Components:

COMPONENTS: Strong horseshoe magnet (N-S poles), rectangular armature coil ABCD, two slip rings R1 and R2 (complete/continuous rings, attached to ends of coil, rotate with it), two stationary carbon brushes B1 and B2 (press against slip rings), external circuit/galvanometer.

Working of AC Generator:

1. Coil ABCD is mechanically rotated between poles of magnet (by turbine, engine, etc.). 2. As coil rotates, it CUTS through magnetic field lines. 3. By Faraday's law, an EMF is INDUCED in the rotating coil (electromagnetic induction). 4. FIRST HALF ROTATION (0 deg to 180 deg): Arm AB moves upward in field, arm CD moves downward. Induced current flows A->B->C->D in coil, then via slip rings to external circuit. 5. SECOND HALF ROTATION (180 deg to 360 deg): Arms AB and CD have swapped positions. Current direction REVERSES: D->C->B->A. 6. Since slip rings are CONTINUOUS (not split), they do not reverse the external connections. 7. Result: External circuit receives current that ALTERNATES direction each half cycle -> AC. 8. One complete rotation = one complete cycle of alternating current.

Converting to DC Generator:

Replace the two slip rings with a SPLIT-RING COMMUTATOR (two half-cylinders, insulated at the split). The split ring reverses the brush-coil connection every half rotation, compensating exactly for the current reversal in the coil. Result: External circuit always receives current in ONE DIRECTION -> DC output. The output is pulsating DC (varying magnitude but fixed direction).

Tip: AC generator: slip rings (continuous) -> alternating output. Change to split-ring commutator -> DC. Key difference is the ring type.

Q32. Draw a schematic diagram showing common domestic circuits and discuss the importance of fuse. Why should a burnt out fuse be replaced by another fuse of IDENTICAL rating?

Domestic circuit schematic:

SUPPLY enters home as: Live wire (L, Red, 220V AC) + Neutral wire (N, Black, 0V) + Earth wire (E, Green). SEQUENCE: Electricity board supply -> Main fuse -> Electricity meter -> Main switch -> Distribution board (with individual fuses for each circuit). CIRCUITS from distribution board: (i) Lighting circuit: 5A fuse, connects all lights and fans. (ii) Power circuit: 15A fuse, connects heavy appliances (AC, geyser, washing machine). KEY FEATURE: All appliances connected in PARALLEL -- each appliance gets full 220V supply. Individual switches allow independent on/off control. Earth wire connected to metal body of each appliance for safety.

Importance of fuse:

1. OVERLOAD PROTECTION: When too many appliances run simultaneously, total current may exceed safe limit. Fuse melts, breaking circuit before wires overheat. 2. SHORT CIRCUIT PROTECTION: If live and neutral wires accidentally contact, huge current flows. Fuse melts instantly, preventing fire and equipment damage. 3. FIRE PREVENTION: Without fuse, overheated wires could ignite insulation and cause fires. 4. APPLIANCE PROTECTION: Saves expensive equipment from current surges. 5. FIRST LINE OF DEFENCE: Fuse is the most immediate and reliable protection in the circuit.

Why identical rating fuse must be used:

The fuse rating is carefully chosen to equal the MAXIMUM SAFE CURRENT for that specific circuit. If a HIGHER-rated fuse replaces the original: - It requires more current to melt than the circuit can safely carry. - During a fault, the excess dangerous current will flow through wires and appliances. - This causes wire overheating (fire risk), appliance damage, and potentially electric shock. The fuse with identical rating provides protection at exactly the right current level. The fuse is rated for the circuit, not the appliance -- it must match the circuit design.

Tip: Parallel domestic circuits: all appliances get 220V independently. Identical fuse: protection works only at original rated current.

COMMON MISTAKES TO AVOID

MISTAKE 1: Confusing the three hand rules

RIGHT-HAND THUMB RULE: field direction AROUND a conductor (no external field). FLEMING'S LEFT-HAND RULE: force ON conductor in EXTERNAL field (MOTORS). FLEMING'S RIGHT-HAND RULE: direction of INDUCED current in GENERATORS. Memory: Mo-tor = Left. Gene-rator = Right. Thumb rule = for field only.

MISTAKE 2: Thinking AC changes direction every 1/50 second

50 Hz means 50 complete cycles per second. Each cycle = 2 direction changes. Total = 100 direction changes per second. Change every 1/100 s NOT 1/50 s. Time period T = 1/50 s (full cycle) but direction change = T/2 = 1/100 s.

MISTAKE 3: Thinking solenoid field is different from bar magnet

Solenoid and bar magnet have IDENTICAL field patterns -- both inside and outside. Option (c) in Q4 is WRONG. Solenoid IS like a bar magnet. Inside: uniform straight lines. Outside: same curved pattern as bar magnet.

MISTAKE 4: Thinking permanent electromagnet needs soft iron core

Soft iron = LOW retentivity = TEMPORARY electromagnet (loses field when current off). STEEL = HIGH retentivity = PERMANENT electromagnet. Always: soft iron for temporary; steel/alnico/ferrite for permanent magnets.

MISTAKE 5: Thinking neutral particles produce magnetic fields

Only CHARGED particles (alpha particles, electrons, protons) moving as a beam constitute electric current and produce magnetic fields. NEUTRONS are neutral -> no current -> no magnetic field produced. A common exam trap.

MISTAKE 6: Confusing slip rings and split-ring commutator

SLIP RINGS (complete rings) -> AC generator: allows current alternation -> AC output. SPLIT-RING COMMUTATOR (two halves) -> DC motor/generator: reverses connections to keep rotation direction constant (motor) or output direction constant (DC generator). AC = slip rings. DC = split ring. Easy to confuse in exams.

MISTAKE 7: Fuse vs Earthing confusion

FUSE (in series): Protects CIRCUIT and APPLIANCES from excess current (overloading/short circuit). EARTHING (earth wire): Protects the USER from electric shock if appliance body becomes live. Both are needed but for completely different purposes. Earthing does NOT protect against overloading.

QUICK REVISION TABLE

Topic	Key Point	Exam Tip
Magnetic field lines	Closed curves; emerge N, enter S; density=strength; never intersect	Parallel equidistant = UNIFORM (not zero) field
Solenoid	Acts like bar magnet; uniform field inside; N/S poles at ends	Soft iron=temporary; Steel=permanent
Right-hand thumb rule	Thumb=current, fingers=field direction around conductor	For straight conductors and solenoids only
Fleming's LHR	Forefinger=B, Middle=I, Thumb=Force; for motors	LEFT hand for Motor (force on conductor)
Fleming's RHR	Thumb=motion, Forefinger=B, Middle=induced I	RIGHT hand for generator (induced current)

AC in India	50 Hz; 100 direction changes/second; every 1/100 s	T=1/50 s per full cycle; changes every T/2=1/100 s
AC vs DC generator	AC: slip rings -> alternating. DC: split ring -> one direction	Replace slip rings with split ring = AC to DC
Electromagnetic induction	Changing flux -> induced current; steady flux = zero induction	Change in flux essential -- not magnitude alone
Commercial motor	Electromagnet + many turns + soft iron core	3 differences from simple motor -- all increase power
Fuse	Series device; melts on excess current; protects circuit	Same rating when replacing; higher rating = no protecti
Earthing	Earth wire (green); protects USER from shock	Different from fuse; fuse=circuit, earth=user
Force on conductor	F=BIL perpendicular to both I and B	Only when conductor is perpendicular to field
Moving charges & field	Charged particles (alpha) -> field. Neutral (neutrons) -> no field	Current = flow of charges only