13.11 DIAMAGNETISM

Diamagnetic substances are those in which the atoms have no *net magnetic moment*. They get weakly magnetised in a **direction opposite** to that of the applied field, *e.g.* antimony, bismuth, copper, water, alcohol etc.

Properties

(*i*) In a non-uniform field, a diamagnetic substance tries to move from the **stronger** to the **weaker** parts of the field. This means they are feebly repelled by magnets.

(*ii*) If a diamagnetic bar is freely suspended in a magnetic field, it turns until it is at **right angles** to the applied field. [See Fig. 13.6 (*a*)]

(*iii*) When a diamagnetic substance is placed in a magnetic field, the flux density inside is less than that in the free space. Hence the relative permeability $\mu_r < 1$.

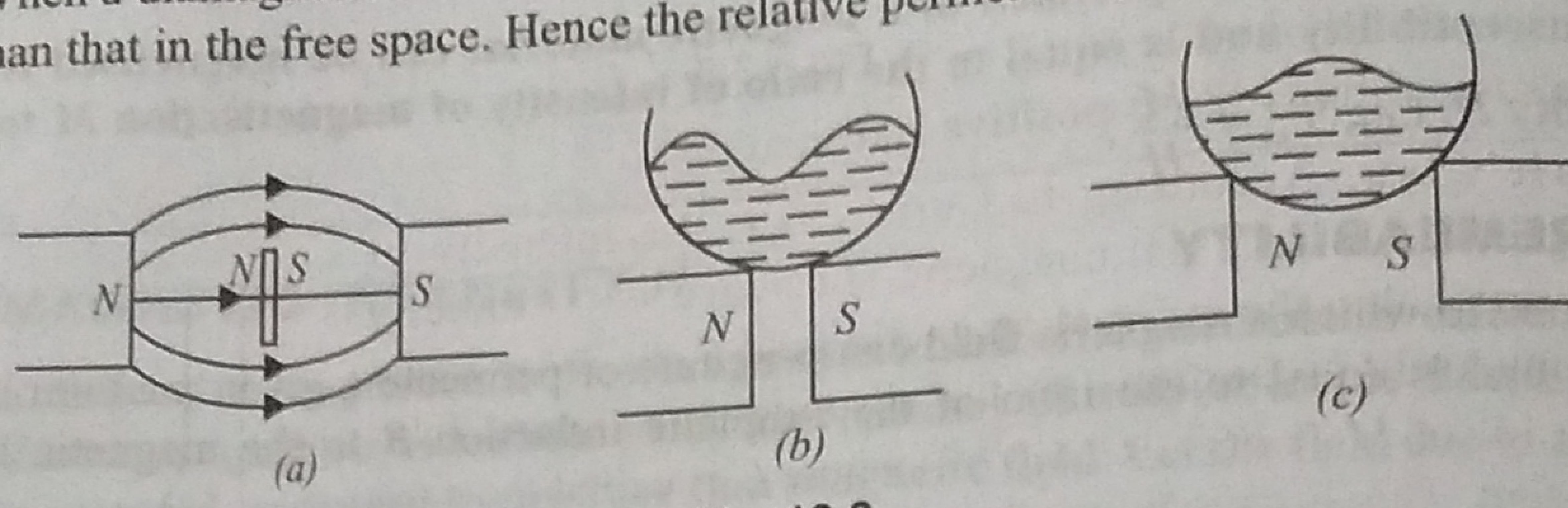

Fig. 13.6

(*iv*) When a diamagnetic liquid taken in a watch-glass is kept on two pole-pieces, placed very **close together**, the liquid accumulates on the sides where the field is weaker [See 13.6 (*b*)], thereby producing a **depression in the middle**. If the pole-pieces are kept apart, the reverse effect is seen, because now the field is weakest in the middle [See Fig. 13.6 (*c*)].

(*v*) The susceptibility is small and negative.

(*vi*) The susceptibility is **independent** of temperature.

(*vii*) When a diamagnetic bar is placed in a uniform magnetic field, it gets magnetised in a **direction opposite** to that of the magnetising field.

(*viii*) A diamagnetic liquid is taken in a U-tube and its one limb is placed between the poles of a magnet. Initially the liquid in the two limbs are at the same level *AA′*. The liquid in the limb which is in the magnetic field is **seen to get depressed** from *A* to *B*, as shown in Fig. 13.7.

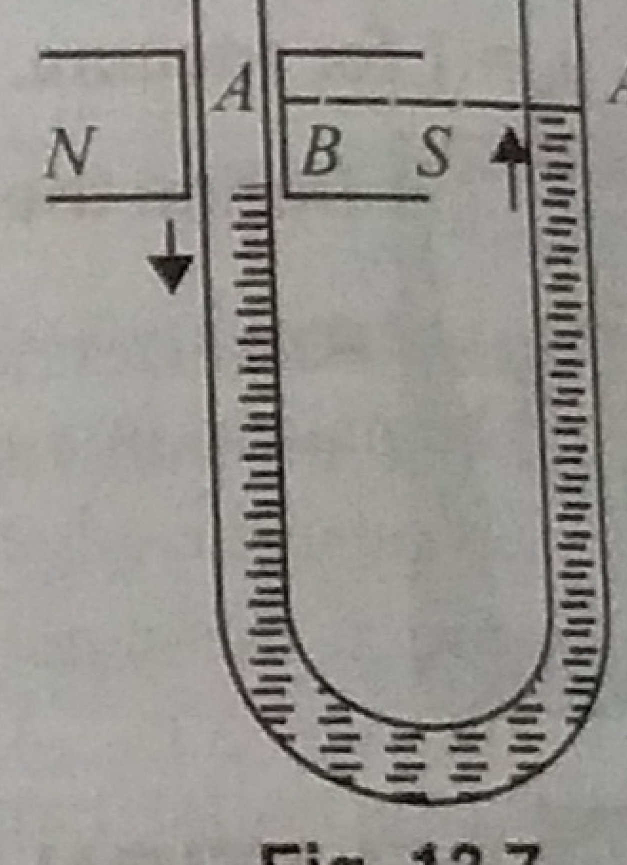

Fig. 13.7

(*ix*) The magnetisation of diamagnetic materials lasts as long as the magnetising field lasts and disappears when the magnetising field is removed.

13.12 PARAMAGNETIC SUBSTANCE

The atoms of a paramagnetic substance, in their normal state, have a **non-zero magnetic moment**. When they are placed in a strong magnetic field they become weakly magnetised in the *same sense* as the external magnetic field.

e.g., aluminium, chromium, liquid oxygen, manganese etc.

Properties

(*i*) In a non-uniform field, a paramagnetic substance tries to move from the weaker to the stronger parts of the field. This means they are **weakly attracted** by magnets.

(*ii*) If a paramagnetic bar is freely suspended in a magnetic field, it turns until it lies **along the field**, as shown in Fig. 13.8 (*a*).

(*iii*) When a paramagnetic substance is placed in a magnetic field the flux density inside a **slightly greater** than that in free space *i.e.*, μ_r is slightly greater than one.

(*iv*) When a paramagnetic liquid taken in a watch-glass is, kept on two pole-pieces, placed **very close together**, the liquid accumulates *in the middle* where the field is strongest [See Fig. 13.8 (*b*)]. If the pole pieces are far apart, the field is strongest near the poles and the liquid moves away from the centre, and gets collected in the formed two heaps at the corners. The field in weakest (W) at the centre and a depression is produced as shown in Fig. 13.8 (*c*).

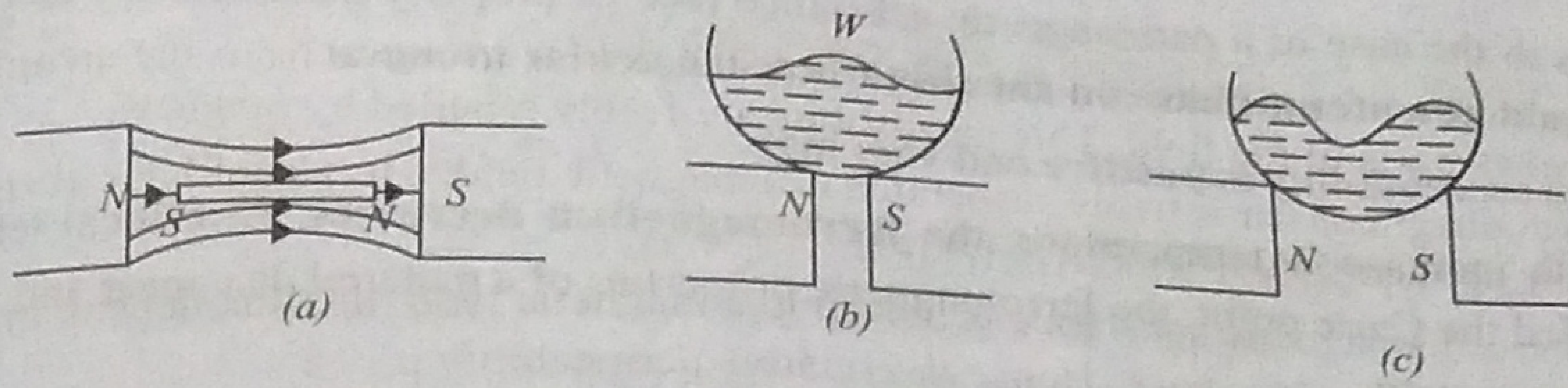

Fig. 13.8

(*v*) The susceptibility Ψ_m is **positive** and small.

(*vi*) **Curie's law.** According to Curie's law, the intensity of magnetisation of a paramagnetic substance is (*i*) directly proportional to the external magnetic field B. *i.e.* $M \propto B$ and (*ii*) inversely proportional to the absolute temperature T *i.e.* $M \propto 1/T$ or $M \propto B/T$, $M = C(B/T)$ where C is called the curie constant. This is called curie law. But $B \propto H$. So $M \propto H/T$ or susceptibility $\Psi_m \propto 1/T$, where $\Psi_m = M/H$. The variation of Ψ_m with temperature is as shown in Fig. 13.9. The susceptibility decreases with rise in temperature. Susceptibility varies inversely with temperature.

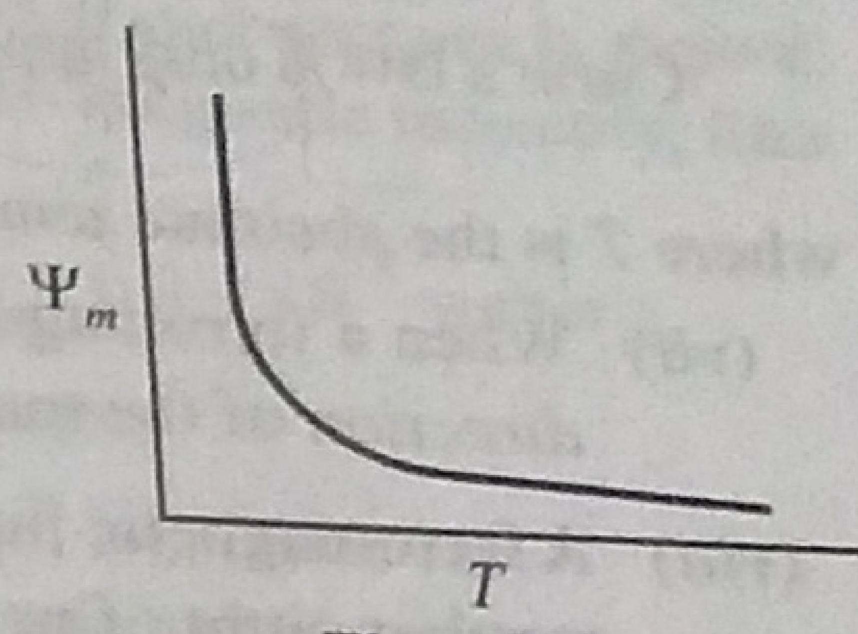

Fig. 13.9

(*vii*) When a paramagnetic bar is placed in a uniform magnetic field, it gets magnetised **in the direction** of the magnetising field.

(*viii*) Let one limb of a narrow U-tube, containing a paramagnetic liquid be placed in a magnetic field. The level of the liquid in the limb P is near the edge of the pole pieces at A. The liquid in the two limbs are at the same level when the electromagnet is not switched on. But when the electromagnet is switched on, the level of the liquid in the limb placed in the magnetic **field is seen to rise to B** as shown in Fig. 13.10.

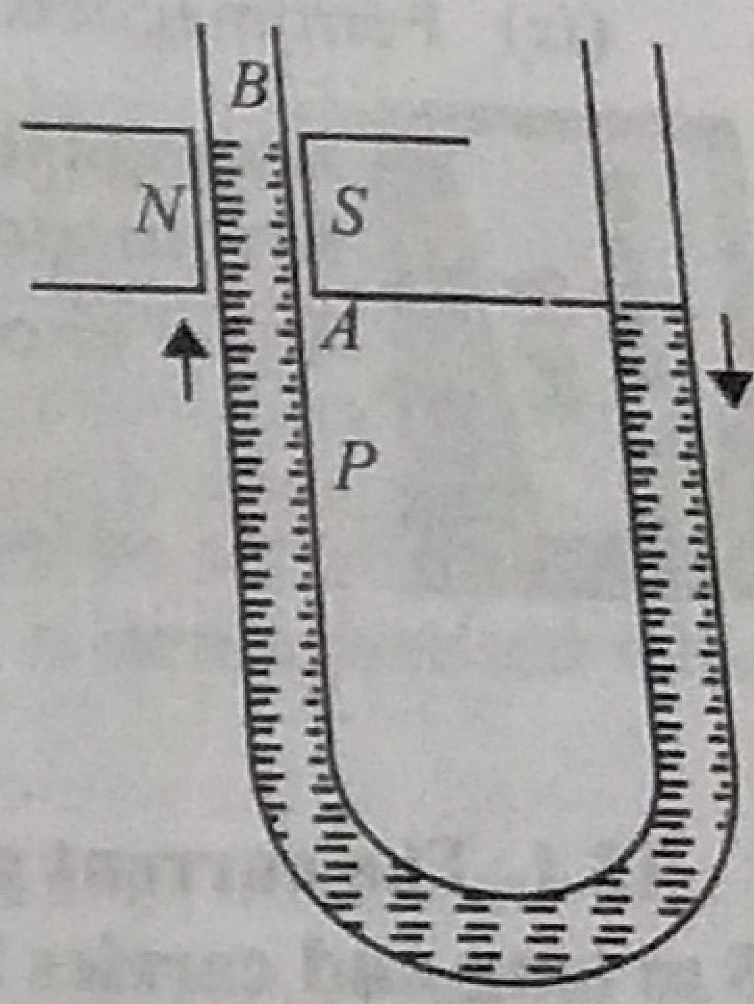

Fig. 13.10

(*ix*) If a paramagnetic gas is allowed to rise between the pole-pieces of a magnet it **spreads** along the field.

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What is meant by a paramagnetic substance ? State Curie law.

Ans. See text notes given just above.

13.13 FERROMAGNETISM

The atoms of a ferromagnetic substance have a **magnetic moment of a high degree** in their normal state. They are strongly magnetised when kept even in a weak field in the same sense as the applied field, *e.g.*, iron, cobalt, nickel, gadolinum and their alloys, etc.

Properties or Characteristics

(*i*) Ferromagnetic materials get **strongly attracted** by magnets and they move from the weaker to the stronger parts of the field.

(*ii*) If a ferromagnetic bar is freely suspended in a magnetic field, it aligns along the field quickly.

(*iii*) When a ferromagnetic material is kept in a magnetic field, the flux density inside a **larger** than that in vacuum *i.e.*, μ_r is very high.

(*iv*) As in the case of a paramagnetic substance (see its property number four) ferromagnetic liquid also **accumulates on the side** where the *field is strongest.*

(*v*) The susceptibility is **positive** and very high.

(*vi*) With increase in temperature, the **ferromagnetism decreases.** At critical temperature, called the Curie point, the ferromagnetic properties of a material disappear and it becomes paramagnetic.

The susceptibility Ψ_m of a ferromagnetic substance is inversely proportional to the absolute temperature T.

Curie's law is only approximate. An accurate relation is given by Curie-Wiess law $\Psi_m = \frac{C}{T - T_C}$

where T is the absolute temperature of the specimen and T_c is the Curie point.

(*vii*) When a ferromagnetic bar is placed in a uniform magnetic field, it gets magnetised *in the direction* of the magnetising field.

(*viii*) A ferromagnetic liquid rises is one limb, as the case of a paramagnetic liquid. (See property number eight of paramagnetism).

(*ix*) Ferromagnets remain magnetised even after the removal of the magnetising field.

sket

Arrange the three types of magnetic materials i.e. paramagnetic, diamagnetic and ferromagnetic materials in ...