PHYSICS

BOOKS - HC VERMA PHYSICS (HINGLISH)

PERMANENT MAGNETS

Examples

1. A solenoid of length 10 cm and radius 1 cm contains 200 turns and carries a current of 10

A. Find the magnetic field at a point on the axis at a distance of 10cm from the centre.

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2. A bar magnet having a magnetic moment of $1.0 \times 10^4 JT^{-1}$ is free to rotate in a horizontal plane. A horizontal magnetic field $B = 4 \times 10^{-5} T$ exists in the space. Find the work done in rotating the magnet slowly from a direction parallel to the field to a direction 60° from the field.

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3. A magnet is 10cm long and its pole strength is 120 CGS units (1 CGS unit of pole strength $= 0.1 Am$). Find the magnitude of the magnetic field B at a point on its axis at a distance 20cm from it.

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4. Find the magnetic field due to a dipole of magnetic moment $1.2 Am^2$ at a point $1 m$ away from it in a direction making an angle of 60° with the dipole-axis`.

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5. The horizontal component of the earth's magnetic field is $3.6 \times 10^{-5} T$ where the dip is 60°. Find the magnitude of the earth's magnetic field.

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6. At 45° to magnetic meridian, the apparent dip is 30°. What is the true value of dip?

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7. A tangent galvanometer has 66 turns and the diameter of its coil is 22cm. It gives a deflection of $45^\circ f$ or 0.10 A current. What is the value of the horizontal component of the earth's magnetic field?

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8. A compass needle oscillates 20 times per minute at a place where the dip is 45° and 30 times per minute where the dip is 30°. Compare the total magnetic field due to the earth at the two places.

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Worked Out Examples

1. A bar magnet has a pole strength of $3.6Am$ and magnetic length $8cm$. Find the magnetic field at (a) a point on the axis at a distance of $6cm$ from the centre towards the north pole and (b) a point on the perpendicular bisector at the same distance.

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2. A magnet is suspended by a vertical string attached to its middle point. Find the position in which the magnet can stay in equilibrium. The horizontal component of the earth's magnetic field $= 25\mu T$ and its vertical component $40\mu T$. Assume that the string makes contact with the magnet only at a single point.

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3. A magnetic needle having magnetic moment $10 Am^2$ and length 2.0 cm is clamped at its centre in such a way that it can rotate in the vertical east-west plane. A horizontal force towards east is applied at the north pole to keep the needle fixed at an angle of 30^0 with the vertical. Find the magnitude of the applied force. The vertical component of the earth's magnetic field is $40\mu T$.

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4. The magnetic scalar potential due to a magnetic dipole at a point on its axis situated at a distance of 20cm from its centre is found to be $1.2 \times 10^{-5} Tm$. Find the magnetic moment of the dipole.

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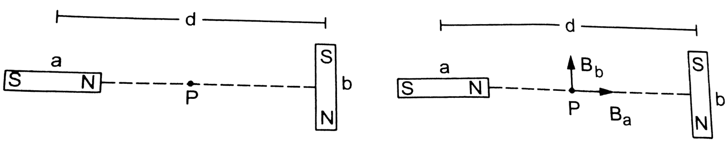
5. A bar magnet of magnetic moment $2.0 Am^2$ is free to rotate about a vertical axis through its centre. The magnet is released from rest from the east-west position. Find the kinetic energy of the magnet as it takes the north-south position. The horizontal component of the earth's magnetic field is $B = 25 \mu T$.

6. Figure shows two identical magnetic dipoles a and b of magnetic moments M each, placed at a separation d, with their axes perpendicular to each other. Find the magnetic field at the point P midway between the dipoles.



7. A bar magnet of length $8cm$ and having a pole strength of $1.0Am$ is placed vertically on a horizontal table with its south pole on the table. A neutral point is found on the table at a distance of 6.0 cm north of the magnet. Calculate the earth's horizontal magnetic field.

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8. The magnetic field at a point on the magnetic equator is found to be $3.1 \times 10^{-5}T$. Taking the earth's radius to be 6400 km, calculate the magneitc moment of the assumed dipole at the earth's centre.

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9. A earth's magnetic field at geomagnetic poles has a magnitude $6.2 \times 10^{-5} T$. Find the magnitude and the direction of the field at a point on the earth's surface where the radius makes an angle of 135° with the axis of the earth's assumed magnetic dipole. What is the inclination (dip) at this point?

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10. A magnetic needle free to rotate in a fixed vertical plane stays in a direction making an angle of 60° with the horizontal. If the dip at that plane is 37°, find the angle of the fixed vertical plane with the meridian.

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11. A dip circle shows an apparent dip of 60° at a place where the true dip is 45°. If the dip circle is rotated through 90°, what apparent dip will it show?

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12. A magnetic needle of length 10cm, suspended at its middle point through a thread, stays at a an angle of 45° with the horizontal. The horizontal component of the earth's magnetic field is $18\mu T$. (a) Find the vertical component of this field. (b) If the pole strength of the needle is $1.6A - m$, what vertical force should be applied to an end so as to keep it in horizontal position?

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13. A tangent galvanometer has a coil of 50 turns and a radius of 20cm. The horizontal component of the earth's magnetic field is $B_H = 3 \times 10^{-5} T$. Find the current which gives a diflection of $45^{)}$.

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14. A moving coil galvanometer has 100 turns and each turn has an area $2.0cm^2$. The magnetic field produced by the magnet is $0.01T$. The deflection in the coil is 0.05 radian when a current of $10mA$ is passed through it. Find the torsional constant of the suspension wire.

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15. A galvanometer coil has a resistance of 100Ω. When a current passes through the galvanometer, 1% of the current goes through the coil and the rest through the shunt. Find the resistance of the shunt.

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16. The needle of a deflection magnetometer deflects through 45° from north to south when the instrument is used in Tan-A position with a magnet of length 10cm placed at a distance of 25cm. (a) Find the magnetic moment of the magnet if the earth's horizontal magnetic field is $20\mu T$. (b) If the magnetometer is used in $\tan - B$ position with the same magnet at the same separation from the needle, what will be the deflection?

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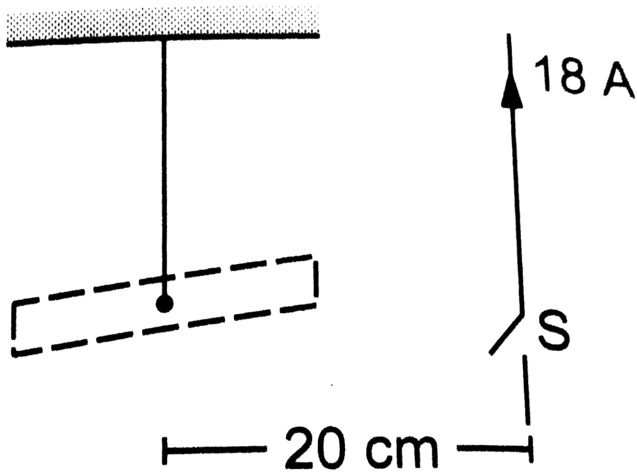
17. Figure shows a short magnet executing small oscillations in an oscillation magnetometer in earth's magnetic field having horizontal component $24\mu T$. The time period of oscillation is $0.10s$. An upward electric current of $18A$ is established in the vertical wire placed 20cm east of the magnet by closing the switch S. Find the new time



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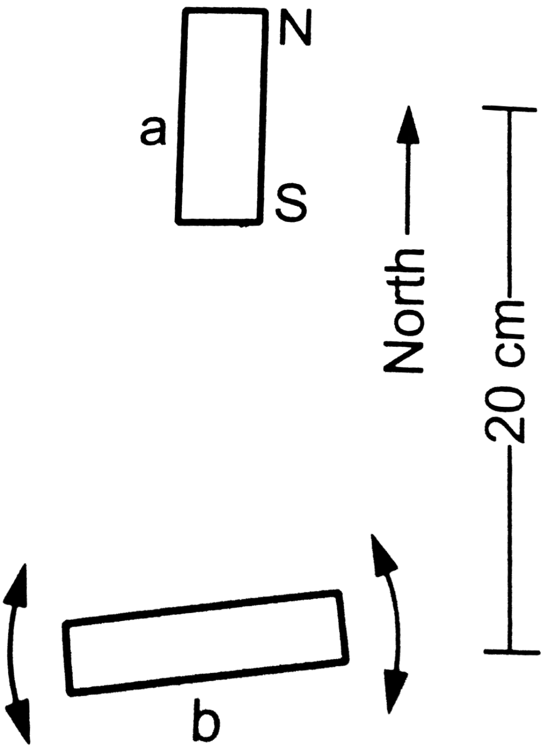
18. The frequency of oscillation of the magnet in an oscillation magnetometer in the earth's magnetic field is 40 oscillations per minute. A short bar magnet is placed to the north of the magnetometer, at a separation of 20cm from the oscillating magnet, with its north pole pointing towards north (figure). The frequency of oscillation is found to increase to 60 oscillations per minute. Calculate the magnetic moment of this short bar magnet. Horizonatl component of the earth's magnetic field is $24 \mu T$.



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19. A bar magnet of mass 100 g, length 7.0 cm, width 1.0 cm and height 0.50 cm takes $\frac{\pi}{2}$ seconds to complete an oscillation in an oscillation magnetometer placed in a horizontal magnetic field of $25\mu T$. (a) Find the magnetic moment of the magnet. (b) If the magnet is put in the magnetometer with its $0.50cm$ edge horizontal, what would be the time period?

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Short Answer

1. Can we have a single north pole, or a single south pole?

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2. Do two distinct poles actually exist at two nearby points in a magnetic dipole?

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3. An iron needles is attracted to the ends of a bar magnet but not to the middle region of the magnet. Is the material making up the ends of a bar magnet different from that of the middle region?

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4. Compare the direction of the magnetic field inside a solenoid with that of the field there if the solenoid is replaced by its equivalent combination of north pole and south pole.

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5. Sketch the magnetic field lines for a current-carrying circular loop near its centre. Replace the loop by an equivalent magnetic dipole and sketch the magnetic field lines near the centre of the dipole. Identify the difference.

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6. The force on a north pole, $\vec{F} = m\vec{B}$, is parallel to the field $m\vec{B}$, is parallel to the field

$vetB$. Does it contradict our earlier knowledge that a magnetic field can exert forces only perpendicular to itself?

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7. Two bar magnets are placed close to each other with their opposite poles facing each other. In absence of other forces, the magnets are pulled towards each other and their kinetc energy increases. Does it contradict our earlier knowledge that magnetic forces cannot do any work and hence cannot increase kinetic energy of a system?

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8. Magnetic scalar potential is diffined as

$$U\left(\overrightarrow{r}_2\right) - U\overrightarrow{r_1} = -\int_{\overrightarrow{r_1}}^{\overrightarrow{r_2}} \overrightarrow{B}.\overrightarrow{dl}$$

Apply this equation to a closed curve enclosing a long straight wire. The RHS of the above equation is then $\mu_0 i$ by Ampere's law. We see that $U\overrightarrow{r}_2\Big) \ne U\left(\overrightarrow{r}\right)$ even when $\overrightarrow{r}_2$

$= \vec{r}_1$. Can we have a magnetic acalar potential in this case.?

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9. Can the earth's magnetic field be vertical at a place? What will happen to a freely suspended magnet at such a place? What is the value of dip here?

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10. Can the dip at a place be (a) zero (b) 90° ?

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11. The reduction factor K of a tangent galvanometer is written on the instrument. The manual says that the current is obtained by multiplying this factor to $\tan \theta$. The procedure works well at Bhuwaneshwar. Will the procedure work if the instrument is taken to Nepal? If there is some error, can it be corrected by correcting the manual or the instrument will have to be taken back to the factory?

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Objective 1

1. A circular loop carrying a current is replaced by an equivalent magnetic dipole. A point on the axis of the loop is in

A. end-on position

B. broadside-on position

C. both

D. none

Answer: A

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2. A circular loop carrying a current is replaced by an equivalent magnetic dipole. A point on the loop is in

A. end-on position

B. broadside-on position

C. both

D. none

Answer: B

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3. When a current in a circular loop is equivalently replaced by a magnetic dipole.

A. the pole strength m of each pole is fixed

B. the distance d between the poles is fixed

C. the product md is fixed

D. none of the above

Answer: C

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4. Let r be the distance of `a point on the axis of a bar magnet from its centre. The magnetic field at such a point is proportional to

A. $\frac{1}{r}$

B. 1/r^2`

C. 1/r^3`

D. none of these

Answer: D

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5. Let r be the distance of a point on the axis of a magnetic dipole from its centre. The magnetic fiedl at such a point is proportional to

A. $\frac{1}{r}$

B. 1/r^2`

C. 1/r^3`

D. none of these

Answer: C

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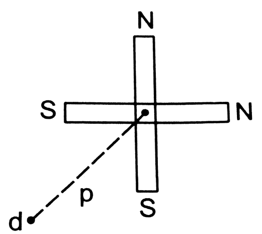
6. Two short magnets of equal dipole moments M are fastened perpendicularly at their centres (figure). The magnitude of the magnetic field at a distance d from the centre on the bisector of the right angle is



A. $\frac{\mu_0}{4\pi}\frac{M}{d^3}$

B. $\frac{\mu_0}{4\pi}\frac{\sqrt{2}M}{d^3}$

C. $\frac{\mu_0}{4\pi}\frac{2\sqrt{2}M}{d^3}$

D. $\frac{\mu_0}{4\pi}\frac{2m}{d^3}$

Answer: C

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7. Magnetic meridian is:

A. a point

B. a line along north-south

C. a horizontal plane

D. a vertical plane

Answer: D

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8. A compose needle which is allowed to move in a horizontal plane is taken to a geomagnetic pole. It

A. will stay in north-south direction only

B. will stay in east-west direction only

C. will become rigid showing no movement

D. will stay in any position

Answer: D

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9. A dip circle is taken to geomagnetic equator. The needle is allowed to move in a vertical plane perpendicular to the magnetic meridian. The needle will stay

A. in horizontal direction only

B. in vertical direction only

C. in any direction except vertical and horizontal

D. in any direction it is released.

Answer: D

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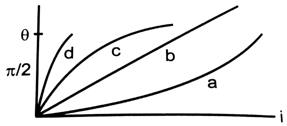
10. Which of the following four graphs may best represent the current deflection relation in a tangent galvanometer?



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11. A tangent galvanometer is connected directly to an ideal battery. If the number of turns in the coil is doubled, the deflection will

A. increase

B. decrease

C. remain unchanged

D. either increase or decrease

Answer: C

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12. In the current is doubled, the deflection is also doubled in

A. a tangent galvanometer

B. a moving coil galvanometer

C. both

D. none

Answer: B

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13. A very long bar magnet is placed with its north pole coinciding with the centre of a circular loop carrying an electric current. i. The magnetic field due to the magnet at a point on the periphery of the wire is B. The radius of the loop is a. The force on the wire is

A. very nearly $2\pi aiB$ perpendicular to the plane of the wire.

B. 2piaiB` in the plane of the wire

C. πaiB along the magnet

D. zero

Answer: A

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Objective 2

1. Pick the correct option

A. Magnetic field is produced by electric charges only

B. Magnetic poles are only mathematical assumptions having no real existence

C. A north pole is equivalent to a clockwise current and a south pole is equivalent to an anticlockwise current.

D. A bar magnet is equivalent to a long, straight current.

Answer: A::B

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2. A horizontal circular loop carries a current that looks clockwise when viewed from above. It is replaced by an equivalent magnetic dipole consisting of a south pole S and a north pole N.

A. The line SN shoult be along a diameter of the loop.

B. The line SN should be perpendicular to the plane of the loop

C. The south pole should be below the loop

D. The north pole should be below the loop

Answer: B::D

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3. Consider a magnetic dipole kept in the north to south direction. Let P_1, P_2, Q_1, Q_3 be four points at the same distance from the dipole towareds north, south, east and west of the dipole respectively. The directions of the magnetic field due to the dipole are the same at

A. P_1 and P_2

B. Q_1 and Q_2

C. P_1 and Q_1

D. P_2 and Q_2

Answer: A::B

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4. Consider the situation of the previous problem. The directions of the magnetic field due to the dipole are opposite at

A. a tangent galvanometer

B. a diflection galvanometer if the earth's horizontal field is known

C. an oscillation magnetometer if the earth's horizontal field is known

D. both diflection and oscillation magnetometer if the earth's horizontal field is not known.

Answer: B::C::D

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5. To measure the magnetic moment of a bar magnet, one may use

A. a langent galvanometer

B. a deflection galvanometer if the earth's horizontal field is is known

C. an uscillation magnetometer if the earth horizontal field is known

D. both deflecation and oscillation magnatormeter if the earth's horizontal field is not known

Answer: B::C::D

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Exercises

1. A long bar magnet has a pole strength of $10Am$. Find the magnetic field at a point on the axis of the magnet at a distance of 5cm from the north pole of the magnet.

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2. Two long bar magnets are placed with their axes coinciding in such a way that the north pole of the first magnet is 2.0cm from the south pole of the second. If both the magnets have a pole strength of $10Am$, find the force exerted by one magnet on the other.

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3. A uniform magnetic field of $0.20 \times 10^{-3}T$ exists in the space. Find the the change in the magnetic scalar potential as one moves through 50cm along the field.

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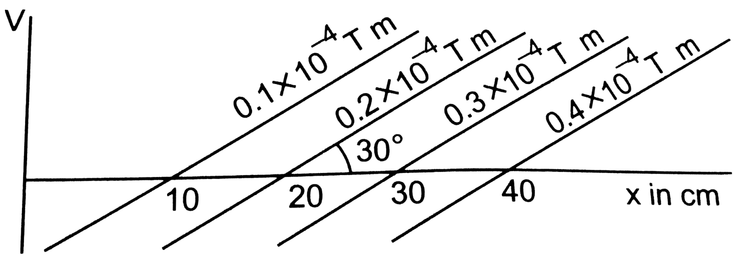
4. Figure shows some of the equipotential surfaces of the magnetic scalar potential. Find the magnetic field B at a point in the region.



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5. The magnetic field at a point, 10cm away from a magnetic dipole, is found to be $2.0 \times 10^{-4} T$. Find the magnetic moment of the dipole if the point is (a) in end on position of the dipole and (b) in broadside-on position of the dipole.

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6. Show that the magnetic field at a point due to a magnetic dipole is perpendicular to the magnetic axis if the line joining the point with the centre of the dipole makes an angle of $\tan^{-1}(\sqrt{2})$ with the magnetic axis.

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7. A bar magnet has a length of 8cm. The magnetic field at a point at a distnace 3cm from the centre in the broadside-on position is found to be $4 \times 10^{-6} T$. Find the pole strength of the magnet.

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8. A magnetic dipole of magnetic moment $1.44 Am^2$ is placed horizontally with the north pole pointing towards north. Find the positon

of the neutral point if the horizontal component of the earth's magnetic field is $18 \mu T$.

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9. A magnetic dipole of magnetic moment $0.72 Am^2$ is placed horizontally with the north pole pointing towards south. Find the position of the neutral point if the horizontal component of the earth's magnetic field $18 \mu T$.

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10. A magnetic dipole of magnetic moment $0.72(\sqrt{2}Am^2)$ is placed horizontally with the north pole pointing towards east. Find the position of the neutral point if the horizontal component of the earth's magnetic field is $18\mu T$.

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11. The magnetic moment of the assumed dipole at the earth's centre is $8.0 \times 10^{22} Am^2$.

Calculate the magnetic field B at the geomagnetic poles of the earth. Radius of the earth is $6400km$.

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12. If the earth's magnetic field has a magnitude $3.4 \times 10^{-5} T$ at the magnetic equator of the earth, what would be its value at the earth's goemagnetic poles?

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13. The magnetic field due to the earth has a horizontal component of $26\mu T$ at a place where the dip is 60°. Find the vertical component and the magnitude of the field.

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14. A magnetic needle is free to rotate in a vertical plance which makes an angle of 60° with the magnetic meridian. If the needle stays in a direction making an angle of $\tan^{-1}(2\sqrt{3})$

with the horizontal, what would be the dip at that place?

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15. The needle of a dip circle shows an apparent dip of 45° in a particular position and 53° when the circle is rotated through 90°. Find the true dip.

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16. A tangent galvanometer shown a deflection of 45° when $10mA$ of current is passed through it. If the horizontal component of the earth's magnetic field is $B_H = 3.6 \times 10^{-5} T$ and radius of the coil is $10cm$, find the number of turns in the coil.

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17. A moving coil galvanometer has a 50-turn coil of size $2cm \times 2cm$. It is suspended between the magnetic poles producing a magnetic field of $0.5T$. Find the torque on the coil due to the magnetic field when a current of $20mA$ passes through it.

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18. A short magnet produces a deflection of $37^{\circ} \in adef \leq ctionmag \neq \rightarrow meter \in$ Tan-A` position when placed at a separation of 10cm from the needle. Find the ration of the magnetic moment of the magnet to the earth's horizontal magentic field.

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19. The magnetometer of the previous problem is used with the same magent in $\tan - B$ position. Where should the magnet be placed to produce a 37° deflection of the needle?

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20. A deflection megnetometer is placed with its arms in north-south direction. How and where should a short magnet having $\frac{M}{B_H} = 40Am^2T(-1)$ be placed so that the needle can stay in any position?

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21. A bar magnet takes $\frac{\pi}{10}$ second to complete one oscillation in an oscillation magnetometer. The moment of inetria of the magnet about the axis of rotation is 1.2 xx

10^(-4) kg m^2

and $theearth' sh$ or $izontalmag \neq ticfieldis$

30 muT`. Find the magentic moment of the magnet.

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22. The combination of two bar magnets makes 10 oscillations per second in an oscillation magnetometer when like poles are tied together and 2 oscillations per second when unlike poles are tied together. Find the ratio of the magnetic moments of the magnets. Neglect any induced magnetism.

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23. A short magnet oscillates in a vibration magnetometer with a time period of 0.10 s where the horizontal component of earth's magnetic field is $24\mu T$. An upward current of 18 A is established in the vertical wire placed 20 cm east of the magnet . Find the new time period.

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24. A bar magnet makes 40 oscillations per minute in an oscillation magnetometer. An identical magnet is demagnetized completely and is placed over the magnet in the magnetometer. Find the time taken for 40 oscillations by this combination. Neglect any induced magnetism.

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25. A short magnet makes 40 oscillations per minute when used in an oscillation magnetometer at a place where the earth's horizontal magnetic field is $25\mu T$. Another short magnet of magnetic moment $1.6Am^2$ is placed 20 cm east of the oscillating magnet. Find the new fregquency of oscillation if the magnet has its north pole (a) towards north and (b) towards south.

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