Sl.No.: 226690

नामांक Roll No.

No. of Questions — 20

No. of Printed Pages — 18

SS–40–Physics

उच्च माध्यमिक परीक्षा, 2024

SENIOR SECONDARY EXAMINATION, 2024

भौतिक विज्ञान

PHYSICS

समयः 3 घण्टे 15 मिनिट

पूर्णांकः 56

परीक्षार्थियों के लिए सामान्य निर्देशः
GENERAL INSTRUCTIONS TO THE EXAMINEES:

1) परीक्षार्थी सर्वप्रथम अपने प्रश्न पत्र पर नामांक अनिवार्यतः लिखें।
Candidates must write his / her Roll No. first on the question paper compulsorily.

2) सभी प्रश्न करने अनिवार्य हैं।
All the questions are compulsory.

3) सभी प्रश्नों का उत्तर दी गई उत्तर–पुस्तिका में ही लिखें।
Write the answer to each question in the given answer-book only.

4) जिन प्रश्नों में आन्तिरक खण्ड हैं, उन सभी के उत्तर एक साथ ही लिखें।
For questions having more than one part, the answers to those parts are to be written together in continuity.

5) प्रश्न पत्र के हिन्दी व अंग्रेजी रूपान्तर में किसी प्रकार की त्रुटि/अन्तर/विरोधाभास होने पर हिन्दी भाषा के प्रश्न को ही सही मानें।
If there is any error/difference/contradiction in Hindi & English versions of the question paper, the question of Hindi version should be treated valid.

6) प्रश्न का उत्तर लिखने से पूर्व प्रश्न का क्रमांक अवश्य लिखें।
Write down the serial number of each question before attempting it.

7) प्रश्न क्रमांक **16, 17, 18, 19** व **20** में आन्तरिक विकल्प हैं।
There are internal choices in Question Nos. **16, 17, 18, 19** & **20**.

खण्ड–अ (SECTION – A)

(1) Choose the correct answer from multiple choice questions (i to xvi) and write in given answer book.
बहुविकल्पी प्रश्न (i से xvi) : निम्न प्रश्नों के उत्तर का सही विकल्प का चयन कर दी गई उत्तर पुस्तिका में लिखिए।

(i) The electric flux on a Gaussian spherical surface of radius 15cm, drawn with a point charge as the centre, is 'ϕ'. If the radius of this surface is tripled then the electric flux passing through the surface will be -

(A) Zero (B) Infinity (C) 3ϕ (D) ϕ

किसी बिंदु आवेश को केन्द्र मानकर खींचे गए 15cm त्रिज्या के गोलीय गाउसीय पृष्ठ पर विद्युत फ्लक्स का मान 'ϕ' है। यदि इस पृष्ठ की त्रिज्या तिगुनी कर दें तो पृष्ठ से गुजरने वाला विद्युत फ्लक्स का मान होगा – **[½]**

(अ) शून्य (ब) अनंत (स) 3ϕ (द) ϕ

Ans. (D) ϕ

(ii) The value of dielectric strength for air is -

(A) 3×10^6 V/m (B) 3×10^8 V/m (C) Zero (D) Infinity

वायु के लिए परावैद्युत सामर्थ्य का मान होता है – **[½]**

(अ) 3×10^6 V/m (ब) 3×10^8 V/m (स) शून्य (द) अनंत

Ans. (A) 3×10^6 V/m

(iii) The SI unit of resistivity is -

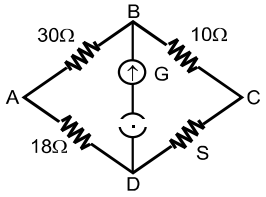
(A) Ω/m (B) Ω (C) Ω m (D) $2m^2$

प्रतिरोधकता का SI मात्रक है – **[½]**

(अ) Ω/m (ब) Ω (स) Ω m (द) Ωm^2

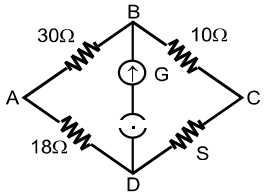
Ans. (C) Ω m

(iv) In the given figure, if the Wheatstone bridge is in balanced condition, then the value of resistance 'S' will be



(A) 12 Ω (B) 9 Ω (C) 3.0 Ω (D) 6 Ω

दिये गए चित्र में यदि व्हीटस्टोन सेतु संतुलित अवस्था में हो तो प्रतिरोध 'S' का मान होगा – **[½]**



(अ) 12 Ω (ब) 9 Ω (स) 3.0 Ω (द) 6 Ω

Ans. (D) 6 Ω

(v) When a charged particle moves in a uniform magnetic field in a direction perpendicular to the field, then the path of the particle will be- [½]

(A) Parabolic (B) Circular (C) Straight line (D) Helical

जब कोई आवेशित कण एकसमान चुंबकीय क्षेत्र में क्षेत्र के लंबवत् दिशा में गति करता है तो कण का पथ होगा–

(अ) परवलयाकार (ब) वृत्ताकार (स) सरल रेखीय (द) कुंडलिनी (सर्पिलाकार)

Ans. (B) Circular वृत्ताकार

(vi) The device is based on the principle of mutual induction is – [½]

(A) ac generator (B) galvanometer (C) voltmeter (D) transformer

अन्योन्य प्रेरण के सिद्धांत पर आधारित उपकरण है –

(अ) प्रत्यावर्ती धारा जनित्र (ब) गेल्वेनोमीटर (स) वोल्टमीटर (द) ट्रांसफार्मर

Ans. (D) transformer ट्रांसफार्मर

(vii) The formula for displacement current (I_d) is - [½]

विस्थापन धारा (I_d) का सूत्र है–

(A) $\mu_0 \frac{d\phi_E}{dt}$ (B) $\mu_0\varepsilon_0 \frac{d\phi_E}{dt}$ (C) $\varepsilon_0 \frac{d\phi_E}{dt}$ (D) $\frac{1}{\varepsilon_0}\frac{d\phi_E}{dt}$

Ans. (C) $\varepsilon_0 \frac{d\phi_E}{dt}$

(viii) If the magnification of a optical instrument is negative then the image will always be formed.

(A) Real and inverted (B) Virtual and erect

(C) Real and erect (D) Virtual and inverted

यदि किसी प्रकाशिक उपकरण का आवर्धन ऋणात्मक हो तो प्रतिबिम्ब सदैव होगा– [½]

(अ) वास्तविक एवं उल्टा (ब) आभासी एवं सीधा (स) वास्तविक एवं सीधा (द) आभासी एवं उलटा

Ans. (D) Virtual and inverted आभासी एवं उलटा

(ix) If the magnification of objective and eyepiece in a compound microscope is 'm_o' and 'm_e' respectively, then the total magnifying power (m) of the microscope will be -

(A) $m_o + m_e$ (B) $m_o - m_e$ (C) $m_o \cdot m_e$ (D) $\frac{m_o}{m_e}$

यदि संयुक्त सूक्ष्मदर्शी में अभिदृश्यक एवं नेत्रिका का आवर्धन क्रमशः 'm_o' एवं 'm_e' हो तो सूक्ष्मदर्शी की कुल आवर्धन क्षमता (m) होगी – [½]

(अ) $m_o + m_e$ (ब) $m_o - m_e$ (स) $m_o \cdot m_e$ (द) $\frac{m_o}{m_e}$

Ans. (C) $m_o \cdot m_e$

(x) Natural light from the sun is

(A) polarised (B) unpolarised (C) partially polarised (D) linear polarised

सूर्य से प्राप्त प्राकृतिक प्रकाश होता है – [½]

(अ) ध्रुवित (ब) अध्रुवित (स) आंशिक ध्रुवित (द) रेखीय ध्रुवित

Ans. (B) unpolarised अध्रुवित

(xi) The maximum kinetic energy of a photo electron emitted from a metal is 1.8 eV. The value of stopping potential (cut-off voltage) will be -

(A) 3.6 V (B) 2.0 V (C) 1.8 V (D) 0.9 V

किसी धातु से उत्सर्जित प्रकाशिक इलेक्ट्रॉन की अधिकतम गतिज ऊर्जा 1.8 eV है निरोधी विभव (अंतक वोल्टता) का मान होगा– **[½]**

(अ) 3.6 V (ब) 2.0 V (स) 1.8 V (द) 0.9 V

Ans. (C) 1.8 V

Sol. $eV_0 = K.E.$

$$V_0 = \frac{K.E.}{e} = \frac{1.8\ eV}{e} = 1.8\ V$$

(xii) The moment (p) of photon is-

(A) $\frac{h}{\lambda}$ (B) $\frac{\lambda}{h}$ (C) $\frac{hC}{\lambda}$ (D) $h\lambda$

फोटॉन का संवेग (p) होता है – **[½]**

(अ) $\frac{h}{\lambda}$ (ब) $\frac{\lambda}{h}$ (स) $\frac{hC}{\lambda}$ (द) $h\lambda$

Ans. (A) $\frac{h}{\lambda}$

(xiii) The value of scattering angle of alpha particle for maximum value of impact, parameter is

(A) 90° (B) 60° (C) 45° (D) 0°

संघट्ट प्राचल के अधिकतम मान के लिए ऐल्फा–कण का प्रकीर्तन कोण होता है – **[½]**

(अ) 90° (ब) 60° (स) 45° (द) 0°

Ans. (D) 0°

(xiv) The value of excitation energy required to bring an electron to the first excited state in hydrogen atom is-

(A) 13.6 eV (B) 10.2 eV (C) 10.2 eV (D) –3.4 eV

हाइड्रोजन परमाणु में किसी इलेक्ट्रॉन की पहली उत्तेजित अवस्था में आवश्यक उत्तेजन ऊर्जा का मान होता है– **[½]**

(अ) 13.6 eV (ब) 10.2 eV (स) 3.4 eV (द) –3.4 eV

Ans. (B) 10.2 eV

(xv) Those atoms which have the same atomic number but different mass number are called -

(A) isobars (B) isotones (C) isotopes (D) isomers

वे परमाणु जिनके परमाणु क्रमांक समान लेकिन द्रव्यमान संख्या भिन्न होते हैं, कहलाते हैं– **[½]**

(अ) समभारिक (ब) समन्यूट्रॉनिक (स) समस्थानिक (द) समअवयवी

Ans. (C) isotopes समस्थानिक

(xvi) Example of inorganic semiconductor is -

(A) Ge (B) CdS (C) anthracene (D) polyaniline

अकार्बनिक अर्धचालन का उदाहरण है– **[½]**

(अ) Ge (ब) CdS (स) एन्थ्रासीन (द) पॉलीऐनिलीन

Ans. (A) Ge

(2) Fill in the blanks: (i to x)
रिक्त स्थानों की पूर्ति कीजिएः (i से x)

(i) The field lines of a single positive charge are radially.....
एकल धनावेश के कारण वैद्युत क्षेत्र त्रिज्यतः ..... होती है। **[½]**

Ans. Outward

(ii) The magnitude of drift velocity of electron per unit electric field is called.....
इकाई विद्युत क्षेत्र लगाने पर इलेक्ट्रॉनों के अपवाह वेग के परिमाण को .....कहते है। **[½]**

Ans. Mobility

(iii) To convert a galvanometer into a voltmeter a resistance of.....value is connected in series to it.
एक गेल्वेनोमीटर को वोल्टमीटर में रूपांतरित करने हेतु उसके श्रेणीक्रम में ..... मान का प्रतिरोध जोडा जाता है। **[½]**

Ans. High

(iv) The resultant magnetic moment produced per unit volume of a substance is called.....
किसी पदार्थ के प्रति इकाई आयतन में उत्पन्न परिणामी चुबकीय आघूर्ण को.....कहते है। **[½]**

Ans. Intensity of magnetisation

(v) The mean value of alternating current in a complete cycle is.....
एक सम्पूर्ण चक्र में प्रत्यावर्ती धारा का माध्य मान ..... होता है। **[½]**

Ans. Zero

(vi) The radius of curvature of a concave mirror is 24 cm. The value of its focal length will be.....cm.
एक अवतल दर्पण की वक्रता त्रिज्या 24 cm है। इसकी फोकस दूरी का मान .....cm होगा। **[½]**

Ans. – 12 cm.

Sol. $f = \frac{R}{2} = -12$ cm.

(vii) Bending of waves from their path by the edges of an obstacle is called.....
किसी अवरोध के किनारों द्वारा तंरगों का अपने मार्ग से मुड जाना, ... कहलाता है। **[½]**

Ans. Diffraction

(viii) The formula for the de Broglie wavelength associated with an electron accelerated by a potential 'V' is λ =.....nm.
विभव 'V' द्वारा त्वरित किसी इलेक्ट्रॉन से संबद्ध दे ब्रोग्ली तंरगदैर्ध्य का सूत्र λ = ...nm होती है। **[½]**

Ans. $\lambda = \frac{12.23}{\sqrt{V}}\text{Å} = \frac{1.223}{\sqrt{V}}\text{nm}$

(ix) If the radius of first orbit of hydrogen atom is 0.5×10^{-10} m, then the radius of its second orbit will be.....m.
यदि हाइड्रोजन परमाणु के प्रथम कक्षा की त्रिज्या 0.5×10^{-10} m, हो तो इसके दूसरी कक्षा की त्रिज्या.....m होगी। **[½]**

Ans. 2×10^{-10} m

Sol. $r = 0.5 \times 10^{-10}\left(\frac{n^2}{Z}\right)$ m

$r = 0.5 \times 10^{-10} \times 4 = 2 \times 10^{-10}$ m.

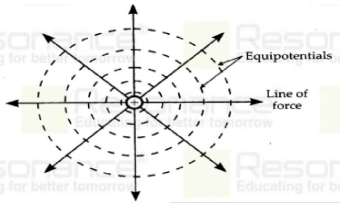
(x) .....types of extrinsic semiconductors are found.
अपद्रव्यी अर्धचालक .....प्रकार के होते है। **[½]**

Ans. Two

(3) Give the answer of the following questions in one line:
निम्न प्रश्नों के उत्तर एक पंक्ति में दीजिए:

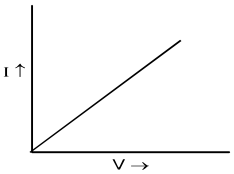
(i) Draw an equipotential surface for a positive charge (q > 0).
किसी एकल धनावेश (q > 0) के लिए समविभव पृष्ठ बनाइए। **[1]**

Sol.



(ii) Draw a graph between potential difference (V) and current (I) according to Ohm's law.
ओम के नियमानुसार विभवांतर (V) तथा धारा (I) के मध्य ग्राफ बनाइए। **[1]**

Sol.



(iii) What is paramagnetic substance?
अनुचुंबकीय पदार्थ किसे कहते है? **[1]**

Sol. Paramagnetic substances are those which develop feeble magnetisation in the direction of the magnetising field. Such substances are feebly attracted by magnets and tend to move from weaker to stronger parts of a magnetic field.
Examples : Manganese, aluminium, chromium, platinum, sodium, copper chloride, oxygen (at STP), etc.

(iv) Why self-inductance is called electrical inertia?
स्वप्रेरकत्व को विद्युत जडत्व क्यों कहते हैं? **[1]**

Sol. Self-induction of the coil is the property by virtue of which it tends to maintain the magnetic flux linked with it and opposes any change in the flux by inducing a current in it. This property of a coil is analogous to mechanical inertia. That is why self-induction is called the inertia of electricity.

(v) Define Coherent source.
कला–संबद्ध स्त्रोत को परिभाषित कीजिए। **[1]**

Sol. The source which emits a light wave with the same frequency, wavelength and phase or having a constant phase difference is known as a coherent source.

(vi) Write the definition of threshold frequency of a substance.
किसी पदार्थ की 'देहली आवृत्ति' की परिभाषा लिखिए। **[1]**

Sol. The threshold frequency is the lowest frequency below which the photoelectric effect does not occur.

(vii) What is ionization energy?
'आयनन ऊर्जा' किसे कहते हैं? **[1]**

Sol. Ionization energy is defined as the amount of energy required to remove an electron from an isolated atom or molecule.

(viii) Write Einstein's mass-energy equivalent relation.
आइंस्टाइन का द्रव्यमान–ऊर्जा समतुल्यता संबंध लिखिए। **[1]**

Sol. $E = mc^2$

खण्ड–ब (SECTION – B)

4. Three capacitors of capacitance 6μF are connected in parallel. Calculate the value of their equivalent capacitance.
6μF धारिता के तीन संधारित्र पार्श्वक्रम में जुडे है। इनकी तुल्य धारिता का मान ज्ञात कीजिए। **[1½]**

Sol. $C_p = C_1 + C_2 + C_3 = 6\ \mu F + 6\ \mu F + 6\ \mu F = 18\ \mu F$

5 Define:
(i) Electromotive force and (ii) Internal resistance of a cell
किसी सेल के
(i) विद्युत वाहक बल तथा (ii) आंतरिक प्रतिरोध को परिभाषित कीजिए। **[1½]**

Sol. (i) The electromotive force of a source may be defined as the work done by the source in taking a unit positive charge from +ve to –ve terminal in the external circuit and from –ve to +ve terminal inside the cell.
(ii) The resistance offered by the electrolyte of a cell to the flow of current between its electrodes is called internal resistance of the cell.

6 Write any two properties of magnetic field lines.
चुंबकीय क्षेत्र रेखाओं के कोई दो गुण लिखिए। **[1½]**

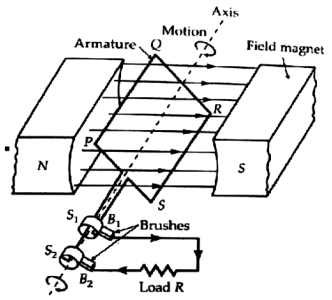
Sol. Properties of lines of force :
1. Magnetic lines of force are closed curves which start in air from the N-pole and end at the S-pole and then return to the N-pole through the interior of the magnet.

2. The lines of force never cross each other. If they do, so, that would mean there are two directions of the magnetic field and the point of intersection. Which is impossible.

3. The lines of force never cross each other. If they do so, that would mean there are two directions of the magnetic field at the point of intersection, which is impossible.

7. Draw a clear and labeled diagram of an alternating current generator. **[1½]**
प्रत्यावर्ती धारा जनित्र का स्पष्ट एवं नामांकित चित्र बनाइए।

Sol.



8. A 5 m long straight horizontal conducting wire situated in the east to west direction is falling with a speed of 2 m/s perpendicular to the horizontal component of the earth magnetic field of 0.3×10^{-4} T. Find the instantaneous value of the emf induced between the ends of the wire.
पूर्व से पश्चिम दिशा में स्थित 5 m लम्बा सीधा क्षैतिज चालक तार 0.3×10^{-4} T के पृथ्वी के चुंबकीय क्षेत्र के क्षैतिज घटक के लम्बवत् 2 m/s की चाल से गिर रहा है। तार के सिरों के मध्य प्रेरित विद्युत वाहक बल का ताक्षणिक मान ज्ञात कीजिए। **[1½]**

Sol. $\varepsilon = B_H \ell v = 0.3 \times 10^{-4} \times 5 \times 2 = 3 \times 10^{-4}$ V

9. Write the names of any three waves (radiations) produced in the electromagnetic spectrum.
वैद्युत चुम्बकीय स्पेक्ट्रम में उत्पन्न किन्हीं तीन तरंगों (विकिरणों) के नाम लिखिए। **[1½]**

Sol. (1) x-Ray, (2) UV-Rays (3) γ-Rays

10. The magnifying power of a small telescope is 9 and the length of the tube is 100 cm. Find the focal lengths of the objective and eyepiece of the telescope.
किसी छोटी दूरबीन की आवर्धन क्षमता 9 तथा नली(ट्यूब) की लम्बाई 100 cm है। दूरबीन के अभिदृश्यक तथा नेत्रिका की फोकस दूरियाँ ज्ञात कीजिए। **[1½]**

Sol. $\because \quad M = \frac{f_0}{f_e}$

$9 = \frac{f_0}{f_e} \quad \Rightarrow \quad f_0 = 9f_e$

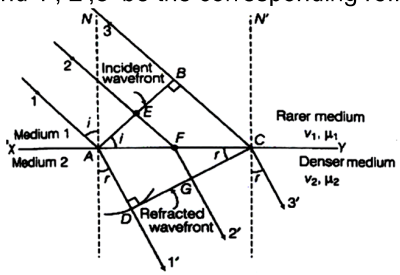
$L = f_0 + f_e$

$100 = 9f_e + f_e$

$f_e = 10$ cm and $f_0 = 90$ cm

11. Derive Snell's law for refraction of light by Huygen's wave theory.
हाइगेंस के तरंग सिद्धान्त से प्रकाश के अपवर्तन हेतु स्नैल के नियम को व्युत्पन्न कीजिए। **[1½]**

Sol. Laws of Refraction (Snell's Law) at a Plane Surface
Let 1, 2, 3 be the incident rays and 1', 2',3' be the corresponding refracted rays.



Laws of refraction by Huygens' principle

If v_1, v_2 are the speeds of light in the two media and t is the time taken by light to go from B to C or A to D or E to G

through F, then $t = \frac{EF}{v_1} + \frac{FG}{v_2}$

In ΔAFE, $\sin i = \frac{EF}{AF}$

In ΔFGC, $\sin r = \frac{FG}{FC}$

$\Rightarrow \quad t = \frac{AF \sin i}{v_1} + \frac{FC \sin r}{v_2} \quad \Rightarrow \quad t = \frac{AC \sin r}{v_2} + AF\left(\frac{\sin i}{v_1} - \frac{\sin r}{v_2}\right)$

For rays of light from different parts on the incident wavefront, the values of AF are different. But light from different points of the incident wavefront should take the same time to reach the corresponding points on the refracted wavefront. So, t should not depend upon AF. This is possible only, if

$\frac{\sin i}{v_1} - \frac{\sin r}{v_2} = 0$

$\Rightarrow \quad \frac{\sin i}{\sin r} = \frac{v_1}{v_2}$

$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} \quad \left(v \propto \frac{1}{\mu}\right)$

This is known as Snell's law of refraction.

12. Define the following:
(a) Interference of light (b) Polarization of light
निम्न को परिभाषित कीजिएः **[1½]**
(a) प्रकाश का व्यतिकरण (b) प्रकाश का ध्रुवण

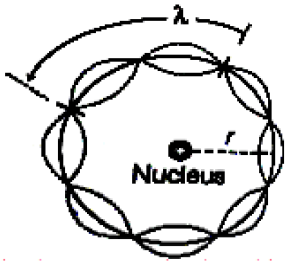
Sol. (a) When two light waves from different coherent sources meet together, then the distribution of energy due to one wave is disturbed by the other, is called "Interference of light".
(b) Polarization of light is a property shown by transverse waves. The light waves which travel only in a single plane are known as polarized light waves. The process of transforming unpolarized light waves to polarized light waves is called the polarization of light.

13. A 20 Watt bulb emits 5×10^9 photons per second. Find the energy of each photon.
20 वॉट के बल्ब से 5×10^9 फोटॉन प्रति सेकण्ड होते हैं। प्रत्येक फोटॉन की ऊर्जा ज्ञात कीजिए। **[1½]**

Sol. $E = \frac{P}{n} = \frac{20}{5\times10^9} = 4 \times 10^{-9}$ J.

14. Explain Bohr's second postulate of quantisation by de Broglie hypothesis.
दे ब्रॉग्ली परिकल्पना से बोर के क्वांटीकरण के द्वितीय अभिगृहीत की व्याख्या कीजिए। **[1½]**

Sol.



A standing wave is shown on a circular orbit

According to de - Broglie, a stationary orbit is that which contains an integral number of de - Broglie standing waves associated with the revolving electron. For an electron revolving in nth circular orbit of radius r_n, total distance covered = circumference of the orbit = $2\pi r_n$.

$\therefore$ For the permissible orbit, $2\pi r_n = n\lambda$

According to de - Broglie wavelength, $\lambda = \frac{h}{mv_n}$

where, v_n is speed of electron revolving in nth orbit.

$\therefore \quad 2\pi r_n = \frac{nh}{mv_n}$ or $mv_n r_n = \frac{nh}{2\pi} = n\left(h/2\pi\right)$

i.e. angular momentum of electron revolving in nth orbit must be an integral multiple of $h/2\pi$, which is the quantum condition proposed by Bohr in his second postulate.

15. Define –
(a) Nuclear fission (b) Nuclear fusion
परिभाषित कीजिएः **[1½]**
(a) नाभिकीय विखंडन (b) नाभिकीय संलयन

Sol. (a) Nuclear fission refers to the splitting of an atomic nucleus into two or lighter nuclei.
(b) Nuclear fusion is the process by which two light atomic nuclei combine to form a single heavier one while releasing massive amounts of energy.

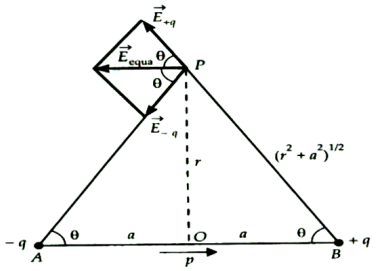
खण्ड–स (SECTION – C)

16. Derive formula for the electric field due to electric dipole at any point on the equatorial plane. Draw necessary diagram.
वैद्युत द्विध्रुव के कारण विषुवतीय तल पर स्थित किसी बिन्दु पर विद्युत क्षेत्र का सूत्र व्युत्पन्न कीजिए। आवश्यक चित्र बनाइए। **[2+1=3]**

OR / अथवा

Obtain an expression for the electric field at any point due to a uniformly charged infinite plane sheet with the help of Gauss's law. Draw necessary diagram. **[2+1=3]**
गाउस नियम द्वारा एकसमान आवेशित अनंत समतल चादर के कारण किस बिन्दु क्षेत्र का व्यंजक प्राप्त कीजिए। आवश्यक चित्र बनाइए।

Sol. Electric field at Equatorial point of a dipole :
As shown in figure. consider an electric dipole consisting of charges –q and +q, separated by distance 2a and placed in vacuum. Let P be a point on the equatorial line of the dipole at distance r from it.
OP = r



Electric field at an equatorial point of a dipole.

Electric field at point P due to + q charge is

$$\vec{E}_{+q} = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{r^2 + a^2}, \text{ directed along BP}$$

Electric field at point P due to –q charge is

$$\vec{E}_{-q} = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{r^2 + a^2}, \text{ directed along PA}$$

Thus the magnitudes of $\vec{E}_{-q}$ and $\vec{E}_{+q}$ are equal i.e.,

$$E_{-q} = E_{+q} = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{r^2 + a^2}$$

Clearly, the components of $\vec{E}_{-q}$ and $\vec{E}_{+q}$ normal to the dipole axis will cancel out. The components parallel to the dipole axis add up. The total electric field $\vec{E}_{equa}$ is opposite to $\vec{p}$.

$$\therefore \quad \vec{E}_{equa} = -\left(E_{-q}\cos\theta + E_{+q}\cos\theta\right)\hat{p} = -2E_{-q}\cos\theta\,\hat{p} \quad [\because E_{-q} = E_{+q}]$$

$$= -2 \times \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2 + a^2} \times \frac{a}{\sqrt{r^2 + a^2}}\hat{p} \quad \left[\because \cos\theta = \frac{a}{\sqrt{r^2 + a^2}}\right]$$

$$\vec{E}_{equa} = -\frac{1}{4\pi\varepsilon_0} \times \frac{p}{\left(r^2 + a^2\right)^{3/2}}\hat{p} = \frac{-kp}{\left(r^2 + a^2\right)^{3/2}}\hat{p}$$

where p = 2qa, is the electric dipole moment. If the point P is located far away from the dipole, r >> a, then

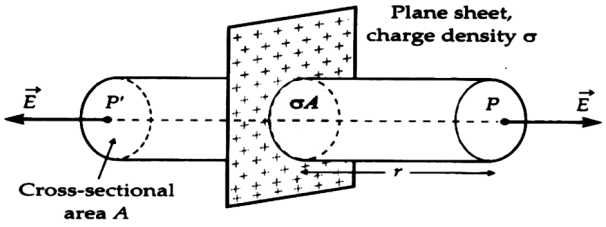
$$\vec{E}_{equa} = -\frac{1}{4\pi\varepsilon_0} \times \frac{p}{r^3}\hat{p} = \frac{-kp}{r^3}\hat{p}$$

Clearly, the direction of electric field at any point on the equatorial line of the dipole will be antiparallel to the dipole moment $\vec{p}$.

OR

Sol. Electric field due to a uniformly charged infinite plane sheet :

Consider a thin, infinite plane sheet of charge with uniform surface charge density σ. We wish to calculate its electric field at a point P at distance r from it.



Gaussian surface for a uniformly charged infinite plane sheet.

By symmetry, electric field E points outwards normal to the sheet. Also, it must have same magnitude and opposite direction at two points P and P′ equidistant from the sheet and on opposite sides. We choose cylindrical Gaussian surface of cross-sectional area A and length 2r with its axis perpendicular to the sheet.

As the lines of force are parallel to the curved surface of the cylinder, the flux through the curved surface is zero. The flux through the plane-end faces of the cylinder is

ϕ_E = EA + EA = 2 EA (A = cross sectional area of plane-end faces)

Charge enclosed by the Gaussian surface,

$q = \sigma A$

According to Gauss's theorem,

$$\phi_E = \frac{q}{\varepsilon_0}$$

$$\therefore \quad 2EA = \frac{\sigma A}{\varepsilon_0} \text{ or } E = \frac{\sigma}{2\varepsilon_0}$$

17. Derive expression of magnetic field at any point on the axis for a current carrying circular loop by Biot-Savart's law. Draw necessary diagram. **[2+1=3]**

बायो सावर्ट नियम से किसी धारावाही पाश के अक्ष पर स्थित किसी बिन्दु पर चुम्बकीय क्षेत्र का व्यंजक व्युत्पन्न कीजिए। आवश्यक चित्र बनाइए।

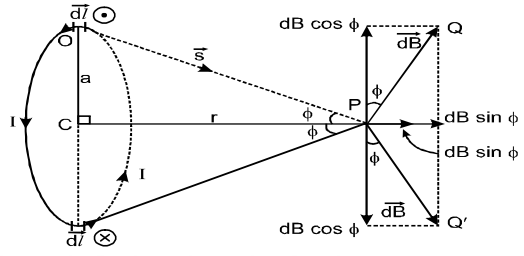
OR / अथवा

Derive formula for the force per unit length acting on the two straight parallel current carrying conductors. Draw necessary diagram. **[2+1=3]**

दो सीधे समांतर धारावाही चालक तारों के मध्य प्रति एकांक लंबाई पर कार्यरत् बल का सूत्र व्युत्पन्न कीजिए। आवश्यक चित्र बनाइए।

Sol. Magnetic field on the axis of a circular current loop:

Consider a circular loop of wire of radius (a) and carrying current (I), as shown in figure. Let the plane of the loop be perpendicular to the plane of paper. We wish to find magnetic field () at an axial point P at a distance (r) from the centre C.



Magnetic field on the axis of a circular current loop

Consider a current element $\vec{dl}$ at top of the loop. It has an outward coming current.

If $\vec{s}$ be the position vector of point P relative to the element $\vec{dl}$, then from Biot-Savart law, the field at point P due to the current element is :

$$dB = \frac{\mu_0}{4\pi} \cdot \frac{I\,dl}{s^2} \sin\theta$$

Since $d\vec{l} \perp \vec{s}$ i.e., $\theta = 90°$, therefore

$$dB = \frac{\mu_0}{4\pi} \cdot \frac{I\,dl}{s^2}$$

The field $d\vec{B}$ lies in the plane of paper and is perpendicular to $\vec{s}$, as shown by $\overrightarrow{PQ}$. Let ϕ be the angle between OP and CP. Then dB can be resolved into two rectangular components.

1. dB sin ϕ along the axis

2. dB cos ϕ perpendicular to the axis.

For any two diametrically opposite elements of the loop, the components perpendicular to the axis of the loop will be equal and opposite and will cancel out. Their axial components will be in the same direction, i.e., along CP and get added up.

$\therefore$ Total magnetic field at the point P in the direction CP is :

$$B = \int dB \sin\phi$$

But $\sin\phi = \frac{a}{s}$ and $dB = \frac{\mu_0}{4\pi} \cdot \frac{I\,dl}{s^2}$

$$\therefore \quad B = \int \frac{\mu_0}{4\pi} \cdot \frac{I\,dl}{s^2} \cdot \frac{a}{s}$$

Since μ_0 and I are constant, and s and a are same for all points on the circular loop, we have

$$B = \frac{\mu_0 Ia}{4\pi s^3} \int dl = \frac{\mu_0 Ia}{4\pi s^3} \cdot 2\pi a = \frac{\mu_0 Ia^2}{2s^3}$$

$$\left[\because \int dl = \text{circumference} = 2\pi a\right]$$

or $$\boxed{B = \frac{\mu_0 Ia^2}{2\left(r^2 + a^2\right)^{3/2}}} \qquad \left[\because s = \left(r^2 + a^2\right)^{1/2}\right]$$

As the direction of the field is along +ve X-direction, so we can write

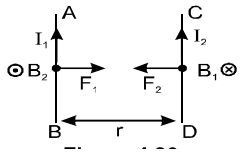
$$\boxed{\vec{B} = \frac{\mu_0 Ia^2}{2\left(r^2 + a^2\right)^{3/2}} \hat{i}}$$

If the coil consists of N turns, then

$$\boxed{B = \frac{\mu_0 NIa^2}{2\left(r^2 + a^2\right)^{3/2}}}$$

OR

Sol. Expression for the force between two parallel current-carrying wires :
Consider two long parallel wires AB and CD carrying currents I_1 and I_2. Let r be the separation between them.



The magnetic field produced by current I_1 at any point on wire CD is

$$B_1 = \frac{\mu_0 I_1}{2\pi r}$$

This field acts perpendicular to the wire CD and point into the plane of paper. It exerts a force on current carrying wire CD will be :

$$F_2 = I_2 B_1 \sin 90° = I_2 l . \frac{\mu_0 I_1}{2\pi r} = \frac{\mu_0 I_1 I_2}{2\pi r} . l$$

Force per unit length,

$$\boxed{f = \frac{F_2}{l} = \frac{\mu_0 I_1 I_2}{2\pi r}}$$

According Fleming's left hand rule, this force acts at right angles to CD, towards AB in the plane of the paper. Similarly, an equal force is exerted on the wire AB by the field of wire CD. Thus when the currents in the two wires are in the same direction, the forces between them are attractive. It can be easily seen that

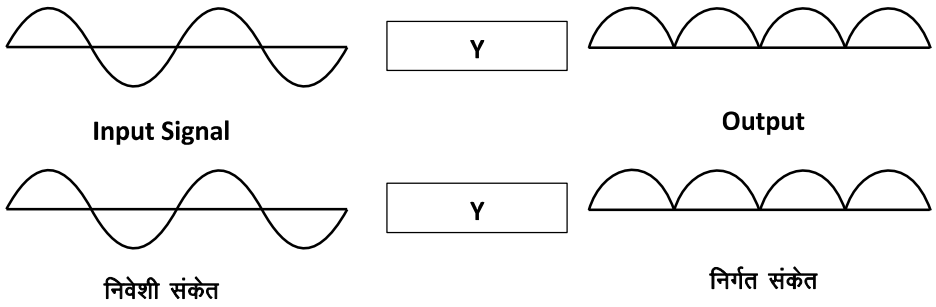
$$\vec{F}_1 = -\vec{F}_2$$

As shown in Figure when the current in the two parallel wires flow in opposite directions (anti-parallel), the forces between the two wires are repulsive.

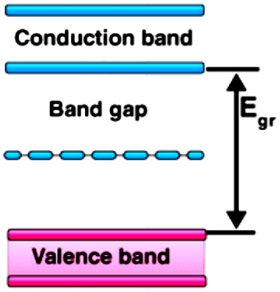
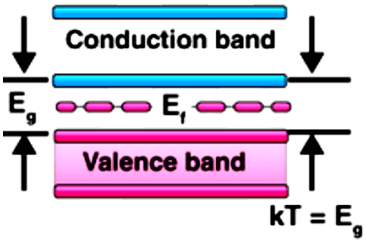
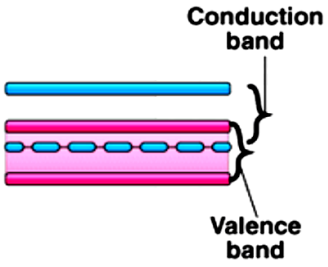
18. (a) On the basis of energy band theory, write the difference between conductor, insulator and semiconductor.
(b) Draw energy band diagram of n-types semiconductor. **[2+1=3]**
(a) ऊर्जा बैण्ड सिद्धान्त के आधार पर चालक, विद्युतरोधी एवं अर्द्धचालक के मध्य अंतर लिखित।
(b) n प्रकार के अर्द्धचालक का ऊर्जा बैंड आरेख बनाइए।

OR / अथवा

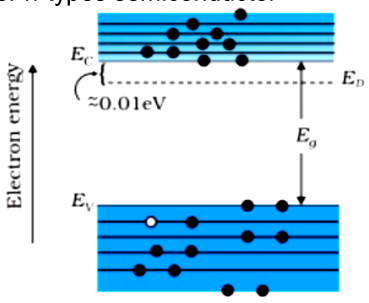
Write the name of device 'Y' in the following given diagram. Explain its working making with circuit diagram. **[1+1+1=3]**
निम्न दिये गए चित्र में युक्ति 'Y' का नाम लिखिए। इसका परिपथ चित्र बनाकर कार्यविधि समझाइए।



Sol. **(a) The points of differences between metals, insulators, and semiconductors are as follows:**

Metal	Insulator	Semiconductor
Metals are the substances that are naturally found below the earth.	Insulators are poor conductor of heat and electricity.	A substance that holds the property of both conductor and insulators are known as semiconductors.
The conduction band in metals is either filled or partially filled while the valence band is partially empty.	The valence band is completely filled while the conduction band is partially filled.	The valence band is completely filled while the conduction band is empty in the case of semiconductors.
There is no forbidden gap in the case of metals.	As a result there is large energy gap.	This results in low gap in energy bands.
		

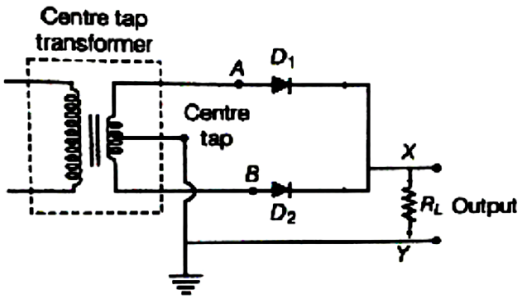
(b) Energy band diagram for n-types semiconductor



OR

Sol. 'Y' is full wave rectifier.

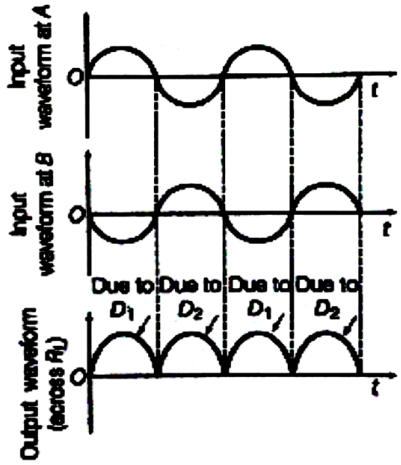
In the full wave rectifier, two p - n junction diodes, D_1 and D_2 are used. This arrangement is shown in the diagram below.



Circuit diagram of full wave rectifier

Working

During the positive half cycle of the input AC, the diode D_1 is forward biased and the diode D_2 is reverse biased. The forward current flows through diode D_1. During the negative half cycle of the input AC, the diode D_1 is reverse biased and diode D_2 is forward biased. Hence, current flows through diode D_2. Hence, we find that during both the halves, current flows in the same direction.



Input and output waveforms

खण्ड–द (SECTION – D)

19. (a) Prove that the peak value (I_m) of an alternating current is $\sqrt{2}$ times of its root mean square (rms) value.

(b) If alternating current $I = 4 \sin \omega t$ and voltage $V = 200\sin\left(\omega t + \frac{\pi}{3}\right)$, then calculate the average power dissipated in the circuit.

(अ) सिद्ध कीजिए की प्रत्यावर्ती धारा का शिखर मान (I_m) उसके वर्ग माध्य मूल (rms) मान का $\sqrt{2}$ गुना होता है।

(ब) यदि प्रत्यावर्ती $I = 4\sin \omega t$ तथा वोल्टता $V = 200\sin\left(\omega t + \frac{\pi}{3}\right)$ हो तो परिपथ में क्षयित औसत शक्ति की गणना कीजिए। **[2+2=4]**

अथवा / OR

(a) Prove that the average power supplied to an inductor over one complete cycle is zero.

(b) If in LCR alternating current circuit $R = 24\Omega$, $X_L = 11\Omega$ and $X_c = 110\Omega$ then find the impedance of the circuit.

(अ) सिद्ध कीजिए कि एक पूरे चक्र में प्रेरक को आपूर्त माध्य शक्ति शून्य होती है।

(ब) यदि किसी LCR प्रत्यावर्ती धरा परिपथ में $R = 24\Omega$, $X_L = 110\Omega$ तथा $X_c = 110\Omega$ हो तो परिपथ की प्रतिबाधा ज्ञात कीजिए **[2+2=4]**

Sol. (a) $I_{eff} = I_{rms} = \sqrt{\frac{I}{T}\int_0^T I^2\, dt}$

Now $\int_0^T I^2\, dt = \int_0^T I_0^2 \sin^2 \omega\, dt$

$$= \frac{I_0^2}{2}\left[t - \frac{\sin 2\omega\, dt}{2\omega}\right]_0^T$$

$$= \frac{I_0^2}{2}\left[(T-0) - \frac{1}{2\omega}\left|\sin\frac{4\omega}{T}t\right|\right]_0^T$$

$$= \frac{I_0^2}{2}\left[T - \frac{1}{2\omega}(\sin 4\omega - \sin 0)\right]$$

$$= \frac{I_0^2}{2}[T-0] = \frac{I_0^2 T}{2}$$

$\therefore$ I_{eff} or $I_{rms} = \sqrt{\frac{1}{T}\cdot\frac{I_0^2 T}{2}}$

or I_{eff} or $I_{rms} = \frac{1}{\sqrt{2}} I_0 = 0.707\, I_0$

Thus the effective or rms value of an a.c. is $\frac{1}{\sqrt{2}}$ times its peak value.

(b) $P = V_{rms}\, I_{rms} \cos\phi$

$= \frac{4}{\sqrt{2}} \times \frac{200}{\sqrt{2}} \cos\frac{\pi}{3}$ = 200 W.

OR

Sol. (a) Instantaneous power in the inductive circuit is given by, P = VI

$P = (V_0 \sin\omega t)(-I_0 \cos\omega t)$

$= -\frac{V_0 I_0}{2}(2\sin\omega t \cos\omega t)$

$= -\frac{V_0 I_0}{2}\sin 2\omega t$

The average power for one time period is

$P_{av} = -\frac{V_0 I_0}{2} \langle \sin 2\omega t \rangle$

$P_{av} = 0$

(b) $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$Z = \sqrt{(24)^2 + (110 - 110)^2}$

$Z = \sqrt{24 \times 24}$ = 24 Ω

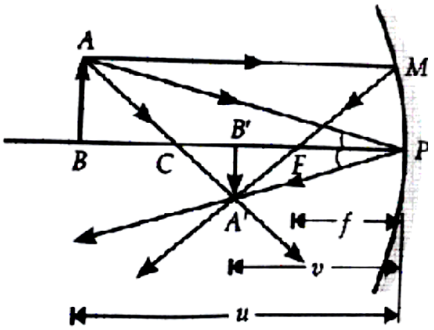
20. Define total internal reflection. Establish relation between u, v and f for a spherical mirror. Draw necessary ray diagram.
पूर्ण आंतरिक परावर्तन को परिभाषित कीजिए। किसी गोलीय दर्पण के लिए u, v तथा f में संबंध स्थापित कीजिए। आवश्यक किरण चित्र बनाइए। **[1+2+1=4]**

अथवा / OR

Define lateral shift. Derive the lens maker's formula $\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$. Draw necessary ray diagram. (where symbols carry usual meaning).

पार्श्विक विस्थापन को परिभाषित कीजिए। लेंस मेकर सूत्र $\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ व्यूत्पत्र कीजिए। आवश्यक किरण चित्र बनाइए (जहाँ संकेतों के सामान्य अर्थ हैं) **[1+2+1=4]**

Sol. When the angle of the incident in the dense medium exceeds the critical angle, then get reflected back in the denser medium and this phenomenon is called total internal reflection.
Derivation of mirror formula for a concave mirror when it forms a real image. Consider an object AB placed on the principal axis beyond the centre of curvature C of a concave mirror of small aperture, as



Object distance, BP = – u
image distance, $B'P = -v$
Focal length, $FP = -f$
Radius of curvature, $CP = -R = -2f$
Now $\Delta A'B'C \sim \Delta ABC$

$$\therefore \frac{A'B'}{AB} = \frac{CB'}{BC} = \frac{CP - B'P}{BP - CP} = \frac{-R + v}{-u + R} \quad \text{.....(1)}$$

As $\angle A'PB' = \angle ABP$, therefore,
$\Delta A'B'P \sim \Delta ABP$
Consequently,

$$\frac{A'B'}{AB} = \frac{B'P}{BP} = \frac{-v}{-u} = \frac{v}{u} \quad \text{.....(2)}$$

From equation (i) and (2), we get

$$\frac{-R + u}{-u + R} = \frac{v}{u}$$

or – uR + uv = uv + vR or vR + uR = 2uv
Dividing both sides by uvR, we get

$$\frac{1}{u} + \frac{1}{v} = \frac{2}{R}$$

But R = 2f $\quad \therefore \frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

OR

Sol. The perpendicular distance between the incident ray and the emergent ray is defined as lateral shift.

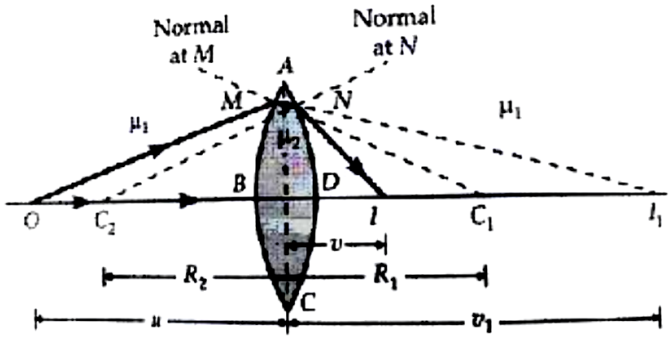
Assumptions made in the derivation of lens maker's formula :

(i) The lens used is thin so that the distances measured from its optical centre.

(ii) The object is a point object placed on the principal axis.

(iii) The aperture of the lens is small.

(iv) All the rays are paraxial, i.e., they make very small angles with the normal to the lens faces and with the principal axis.



Refraction through a double convex lens.

Suppose a point object O is placed on the principal axis in the rarer medium of refractive index μ_1. The ray OM is incident on the first surface ABC. It is refracted along MN, bending towards the normal at this surface. If the second surface ADC were absent, the ray MN would have met the principal axis at I_1. So we can treat I_1 as the real image formed by first surface ABC in the medium of refractive index μ_2

For refraction at surface ABC, we can write the relation between the object distance u, image distance v_1 and radius of curvature R_1 as

$$\frac{\mu_2}{v_1} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R_1} \qquad \text{.....(1)}$$

For refraction at second surface, I_1 acts as a virtual object placed in the medium of refractive index and I is the real image formed in the medium of refractive index. Therefore, the relation between the object distance v_1, image distance v and radius of curvature R_2 can be written as

$$\left\{\frac{\mu}{v} - \frac{\mu_2}{v_1} = \frac{\mu_1 - \mu_2}{R_2}\right\} \qquad \text{.....(2)}$$

Adding equation (1) and (2), we get

$$\frac{1}{v} - \frac{1}{u} = \left[\frac{\mu_2 - \mu_1}{\mu_1}\right]\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \qquad \text{.....(3)}$$

If the object is placed at infinity ($u = \infty$), the image will be formed at the focus, i.e. v = f. Therefore,

$$\frac{1}{f} = (\mu_{21} - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$