# CBSE Class 12 Physics
## Sample Paper 03 (2020-21)

**Maximum Marks: 70**
**Time Allowed: 3 hours**

**General Instructions:**

i. All questions are compulsory. There are 33 questions in all.
ii. This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
iii. Section A contains ten very short answer questions and four assertion reasoning MCQs of 1 mark each, Section B has two case based questions of 4 marks each, Section C contains nine short answer questions of 2 marks each, Section D contains five short answer questions of 3 marks each and Section E contains three long answer questions of 5 marks each.
iv. There is no overall choice. However internal choice is provided. You have to attempt only one of the choices in such questions.

### Section A

1. Do electrons tend to go to regions of low potential or high potential?
2. To which part of the electromagnetic spectrum does a wave of frequency $5 \times 10^{19}$ Hz belong?

OR

Write two uses of X- rays.

3. Name the shape of a wavefront originating from
   i. a point source.
   ii. a line source.
4. State Biot Savart's law.

OR

Why does not a charged particle moving at right angle to the direction of an electric field follow a circular path?

5. On what factors does the angular dispersion of a prism depend?
6. Is photon a wave or a particle?
7. Define mass defect of a nucleus.

OR

Explain fission and fusion.

8. What do you understand by potential barrier?
9. Why soft iron is used in making the core of a transformer?
10. Which type of semiconductor is formed, when
    i. germanium is doped with indium?
    ii. germanium is doped with arsenic?
11. **Assertion (A):** A current flows in a conductor only when there is an electric field within the conductor.

    **Reason (R):** The drift velocity of electrons in the presence of electric field decreases.
    a. Both A and R are true and R is the correct explanation of A
    b. Both A and R are true but R is NOT the correct explanation of A
    c. A is true but R is false
    d. A is false and R is also false
12. **Assertion (A):** Circuits containing high capacity capacitors, charged to high voltage should be handled with caution, even when the current in the circuit is switched off.

    **Reason (R):** When an isolated capacitor is touched by hand or any other part of the human body, there is an easy path to the ground available for the discharge of the capacitor.
    a. Both A and R are true and R is the correct explanation of A
    b. Both A and R are true but R is NOT the correct explanation of A
    c. A is true but R is false
    d. A is false and R is also false
13. **Assertion (A):** In Young's double slit experiment the fringes become indistinct if one of the slits is covered with cellophane paper.

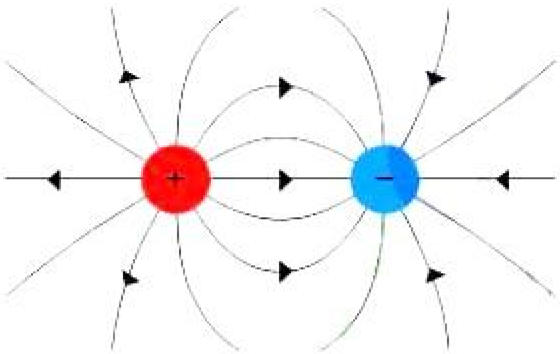
    **Reason (R):** The cellophane paper decreases the wavelength of light.
    a. Both A and R are true and R is the correct explanation of A

b. Both A and R are true but R is NOT the correct explanation of A
c. A is true but R is false
d. A is false and R is also false

14. **Assertion:** In Rutherford's experiment majority of $\alpha$-particles went straight through the metal foil without being stopped or even appreciably deflected.
**Reason:** Almost all the spac3e occupied by an atom is empty.
a. Both A and R are true and R is the correct explanation of A
b. Both A and R are true but R is NOT the correct explanation of A
c. A is true but R is false
d. A is false and R is also false

## Section B

15. **Read the following source and answer any four out of the following questions:**
Electric charge is the physical property of matter that causes it to experience a force when placed in an electromagnetic field. There are two types of charges positive and negative charges. Also, like charges repel each other whereas unlike charges attract each other.




i. Charge on a body which carries 200 excess electrons is:
a. $-3.2 \times 10^{-18}$ C
b. $3.2 \times 10^{18}$ C
c. $-3.2 \times 10^{-17}$ C
d. $3.2 \times 10^{-17}$ C

ii. Charge on a body which carries 10 excess electrons is:
a. $-1.6 \times 10^{-18}$ C
b. $1.6 \times 10^{-18}$ C
c. $2.6 \times 10^{-18}$ C

d. $1.6 \times 10^{-21}$ C

iii. Mass of electron is:

a. $9.1 \times 10^{-31}$ kg

b. $9.1 \times 10^{-31}$ g

c. $1.6 \times 10^{-19}$ kg

d. $1.6 \times 10^{-19}$ g

iv. A body is positively charged, it implies that:

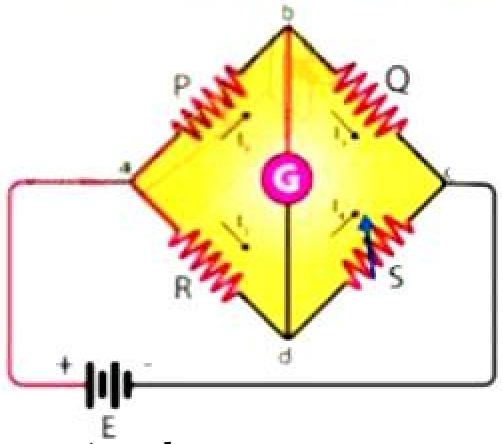
a. there is only a positive charge in the body
b. there is positive as well as negative charge in the body but the positive charge is more than negative charge
c. there is equally positive and negative charge in the body but the positive charge lies in the outer regions
d. the negative charge is displaced from its position

v. On rubbing, when one body gets positively charged and other negatively charged, the electrons transferred from positively charged body to negatively charged body are:

a. valence electrons only
b. electrons of inner shells
c. both valence electrons and electrons of the inner shell.
d. none of the above

16. **Read the source given below and answer any four out of the following questions:**

The Wheatstone bridge works on the principle of null deflection, i.e. the ratio of their resistances are equal and no current flows through the circuit. And The principle of working of Meter bridge is wheat stone bridge principle and it is used to find the resistance of an unknown conductor or to compare two unknown resistance.

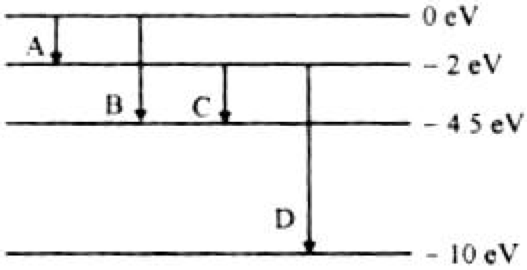


i. When a metal conductor connected to the left gap of a meter bridge is heated, the balancing point shifts
   a. right
   b. left
   c. unchanged
   d. none of these
ii. Wheatstone bridge is a/an:
   a. a.c. bridge
   b. d.c. bridge
   c. high voltage bridge
   d. none of these
iii. Wheatstone bridge is used to measure the d.c. the resistance of various types of wires for:
   a. determining their effective resistance
   b. computing the power dissipation
   c. quality control of wire
   d. none of these
iv. By using the variations on a Wheatstone bridge we can:
   a. measure quantities such as voltage, current, and power
   b. measure high resistance values
   c. measure quantities such as complex power
   d. measure quantities such as capacitance, inductance and impedance
v. For a Wheatstone bridge arrangement of four resistances – $R_1$, $R_2$, $R_3$, $R_4$ (Junction of $R_1$ and $R_2$ is connected to anode and Junction of $R_3$ and $R_4$ to the cathode of the cell). The null-point condition is given by
   a. $\frac{R_1}{R_3} = \frac{R_2}{R_4}$
   b. $(R_1 \times R_3) = (R_2 \times R_4)$
   c. $(R_1 + R_3) = (R_2 + R_4)$
   d. $(R_1 - R_3) = (R_2 - R_4)$

**Section C**

17. The energy levels of hydrogen atoms are as shown in figure. Which of the shown transition will result in the emission of a photon of wavelength 275 nm? Which of the

transition corresponds to emission of radiation of (i) maximum and (ii) minimum wavelength?




18. An empty test tube dipped into water in a beaker appears silvery, when viewed from a suitable direction. Why?

OR

Draw a ray diagram of a compound microscope. Write the expression for its magnifying power.

19. Two pieces of copper, each weighing 0.01 kg are placed at a distance of 0.1 m from each other. One electron from per 1000 atoms of one piece is transferred to other piece of copper. What will be the coulomb force between two pieces after the transfer of electrons? Atomic weight of copper is 63.5 g/mole. Avagadro's number $= 6 \times 10^{23} / gram\ mole.$

OR

Two equally charged particles, held $3.2 \times 10^{-3} m$ apart, are released from rest. The initial acceleration of the first particle is observed to be 7.0 $m/s^2$ and that of the second to be 9.0 $m/s^2$. If the mass of the first particle is $6.3 \times 10^{-7} kg$, what are

a. the mass of the second particle and
b. the magnitude of the charge of each particle

20. The wavelength of the first member of the Balmer series in hydrogen spectrum is 6563 $\mathring{A}$. What is the wavelength of the first member of Lyman series?
21. Give two advantages and two disadvantages of AC over DC.
22. Differentiate between nuclear fission and fusion.
23. The following data was recorded for values of object distance and the corresponding values of image distance in the experiment on study of real image formation by a convex lens of power +5 D. One of these observations is incorrect. Identify this observation and

give reason for your choice:

| S. No | Object distance ( cm) | Image distance (cm) |
|---|---|---|
| 1. | 25 | 97 |
| 2. | 30 | 61 |
| 3. | 35 | 37 |
| 4. | 45 | 35 |
| 5. | 50 | 32 |
| 6. | 55 | 30 |

24. Consider the plane S formed by the dipole axis and the axis of the earth. Let P be a point on the magnetic equator and in S. Let Q be the point of intersection of the geographical and magnetic equators. Obtain the declination and dip angles at P and Q.

OR

i. How is an electromagnet different from a permanent magnet?
ii. Write two properties of a material which makes it suitable for making an electromagnet.

25. i. Out of blue and red light, which is deviated more by a prism? Give reason.
ii. Give the formula that can be used to determine refractive index of material of a prism in minimum deviation condition.

**Section D**

26. Two different coils have self inductances, $L_1$ = 8mH and $L_2$ = 2mH. At a certain instant, the current in the two coils is increasing at the same constant rate and the power supplied to the two coil is the same.

Find the ratio of :

a. induced voltage
b. current and
c. energy stored in the two coils at that instant?

27. Define the term wavefront. State Huygen's principle. Consider a plane wavefront incident on a thin convex lens. Draw a proper diagram to show how the incident wavefront traverses through the lens and after refraction focusses on the focal point of the lens, giving the shape of the emergent wavefront.

OR

In Young's double slit experiment, monochromatic light of wavelength 630 nm illuminates the pair of slits and produces an interference pattern in which two consecutive bright fringes are separated by 8.1 mm. Another source of monochromatic light produces the interference pattern in which the two consecutive bright fringes are separated by 7.2 mm. Find the wavelength of light from the second source. What is the effect on the interference fringes, when the monochromatic source is replaced by a source of white light?

28. The equivalent capacitance of the combination between points A and B in the given figure is 4 μF.


i. Calculate the capacitance of the capacitor C.
ii. Calculate the charge on each capacitor if a 12 V battery is connected across terminals A and B.
iii. What will be the potential drop across each capacitor?

OR

Two-point charges of magnitude +q and -q are placed at $(-\frac{d}{2}, 0, 0)$ and $(\frac{d}{2}, 0, 0)$ respectively. Find the equation of the equipotential surface where the potential is zero.

29. A proton and an $\alpha$-particle are accelerated through the same potential. Which of the two has (i) greater value of de-Broglie wavelength associated with it and (ii) less kinetic energy? Justify your answer.

30. i. Derive with the help of a diagram the expression for the magnetic field inside a very long solenoid having n turns per unit length carrying a current I.
ii. How is a toroid different from a solenoid?

**Section E**

31. On the basis of energy bands, distinguish between conductors, insulators and semiconductors.

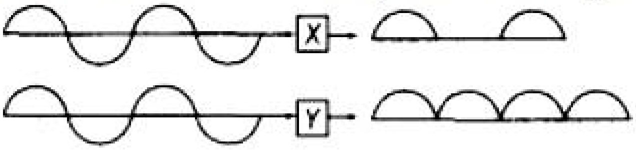
OR

An AC signal is fed into two circuits 'X' and 'Y' and the corresponding output in the two cases have the wave forms as shown.

i. Identify the circuits 'X' and 'Y'. Draw their labelled circuit diagrams.

ii. Briefly explain the working of circuit Y.

iii. How does the output waveform from circuit Y get modified when a capacitor is connected across the output terminals parallel to the load resistor?




32. i. A series L-C-R circuit is connected to an AC source of variable frequency. Draw a suitable phasor diagram to deduce the expressions for the amplitude of the current and phase angle.

ii. Obtain the condition at resonance. Draw a plot showing the variation of current with the frequency of AC source for two resistances $R_1$ and $R_2$ ($R_1 > R_2$). Hence, define the quality factor Q and write its role in the tuning of the circuit.

OR

A series L-C-R circuit is connected to an AC source. Using the phasor diagram, derive the expression for the impedance of the circuit. Plot a graph to show the variation of current with frequency of the source, explaining the nature of its variation.

33. i. Describe any two characteristic features which distinguish between interference and diffraction phenomena. Derive the expression for the intensity at a point of the interference pattern in Young's double slit experiment.

ii. In the diffraction due to a single slit experiment, the aperture of the slit is 3 mm. If monochromatic light of wavelength 620 nm is incident normally on the slit, calculate the separation between the first order minima and the 3rd order maxima on one side of the screen. The distance between the slit and the screen is 1.5 m.

OR

In Young's double slit experiment, deduce the condition for (a) constructive and (b) destructive interference at a point on the screen. Draw a graph showing a variation of intensity in the interference pattern against position x on the screen.

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## Solution

## Section A

1. Electrons, being negatively charged, tend to go to regions of high potential. This reduces their potential energy.
2. A wave of frequency $5 \times 10^{19}$ Hz belong to $\gamma$ - rays of electromagnetic spectrum.

OR

   i. Soft X-ray is used in medical diagnosis as they can pass through the muscles but not through the bones and hard X-ray in chemotherapy or radiotherapy.
   ii. In detecting faults, cracks, etc. in metal products, huge bridges.
3. i. Spherical wavefront
   ii. Cylindrical wavefront.
4. It states that magnetic field due to a small conductor of length dl, carrying a current I at a point at distance r, is given by
   dB = $\frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$
   where $\theta$ is the angle between the direction of flow of current and the line joining the small conductor to the observation point.

OR

   A charged particle moving at a right angle to the direction of the electric field experiences force in the plane of the electric field. The force acts at a right angle to its path only at the instant the charged particle enters the electric field and with the passage of time, it no longer remains at a right angle to the path. Since the force on the charged particle does not remain always perpendicular to the path, it does not move along a circular path.
5. The angle of prism and the refractive indices of the material of the prism for the two colours, for which the dispersive power is to be measured.
6. Photon is a particle. It possesses wave nature also.
7. The difference between the sum of the masses of the nucleons constituting a nucleus and the rest mass of the nucleus is known as mass defect.

OR

The energy harnessed in nuclei is released in nuclear reactions. Fission is the splitting of a heavy nucleus into lighter nuclei and fusion is the combining of nuclei to form a bigger and heavier nucleus.

8. The potential difference developed across the junction due to migration of majority carriers is called potential barrier.
9. The area of the hysteresis loop for soft iron is very small. Since energy dissipated during a complete cycle of magnetisation and demagnetisation is proportional to the area of the hysteresis loop, a small amount of energy will be wasted, when the core of the transformer is made of soft iron.
10. i. p-type
    ii. n-type
11. (c) A is true but R is false

    **Explanation:** Current flows when there in P.D.

    The presence of P.D implies the presence of an Electric field.

    Drift velocity $\propto$ Electric field.
12. (a) Both A and R are true and R is the correct explanation of A

    **Explanation:** Both A and R are true and R is the correct explanation of A
13. (c) A is true but R is false

    **Explanation:** A is true but R is false
14. (a) Both A and R are true and R is the correct explanation of A

    **Explanation:** Both A and R are true and R is the correct explanation of A

**Section B**

15. i. (c) $-3.2 \times 10^{-17}$ C
    ii. (a) $- 1.6 \times 10^{-18}$ C
    iii. (a) $9.1 \times 10^{-31}$ kg
    iv. (b) there is positive as well as negative charge in the body but the positive charge is more than a negative charge
    v. (a) valence electron only.
16. i. (a) right
    ii. (b) d.c bridge
    iii. (c) quality control of wire

iv. (d) measure quantities such as capacitance, inductance and impedance

v. (a) $\frac{R_1}{R_3} = \frac{R_2}{R_4}$

## Section C

17. Given, wavelength of the photon, $\lambda$ = 275 nm

Energy of the photon is given by,

E = h$\nu = h\frac{c}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{275\times10^{-9}\times1.6\times10^{-19}}\text{eV} = 4.5\text{eV}$

This corresponds to transition B as from the figure.

i. $\Delta E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{\Delta E}$

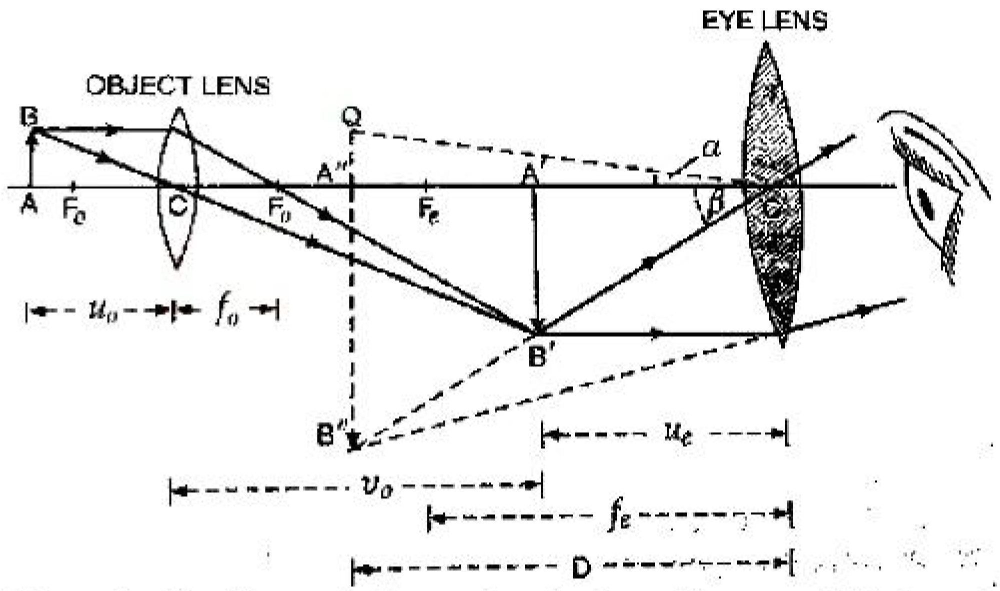
For maximum wavelength, energy should be minimum. Minimum energy corresponds to transition A.

ii. For minimum wavelength, energy should be maximum. Maximum energy corresponds to transition D.

18. The ray of light incident on the water-air interface suffers total internal reflection, in case the angle of incidence is greater than the critical angle. Therefore, if the tube is viewed from a suitable direction (so that the angle of incidence is greater than the critical angle), the rays of light incident on the tube undergo total internal reflection. As a result, the test tube appears as highly polished i.e. silvery.

OR

Ray diagram of a compound microscope:




When the final image is formed at the least distance of distinct vision,

$m = \frac{v_0}{u_0}\left(1 + \frac{D}{f_e}\right)$

For the image formed at infinity,

$m = \frac{v_0}{u_0} \times \frac{D}{f_e}$

where $v_o$ is the distance of the image A'B' from the object lens,

$u_o$ is the distance of the object AB from the object lens,

$f_e$ is the focal length of eye lens,

D is the least distance of distinct vision

19. Number of atoms in each piece of copper = $\frac{6\times10^{23}\times10}{63.5} = 9.45 \times 10^{22}$

Number of electrons transferred, $n = \frac{1}{1000} \times 9.45 \times 10^{22}$

$n = 9.45 \times 10^{19}$

∴Charges on each piece after transfer

$q_1 = q_2 = \pm ne = \pm 9.45 \times 10^{19} \times 1.6 \times 10^{-19}$

$= \pm 15.12C$

Given r = 0.1 m

Thus, $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2} = 9 \times 10^9 \times \frac{(15.12)^2}{(0.1)^2} = 2.06 \times 10^{14} N$

OR

a. Given, $a_1 = 7.0 m/s^2$, $a_2 = 9.0\ m/s^2$

$m_1 = 6.3 \times 10^{-7} kg,\ m_2 = ?$

As $F_1 = F_2$

$\therefore m_1a_1 = m_2a_2$

$m_2 = \frac{m_1a_1}{a_2} = \frac{6.3\times10^{-7}\times7.0}{9.0} = 4.9 \times 10^{-7} kg$

b. As $F_1 = F_2 \Rightarrow \frac{q_1q_2}{4\pi\varepsilon_0 r^2} = m_1a_1$

$\therefore \frac{9\times10^9 q^2}{(3.2\times10^{-3})} = 6.3 \times 10^{-7} \times 7.0$

$\therefore q = 7.1 \times 10^{-11} C$

20. For Balmer series,

$\frac{1}{\lambda_1} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = \frac{5R}{36}$

For Lyman series,

$\frac{1}{\lambda_2} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = \frac{3R}{4}$

Now, $\frac{\lambda_2}{\lambda_1} = \frac{4}{3R} \times \frac{5R}{36} = \frac{20}{108} = \frac{5}{27}$

$\lambda_2 = \frac{5}{27} \times \lambda_1 = \frac{5}{27} \times 6523$

$= 1215\overset{o}{A}$

21. **Advantages of AC over DC :**
    i. The generation and transmission of alternating current (AC) is more economical than direct current (DC).
    ii. The alternating voltage can be easily stepped up or stepped down as per need by using suitable transformers.

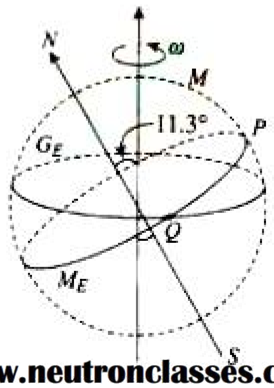
    **Disadvantages of AC over DC :**
    i. It is more dangerous to work with AC than DC.
    ii. It cannot be used for electrolysis.
22. Nuclear fission and fusion have the following points of differences:
    i. In a nuclear fission reaction, a heavy nucleus splits into two lighter nuclei; whereas in a nuclear fusion reaction, two light nuclei unite to form a heavier nucleus.
    ii. The energy released per nucleon is very high in case of nuclear fusion reaction in comparison to that in nuclear fission reaction.
    iii. The nuclear fusion reaction can be carried out only under very high temperature condition, while in case of nuclear fission reaction, there is no such requirement.
23. Here, power of the lens, P = +5D

    Therefore, focal length of the lens,

    $f = \frac{1}{P} = \frac{1}{5} = 0.2 \text{ m} = 20 \text{ cm}$

    When an object is placed between f and 2f i.e. between 20 cm and 40 cm, its image should be formed beyond 2f i.e. beyond 40 cm. The observations 1 and 2 satisfy this condition but the observation 3 is not in agreement with it.

    On the other hand, when an object is placed beyond 2f i.e. beyond 40 cm, its image should be formed between 20 cm and 40 cm. The observations 4, 5 and 6 satisfy this condition. Hence, the **observation 3** is incorrect.

24. 

The point P is on the magnetic equator, so the angle of dip is zero. Also, point Q is on the magnetic equator, so the angle of dip is zero.

Also, point P is in the plane S, and the needle is in the North, so the angle of declination at P is zero.

Now, Q is the point of intersection between the geographical meridian and magnetic meridian. The angle between the axis of rotation of the earth and the magnetic axis is $11.3^{o}$, so the angle of declination at Q is $11.3^{o}$.

OR

i. Electromagnets show magnetism till the current is switched on and as current is switch off, it lost its magnetism while permanent magnet retains its magnetism at room temperature for a long time after being magnetised.

ii. Materials used for making electromagnets must have following properties:
   a. High permeability: To get magnetised by applying small external magnetic field.
   b. Low coercivity: To get demagnetised easily by applying small external field in opposite direction.
   c. Low retentivity: Magetisation is lost as soon as current is switched off.

25. i. Blue light suffers more deviation by a prism than the red light. This happens because of the high value of refractive index of material of prism for blue light because of its smaller wavelength in visible spectrum.

ii. The formula that can be used to determine refractive index of material of a prism in minimum deviation condition is given by-

$$\delta_m = (\mu - 1)A$$

where $\delta_m$ is the angle of minimum deviation, μ = refractive index, and A is prism angle.

**Section D**

26. a. We know $e = L\frac{dI}{dt}$

Thus, $\frac{e_1}{e_2} = \frac{L_1}{L_2} = \frac{8}{2} = 4$

b. We know, P = e I

$P_1 = P_2$

$e_1I_1 = e_2I_2$

$\therefore \frac{I_1}{I_2} = \frac{e_2}{e_1} = \frac{1}{4}$

c. We know,

$U = \frac{1}{2}LI^2$

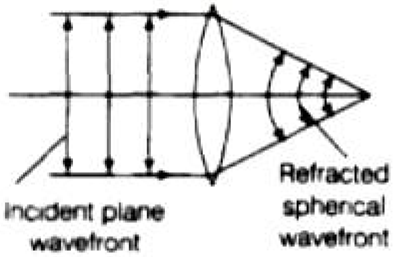
and $\frac{I_1}{I_2} = \frac{e_2}{e_1}$

$\therefore \frac{U_1}{U_2} = \frac{\frac{1}{2}L_1}{\frac{1}{2}L_2}\left(\frac{I_1}{I_2}\right)^2 = \frac{8}{2}\left(\frac{1}{4}\right)^2 = \frac{1}{4}$

27. When light is emitted from a source, then the particles present around it begins to vibrate. The locus of all such particles which are vibrating in the same phase is termed as wavefront.

Huygens' principle: Every point on a wave-front may be considered a source of secondary spherical wavelets which spread out in the forward direction at the speed of light. The new wave-front is the tangential surface to all of these secondary wavelets.

Now when a plane wavefront (parallel rays) is incident on a thin convex lens, the emergent rays are focused on the focal point of the lens. Thus the shape of emerging wavefront is spherical.




OR

Here, we are given young's double slit experiment.

Wavelength of monochromatic light, $\lambda_1 = 630\text{nm} = 630 \times 10^{-9}\text{m}$

Fringe width, $\beta_1 = 8.1 \times 10^{-3}\text{m}$

Fringe width, $\beta_2 = 7.2 \times 10^{-3}\text{m}$

Let d be the slit width and D the distance between slit and screen, then we have

$\beta = D\lambda/d$

For given Young's double slit experiment, D and d are constants

$\Rightarrow \frac{\beta_1}{\beta_2} = \frac{\lambda_1}{\lambda_2}$

Wavelength of light from the second source

$\Rightarrow \lambda_2 = \frac{\beta_2}{\beta_1} \times \lambda_1 = \frac{7.2\times10^{-3}}{8.1\times10^{-3}} \times 630 \times 10^{-9}$

$= \frac{8}{9} \times 630 \times 10^{-9} = 560 \times 10^{-9}\text{m}$

$\lambda_2 = 560\text{nm}$

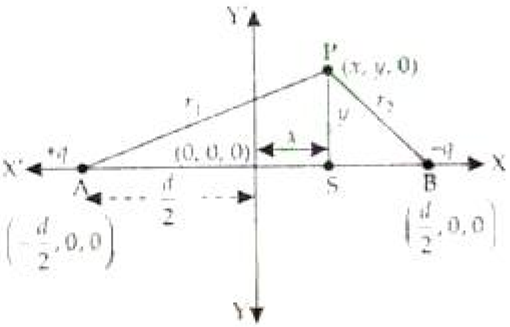
The coloured fringe pattern would be obtained if monochromatic light is replaced by white light. Because if the monochromatic source is replaced by white light, then we will not be able to see the interference fringes because white light is not a coherent source of light.

28. 


i. Capacitors of 20 μF and C are connected in series. The equivalent capacitance,
$4 = \frac{20\times C}{20+C}$ (applying the formula of equivalent capacitance in series connection)
$\Rightarrow$ (20 + C) = 5C $\Rightarrow$ 4C = 20
$\Rightarrow$ C = 5μF, Hence the value of C = 5 $\mu F$
ii. Charge on capacitor (equivalent), q = (4μF) × 12= 48μC. This charge (48 μC) lies on both the capacitors.
iii. Potential drop across the capacitor of capacitance 20 μF,
$V_1 = \frac{q}{C_1} = \frac{48\mu C}{20\mu F} = 2.4V$
Potential drop across 5 μF capacitor,
$V_2 = \frac{q}{C_2} = \frac{48\mu C}{5\mu F} = 9.6V$

OR

The potential due to charge +q and -q will be zero in between the line joining the two charges +q and -q. Let zero potential is at S.



Then equipotential surface will pass through S and perpendicular to line joining two chargers or AB.

$r_1^2 = AS^2 + SP^2$
$= \left(x + \frac{d}{2}\right)^2 + y^2$
$r_1 = \sqrt{\left(x + \frac{d}{2}\right)^2 + y^2}$

Similarly, $r_2 = \sqrt{\left(x - \frac{d}{2}\right)^2 + y^2}$

Since the net potential at P = O, we have

$\frac{kq}{r_1} + \frac{k(-q)}{r_2} = 0$ where k = $\frac{1}{4\pi\varepsilon_0}$

$\Rightarrow kq\left[\frac{1}{r_1} - \frac{1}{r_2}\right] = 0$ [$\because$ kq $\neq$ 0]

$\Rightarrow \frac{1}{r_1} - \frac{1}{r_2} = 0$

$\Rightarrow \left(x + \frac{d}{2}\right)^2 + y^2 = \left(x - \frac{d}{2}\right)^2 + y^2$

$\Rightarrow \left(x + \frac{d}{2}\right)^2 = \left(x + \frac{d}{2}\right)^2$

$\Rightarrow x^2 + \frac{d^2}{4} + dx = x^2 + \frac{d^2}{4} - dx$

2dx = 0

2d $\neq$ 0

$\therefore$ x = 0

So equipotential surface will be perpendicular to X-axis passing through x = 0 i.e., origin in Y-Z plane.

29. From de-Broglie matter wave equation,

$\lambda = \frac{h}{p}$

But, $p = \sqrt{2mK}$ and K = qV$\Rightarrow$ $\lambda \propto \frac{1}{\sqrt{mq}}$

i. Using de-Broglie wavelength formula, we already know that proton and alpha particle are accelerated through the same potential. So, their velocities are same.

Ratio of wavelengths of proton and $\alpha$-particle,

$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha q_\alpha}{m_p q_p}} = \sqrt{\left(\frac{m_\alpha}{m_p}\right)\left(\frac{q_\alpha}{q_p}\right)}$

But,

$\frac{m_\alpha}{m_p} = 4, \frac{q_\alpha}{q_p} = 2$

$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{(4) \times 2} = 2\sqrt{2}$

$\Rightarrow \lambda_p : \lambda_\alpha = 2\sqrt{2} : 1$

Proton have greater de-Broglie wavelength associated with it.

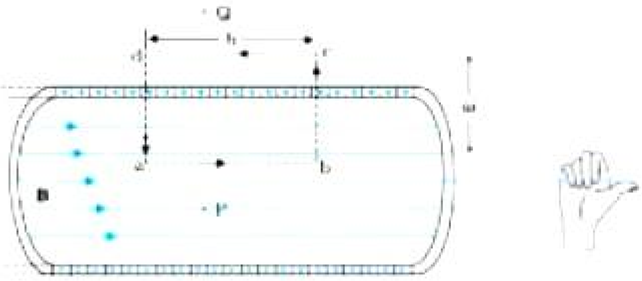
ii. Kinetic energy, K = qV

$\Rightarrow \frac{K_p}{K_\alpha} = \left(\frac{q_p}{q_\alpha}\right)$(for same accelerating voltage)

$\frac{K_p}{K_\alpha} = \frac{1}{2} \Rightarrow K_p = \frac{1}{2}K_\alpha$

Thus, proton has less kinetic energy.

30. i.



Consider the loop abcd. Along cd, the magnetic field is zero. Along bc and ad, the field component is zero, hence makes no contribution. Let field along ab be B. Let n be the number of turns per unit length.

Thus, the total number of turns is nh.

The enclosed current is $I_e = I(nh)$

From Ampere's circuital law,

$BL = \mu_o I_e$

$Bh = \mu_o I(nh)$ [ here L = h ]

Therefore, magnetic field $B = \mu_o nI$

Its direction is given by right hand thumb rule.

ii. The toroid is a hollow circular ring having large number of turns closely wound. It is viewed as solenoid bent into circular shape.

The magnetic field, B of toroid having N turns is,

$B = \frac{\mu_o N I}{2\pi r}$

where $N = 2\pi r n$

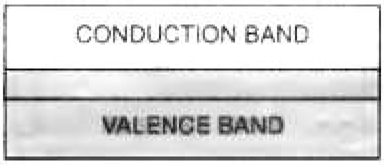
Also, Solenoid behaves like a bar magnet whereas Toroid does not.

**Section E**

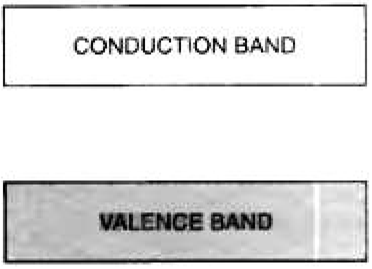
31. **Conductors.** The energy band structure in solids have two possibilities :

i. The valence band may be completely filled and the conduction band partially filled with an extremely small energy gap between them [Figure]. For example, in sodium, the conduction band is partially filled, while the valence band is completely filled.

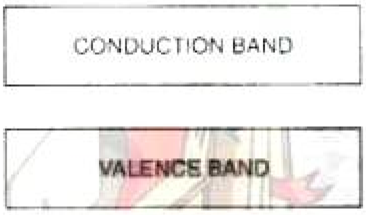

ii. The valence band is completely filled and the conduction band is empty but the two overlap each other [Figure]. Zinc is an example of band overlap metals.




**Insulators.** In insulators, the forbidden energy gap is quite large [Figure]. For example, the forbidden energy gap for diamond is 6 eV, which means that a minimum of 6 eV energy is required to make the electron jump from the completely filled valence band to the conduction band. When electric field is applied across such a solid, the electrons find it difficult to acquire such a large amount of energy and so the conduction band continues to be almost empty. No electron flow occurs i.e. no current flows through such solids. So they behave as insulators.

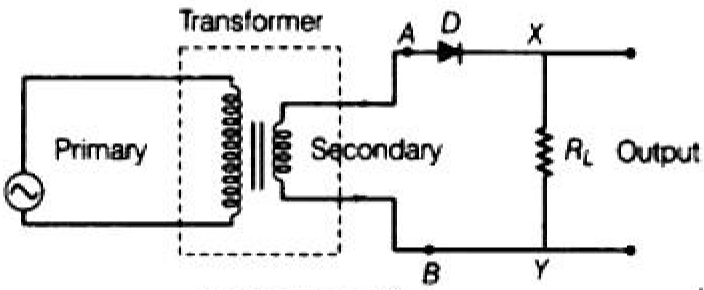



**Semiconductor.** The energy band structure of the semiconductors is similar to the insulators but in their case; the size of the forbidden energy gap is much smaller than that for the insulators [Figure]. For example, the forbidden band for silicon is 1.1 eV. The electronic structure of the silicon (Si) is similar to that of the diamond, but due to the smaller width of the forbidden energy gap, the electrons in the valence band find it comparatively easier to shift to the conduction band. So, the conductivity of the silicon is inbetween the conductors and the insulators and it is termed as a semiconductor.

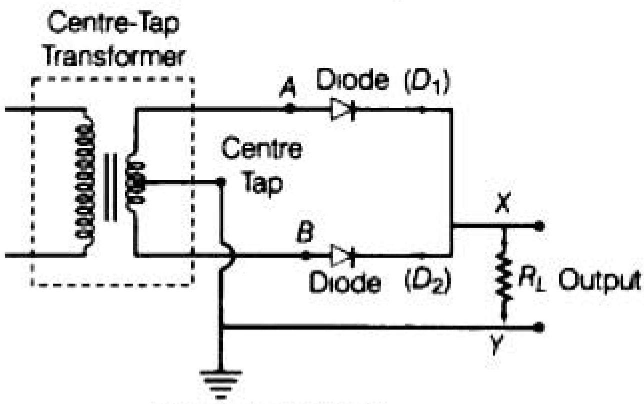



OR

i. Here X is half-wave rectifier and Y is full-wave rectifier



(Half-wave rectifier)

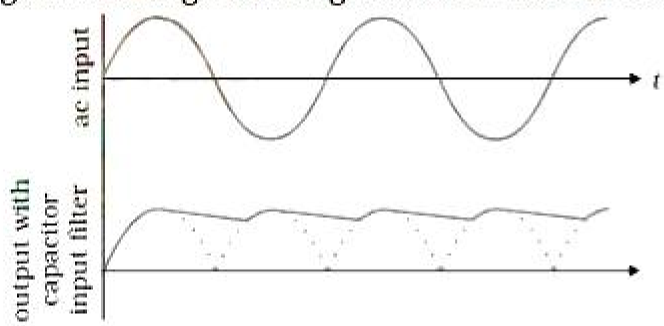


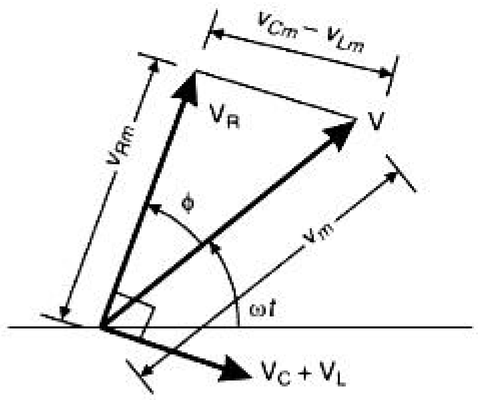
(Full-wave rectifier)

ii. In case of a full wave rectifier during positive half cycle of ac, diode $D_1$ is forward biased and diode $D_2$ is reversed biased and output is taken across the load resistance with a particular polarity. Whereas during negative half cycle of ac, the diode $D_2$ is forward biased and diode $D_1$ is reverse biased, and again the output is taken across the load resistance with the same polarity.

iii. A capacitor of large capacitance is connected in parallel to the load resistor $R_L$. When the pulsating voltage supplied by the rectifier is rising, the capacitor C gets charged. If there is no external load, the capacitor would have remained charged to the peak voltage of the rectified output.

However, when there is no load and the rectified voltage starts falling, the capacitor gets discharged through the load and the voltage across capacitor begins to fall slowly.



32. i. 


From the phasor diagram,

$$\vec{V} = \vec{V}_L + \vec{V}_R + \vec{V}_C$$

Magnitude of net voltage,

$$V_m = \sqrt{(V_{Rm})^2 + (V_{Cm} - V_{Lm})^2}$$

$$V_m = I_m\sqrt{\left[R^2 + (X_C - X_L)^2\right]}$$

$$I_m = \frac{V_m}{\sqrt{\left[R^2+(X_C-X_L)^2\right]}}$$

From the figure,

$$\tan\phi = \frac{V_{Cm}-V_{Lm}}{V_{Rm}}$$

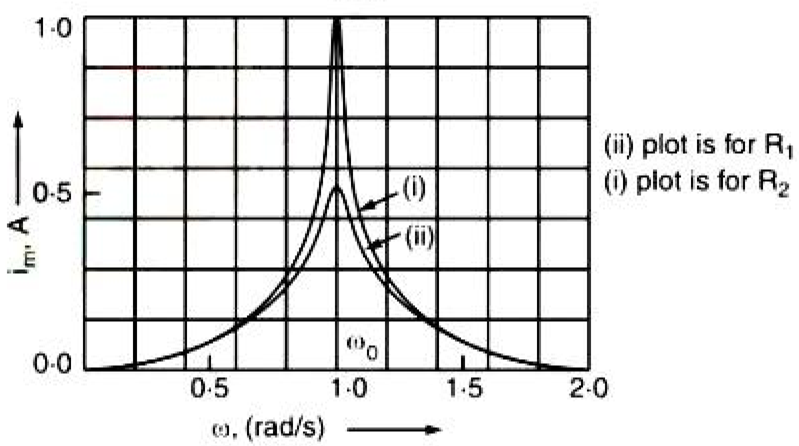
$$= \frac{I_m(X_C-X_L)}{I_mR}$$

$$\therefore \phi = \tan^{-1}\left(\frac{X_C-X_L}{R}\right)$$

ii. At resonance, $I_m$ is maximum

$\Rightarrow X_L = X_C,$

[Alternatively: $\omega_0 = \frac{1}{\sqrt{LC}}$ ]




Quality factor of LCR circuit is defined as $\frac{\omega_0 L}{R}$

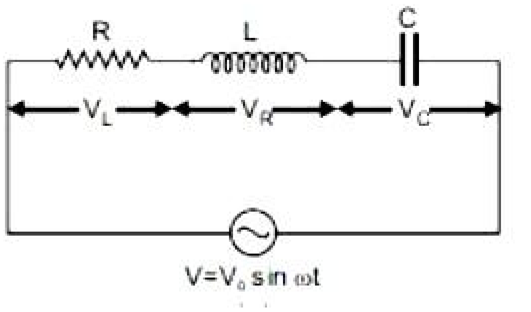
A larger value of qualtiy factor corresponds to a sharper resonance.

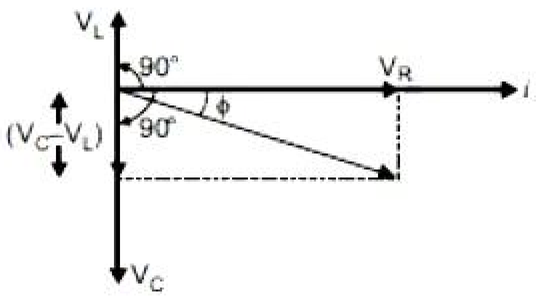
OR

Suppose a resistance R, inductance L and capacitance C in series. An alternating source of voltage $V = V_0 \sin \omega t$ is applied across it. Since all the components are connected in series, the current flowing through all is same.

Voltage across resistance R is $V_R$, voltage across inductance L is $V_L$ and voltage across capacitance C is $V_C$.

$V_R$ and $(V_C - V_L)$ are mutually perpendicular and the phase difference between them is $90^o$.




From the figure above, we have

$V^2 = V_R^2 + (V_C - V_L)^2 \Rightarrow V = \sqrt{V_R^2 + (V_C - V_L)^2}$ ..... (i)

and $V_R = Ri$, $V_C = X_C i$ and $V_L = V_L i$ ..... (ii)

where $X_C = \frac{1}{\omega C}$ = capacitance reactance and $X_L = \omega L$ = inductive reactance

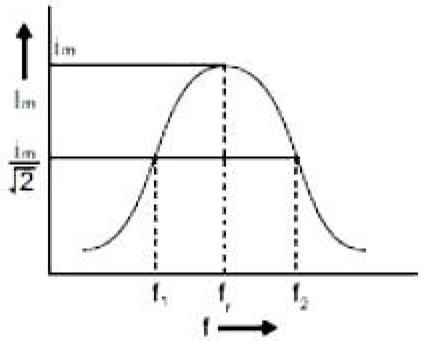
$\therefore \quad V = \sqrt{(Ri)^2 + (X_C i - X_L i)^2}$

$\therefore$ Impendance of circuit, $Z = \frac{V}{i} = \sqrt{R^2 + (X_C - X_L)^2}$

i.e. $Z = \sqrt{R^2 + (X_C - X_L)^2} = \sqrt{R^2 + \left(\frac{1}{\omega C} - \omega L\right)^2}$

The phase difference between current and voltage is given by,

$\tan \phi = \frac{X_C - X_L}{R}$



From the graph, we can see that with increase in frequency, current first increases and then decreases. At resonant frequency, current amplitude is maximum.

33. i. Two characteristic features which distinguish between interference and diffraction phenomena are

(a) Interference pattern has number of equally spaced bright and dark bands while diffraction pattern has central bright maximum which is twice as wide as the other maxima.

(b) Interference is obtained by the superposing two waves originating from two narrow slits. The diffraction pattern is the superposition of the continuous family of waves originating from each point on a single slit

Now displacement produced by source '$s_1$'

$Y_1 = a \cos\omega t$

and displacement produced by the other source '$s_2$'

$Y_2 = a \cos(\omega t + \theta)$

Resultant displacement $Y = Y_1 + Y_2$

$= a [\cos\omega t + \cos(\omega t + \theta)]$

$= 2a \cos\left(\frac{\theta}{2}\right) \cos\left(\omega t + \frac{\theta}{2}\right)$

Amplitude of resultant wave $A = 2a\cos\left(\frac{\theta}{2}\right)$

Intensity, $I \propto A^2$

$I = KA^2 = K\,4a^2\cos^2\left(\frac{\theta}{2}\right)$

ii. Distance of First order minima from centre of the central maxima = $X_{D1} = \frac{\lambda D}{a}$

Distance of third order maxima from centre of the central maxima = $X_{B3} = \frac{7D\lambda}{2a}$

Distance between first order minima and third order maxima = $X_{B3} - X_{D1}$

$= \frac{7D\lambda}{2a} - \frac{\lambda D}{a}$

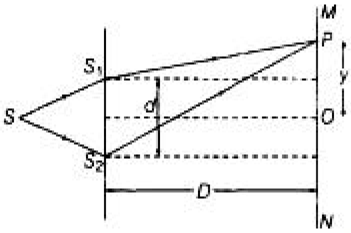
$\frac{5D\lambda}{2a}$

$= \frac{5\times620\times10^{-9}\times1.5}{2\times3\times10^{-3}}$

$= 7.75 \times 10^{-4}$ m

OR

Suppose $S_1$ and $S_2$ are two fine slits, a small distance d apart. They are illuminated by a strong source S of monochromatic light of wavelength $\lambda$. MN is a screen at a distance D from the slits.




Consider a point P at a distance y from 0, the centre of the screen.

The path difference between two waves arriving at point Pis equal to $S_2P$ - $S_1P$.

Now, $(S_2P)^2 - (S_1P)^2$

$$= \left[D^2 + \left(y + \frac{d}{2}\right)^2\right] - \left[D^2 + \left(y - \frac{d}{2}\right)^2\right] = 2yd$$

Thus, $S_2P - S_1P = \frac{2yd}{S_2P+S_1P}$

But $S_2P + S_1P \approx 2D \therefore \quad S_2P - S_1P \approx \frac{dy}{D}$

a. For constructive interference (Bright fringes)

   Path difference $= \frac{dy}{D} = n\lambda$ , where,

   n = 0, 1, 2, 3,......

   $\therefore \quad y = \frac{nD\lambda}{d}$ [$\because$ n = 0, 1, 2, 3, ....]

b. For destructive interference (Dark fringes)

   Path difference $= \frac{dy}{D} = (2n-1)\frac{\lambda}{2}$

The distribution of intensity in Young's double slit experiment is as shown below