SLIDE 1

Question 1

When do magnetic poles attract and repel?

SLIDE 2

Solution 1

Magnetic poles are either *north* poles or *south* poles. Like poles repel, unlike poles attract.

	North	**South**
North	Repel	Attract
South	Attract	Repel

SLIDE 3

Question 2

① What are the ferromagnetic materials?

② Distinguish between magnetically hard and magnetically soft materials.

③ Give the name and composition of an example of (a) a magnetically hard, and (b) a magnetically soft material.

SLIDE 4

Solution 2

Magnetic Conductance

Most materials are insulators against magnetism.

Ferromagnetic materials are iron, nickel and cobalt. These materials conduct magnetism far more than other materials.

A **magnetically hard** material is one that are difficult to magnetise, but once magnetised do not lose their magnetism easily. The opposite type of material, easy to magnetise but losing magnetism also easily, are called **magnetically soft**.

Alnico is an magnetically hard alloy made of 54% iron, 18% nickel and 12% cobalt. Mumetal is a magnetically soft alloy made of 76% nickel, 17% iron, 5% copper and 2% chromium.

SLIDE 5

Question 3

State in qualitative terms three properties of the magnetic force.

SLIDE 6

Solution 3

Properties of the Magnetic Force

Property 1 As the distance between the poles increases the strength of the magnetic force decreases

Property 2 The strength of the magnetic force increases with the strength of the magnetic poles.

Property 3 The strength of the magnetic field is affected by the medium through which it is transmitted. There are magnetic insulators and conductors.

SLIDE 7

Question 4

In what direction do magnetic field lines run?

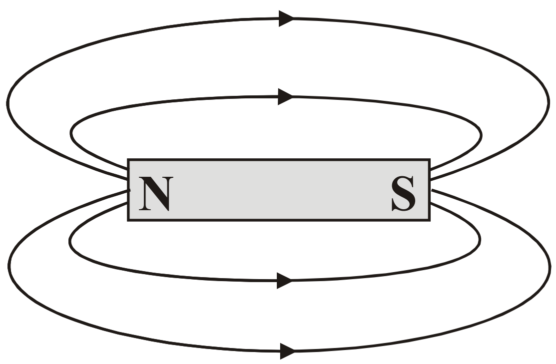
Sketch the field of a bar magnet.

SLIDE 8

Solution 4

Magnetic field

The region surrounding a magnet where the magnetic force is experienced is called a **magnetic field**.



Magnetic **field lines** run from North to South. All field lines, therefore, are strictly curves, as no magnetic monopole has as yet been isolated. However, the Earth's magnetic field may be regarded as effectively uniform (parallel field lines). A soft iron bar will concentrate the Earth's field lines through it.

SLIDE 9

Question 5

What is the corkscrew rule?

SLIDE 10

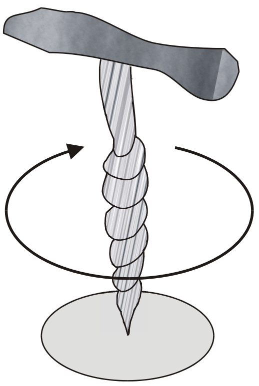
Solution 5

Magnetic effect of electric current

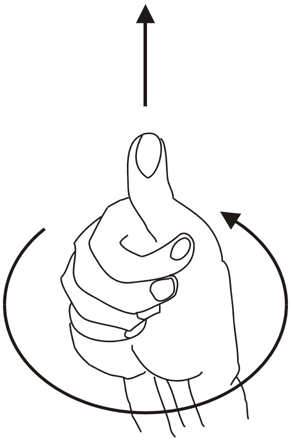
It was discovered by Oersted in 1820 that an electric current creates a magnetic field. The magnetic field is circular around the wire carrying the current.

The Magnetic Field surrounding a current

The field lines obey **Maxwell's corkscrew rule** – the direction of the concentric field lines is clockwise for a current passing into the plane (page), and anti-clockwise, vice-versa.



When current flows the magnetic field produced obeys the corkscrew rule. The direction of the magnetic field, whether it is clockwise or anticlockwise, follows the direction in which a corkscrew turns. The magnetic field is clockwise if the current flows into the page, and anticlockwise if it flows out of it. If you turn a screw in clockwise direction the bore drills into the surface.



Another way to remember this is by the right-hand thumb rule. When the right-hand thumb is pointing upwards the fingers curl in the direction of the magnetic field.

SLIDE 11

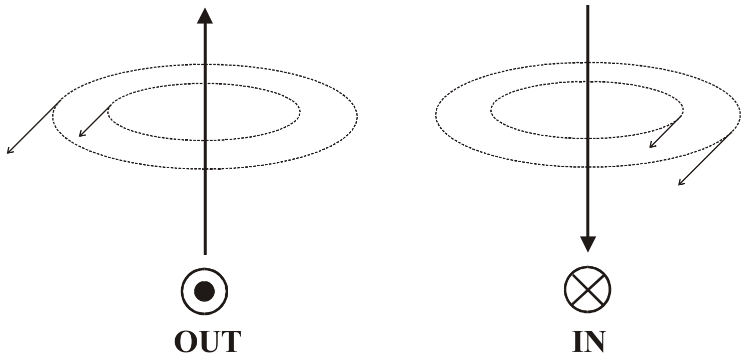
Question 6

Make a diagram showing the magnetic field surrounding a wire carrying a current (a) out of and (b) into a plane.

SLIDE 12

Solution 6

Current into and out of a plane



Diagrammatic representation for the magnetic field induced by an electric current.

SLIDE 13

Question 7

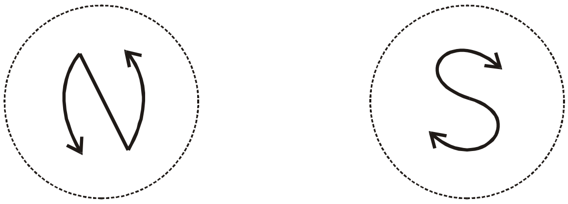
When current flows continuously in a circular coil how do we know which side of the coil is a north pole?

SLIDE 14

Solution 7

Magnetic Poles

A magnetic pole is produced by current flowing in a loop.



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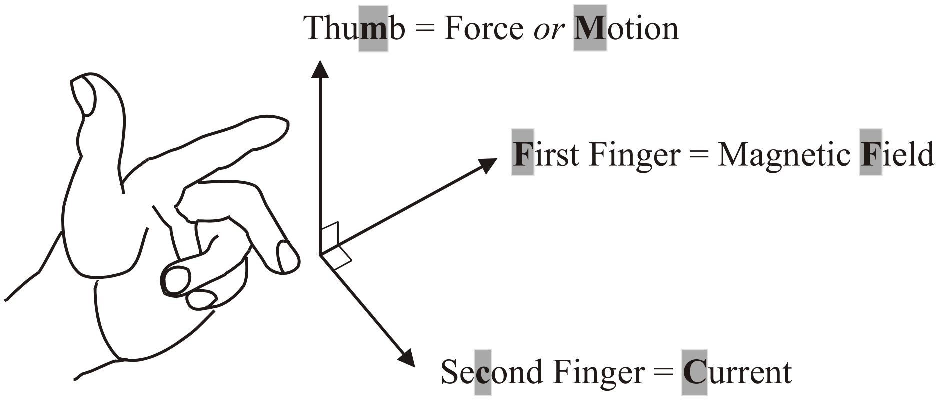
Question 8

State Fleming’s left-hand rule

SLIDE 16

Solution 8

The direction of the force induced by an electric current in a magnetic field is given by **Fleming's left-hand rule**.



In this rule, the current is **conventional current**, which is the movement of positively charged particles. Electrons flow in the opposite direction to conventional current.

SLIDE 17

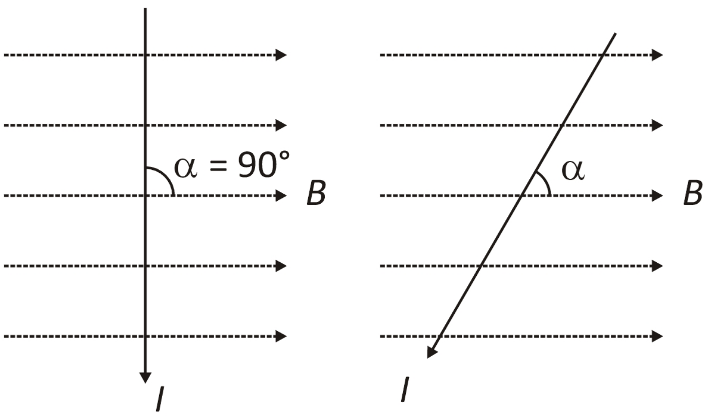
Question 9

State the equation for the magnitude of the force F produced when a wire carries a current. Make a sketch to illustrate your answer.

SLIDE 18

Solution 9

Variance of the angle of the conductor



Let α be the angle made between the direction of the current in a conductor and the magnetic field. Then the forced induced on the conductor is $F = BIl\sin\alpha$.

SLIDE 19

Question 10

Define the SI unit of magnetic flux density.

SLIDE 20

Solution 10

Flux density

From $F = BIL\sin\alpha$ we obtain

$B = \frac{F}{IL}$ when $\alpha = 90°$, $\sin\alpha = 1$

The SI unit of flux density is the **tesla**.

One **tesla** (T) is defined to be the flux density of a uniform field when the force on a conductor 1-metre-long placed perpendicular to the field and carrying a current of 1 ampere, is 1 newton.

SLIDE 21

Question 11

The current in a wire 2 m in length is 10 A. Find the force acting on the wire when it is at 45° to a field of flux density 0.15 T. Give your answer to 3 significant figures.

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Solution 11

Solution

$$
\begin{aligned}
F &= BIL\sin\alpha \\
&= 0.15\times 10\times 2\times \sin 45^\circ \\
&= 2.12\ \text{N}\ (3\ \text{sf})
\end{aligned}
$$

SLIDE 23

Question 12

A straight horizontal rod of mass 50 g and length 0.5 m is placed in a uniform horizontal field of 0.2 T acting perpendicularly to the rod. If the force induced is just sufficient to balance the weight of the rod, find the current passing through it.

SLIDE 24

Solution 12

Solution

$$\text{magnetic force} = \text{weight}$$

$$BIL = mg$$

$$I = \frac{mg}{BL} = \frac{0.050 \times 9.8}{0.2 \times 0.5} = 4.5 \text{ A } \left(2 \text{ sf}\right)$$

SLIDE 25

Question 13

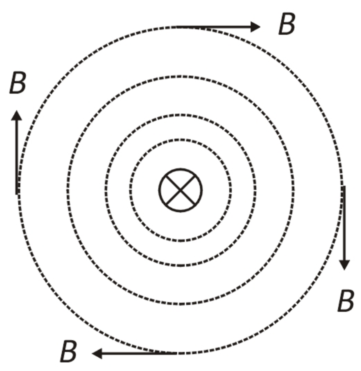
Make a sketch of the filed surrounding a long, straight current-carrying wire going into the plane, and state the magnitude of the flux density produced by such a wire when it carries a current *I*.

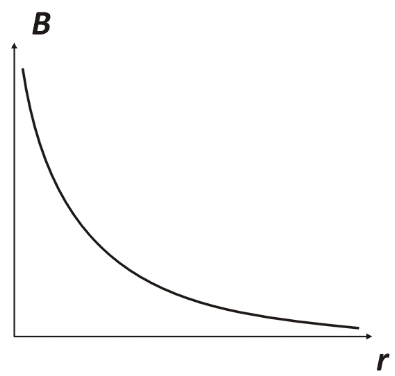
SLIDE 26

Solution 13

Magnetic field of a long straight conductor

The field lines surrounding a long, straight current-carrying conductor comprises concentric circles.





The direction of the field is given by the corkscrew rule. The direction is tangent to the concentric field circles.

Let I be the current in such a wire, and r the radial distance of the field from the wire, then the magnetic flux density is given by $B = \frac{\mu_0}{2\pi r} I$.

The field strength is proportional to the current and inversely proportional to the distance.

SLIDE 27

Question 14

Interaction of two magnetic fields

Two wires *X* and *Y* of infinite length running parallel to each other are carrying currents I_x and I_Y respectively.

① State the direction in which the force between the two wires is acting.

② Derive an expression for the force per unit length acting on the two wires.

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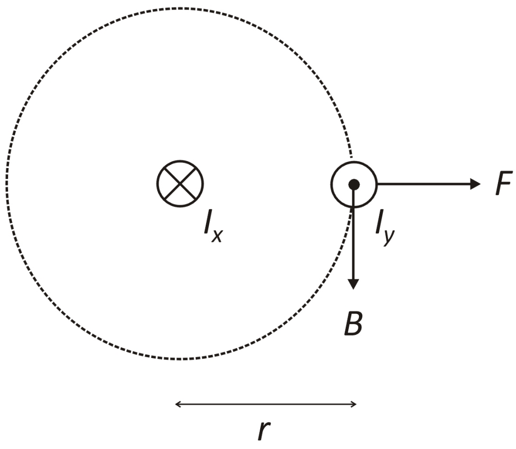
Solution 14



① By Fleming's left-hand rule, the force between the two wires is repulsive.

② $F = BIl \Rightarrow \frac{F_y}{l} = B_x I_x$

$$B_x = \frac{\mu_0}{2\pi r} I_x$$

$$\frac{F_y}{l} = B_x I_x \Rightarrow \frac{F_y}{l} = \frac{\mu_0}{2\pi r} I_x I_y$$

The magnitude of the force acting on *X* due to the current in *Y* is the same as the force acting on *Y* due to the current in *X*. Hence $\frac{F}{l} \propto I_x I_y$.

The force per unit length is proportional to the product of the currents in the two wires, and inversely proportional to the distance separating them.

SLIDE 29

Question 15

① State the law governing the turning effect produced on a coil carrying a current when placed within a magnetic field.

② Make a sketch illustrating this law, being careful to define any angle involved.

③ Derive this law.

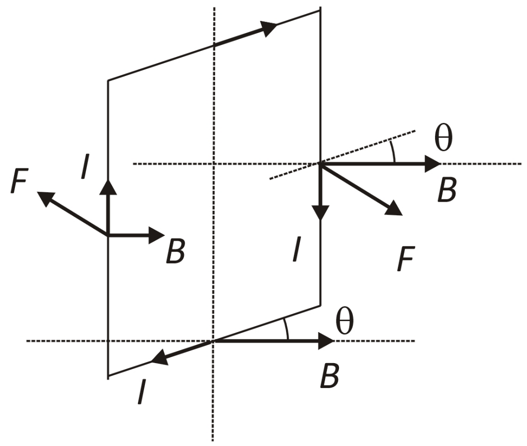
SLIDE 30

Solution 15

① $T = BANI\cos\theta$

where T is the torque, B the flux density of the field, A the cross-sectional area of the coil, N the number of turns of the coil, I is current in the coil, and θ is the angle made between the current and the field when the plane of the coil is parallel to the field, as shown in the sketch.

②



③ The two forces act as a **couple**. The **torque** (turning effect) produced is given by

$T = F \times d$ torque $=$ force$\times$perpendicular distance

Here d is the perpendicular distance from the axis of rotation. Hence $T = 2F \times \frac{x}{2} = Fx$, where $x = 2d$ is the width of the coil. Give $F = BILN$ where L is the length of the current-carrying wire, here the height of the coil, then

$T = Fx = BILNx$

However, $A = xL$ is the cross-sectional area of the coil. Hence, the torque of a rotating current-carrying coil in a magnetic field is given by $T = BANI$

SLIDE 31

Question 16

A rectangular coil has 10 turns height 0.1 m and width 0.05 m. A current of 5 A is passing through the coil. It is suspended from the middle of its upper side in uniform horizontal magnetic field of 0.02 T.

Find the torque on the coil when

① The plane made by the vertical coil is parallel to the magnetic field.

② The plane made by the vertical coil is at 60° to the magnetic field

SLIDE 32

Solution 16

Solution

① $T = BANI$

$= 0.02 \times 0.1 \times 0.05 \times 10 \times 5$

$= 5 \times 10^{-3}$ Nm

② $T = BANI \cos 60^\circ$

$= 0.02 \times 0.1 \times 0.05 \times 10 \times 5 \times 0.5$

$= 2.5 \times 10^{-3}$ Nm

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Question 17

What is the expression for the torque produced on a coil when the plane of the coil is **normal** to the field?

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Solution 17

Torque on a coil at an angle to a uniform field

When the plane of a coil is **parallel** to the field *B,* the torque is

$T = BANI\cos\theta$

If α denotes the angle between *B* and the **normal** to the plane of the coil, then

$T = BANI\sin\alpha$

The two formulas give the same value for the torque since

$\sin\alpha = \sin(90-\alpha) = \cos\theta \qquad \theta = 90-\alpha$

SLIDE 35

Question 18

① State the magnitude of the force acting on an individual electron moving at right-angles to a field.

② Derive this formula.

③ What is the magnitude of the force action on a particle of charge q moving at right-angles to a field.

SLIDE 36

Solution 18

Force on a moving charge in a magnetic field

① The force acting on an individual electron moving at right-angle through a field is given by $F = Bev$ where v is the velocity of the electron, or if the electron is one electron of many in a charge-carrying wire, then v is the average drift of the electrons.

② Let a current I flow through a straight conductor of length L perpendicular to a uniform field of flux density B.

The current is given by $I = nvAe$ where n is the number of electrons per unit volume, v is the drift velocity of the electrons, A is the cross-section of the conductor and e is the electron charge.

$$\begin{aligned} F &= BIL \\ &= BnvAeL \\ &= Bev \times nAL \end{aligned}$$

AL is the volume of the wire, and nAL is the number of electrons in the wire. Hence the force acting on one electron is

$$F' = Bev \times \frac{nAL}{nAL} = Bev$$

③ The force acting on a charge q moving at right-angles to a field of flux density B is given by $F = Bqv$.

CURRENT POSITION IN THE PRODUCTION OF THE BLITZ

SLIDE 31

Proof of this formulas

SLIDE 32

Magnetic force as a deflecting force

Let electrons enter a magnetic field *B* that acts perpendicularly to their direction of motion *v*. The mechanical force *F* on the electron acts perpendicularly to both the direction of motion and the field. Hence, this deflects the electron without changing its velocity. Since *F* is perpendicular to the direction of motion, *F* does no work on the electron. No energy is either gained or lost when the electron enters the magnetic field.

The direction of *F* is given by Fleming's left-hand rule. Since the direction of an electron is changed without change of speed, the electrons are deflected into a circular path.

A magnetic field can be used instead of an electric field to focus an electron beam, and the two can be combined to create a velocity selector.

6 (a) State the type of field, or fields, that may cause a force to be exerted on a p

(i) uncharged and moving,

....

(ii) charged and stationary,

....

(iii) charged and moving at right-angles to the field.

....

(b) A particle X has mass 3.32×10^{-26} kg and charge $+1.60 \times 10^{-19}$ C.

The particle is travelling in a vacuum with speed 7.60×10^{4} m s^{-1}. It enters a magnetic field that is normal to the direction of travel of the particle. The p semicircle of diameter 12.2 cm, as shown in Fig. 6.1.

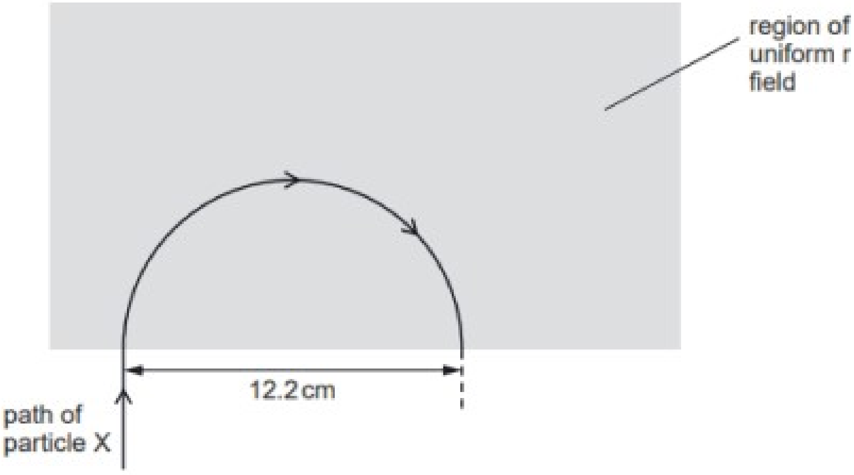

Fig. 6.1

For the uniform magnetic field,

(i) state its direction,

....

....

(ii) calculate the magnetic flux density.

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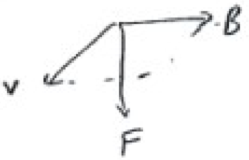
6. (a) (i) uncharged & moving → gravitationa

(ii) charged & stationary
→ gravitational & electric

(iii) charged, right-angle to field
→ gravitational, electric & .

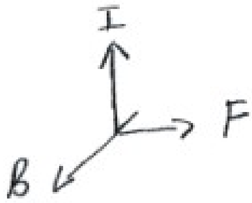
(b) (i) $m = 3.32 \times 10^{-26}$ $q = +1.60 \times 10^{-19}$

$v = 7.60 \times 10^{4}$



general
left-hand rule
thumb → force, motion
index → B, magnetic field
middle → current

out of t



$r =$

(ii) $F = BQv$ $B = \frac{F}{Qv}$

$F =$