16 × 1 = 16

क्षेत्र $\vec{E}$ में रखा है । इस द्विध्रुव को
। कराने में किया गया कार्य है 1

अक्ष के अनुदिश रखा है ।
1

$\frac{q\lambda}{\varepsilon_0 x}$

र चुम्बकीय क्षेत्र $\vec{B}$
1

। होती हैं 1

ों में

रा

SECTION – A

16 × 1 = 16

1. An electric dipole of dipole moment $\vec{p}$ is kept in a uniform electric field $\vec{E}$. The amount of work done to rotate it from the position of stable equilibrium to that of unstable equilibrium will be 1

(A) 2 pE (B) −2 pE

(C) pE (D) zero

2. An infinite long straight wire having a charge density λ is kept along y'y axis in x-y plane. The Coulomb force on a point charge q at a point P (x, 0) will be 1

(A) attractive and $\frac{q\lambda}{2\pi\varepsilon_0 x}$ (B) repulsive and $\frac{q\lambda}{2\pi\varepsilon_0 x}$

(C) attractive and $\frac{q\lambda}{\pi\varepsilon_0 x}$ (D) repulsive and $\frac{q\lambda}{\pi\varepsilon_0 x}$

3. The phase difference between electric field $\vec{E}$ and magnetic field $\vec{B}$ in an electromagnetic wave propagating along z-axis is – 1

(A) zero (B) π

(C) $\frac{\pi}{2}$ (D) $\frac{\pi}{4}$

4. In Balmer series of hydrogen atom, as the wavelength of spectral lines decreases, they appear 1

(A) equally spaced and equally intense.

(B) further apart and stronger in intensity.

(C) closer together and stronger in intensity.

(D) closer together and weaker in intensity.

5. Two long straight parallel conductors A and B, kept at a distance r, carry current I in opposite directions. A third identical conductor C, kept at a distance $\left(\frac{r}{3}\right)$ from A carry current I_1 in the same direction as in A. The net magnetic force on unit length of C is 1

(A) $\frac{3\mu_0 I I_1}{2\pi r}$, towards A (B) $\frac{3\mu_0 I I_1}{2\pi r}$, towards B

(C) $\frac{3\mu_0 I I_1}{4\pi r}$, towards A (D) $\frac{3\mu_0 I I_1}{4\pi r}$, towards B

Series RQSP4/4

Set-3

प्रश्न-पत्र कोड
Q.P. Code **55/4/3**

रोल नं.
Roll No. 1 8 6 1 4 6 4 4

परीक्षार्थी प्रश्न-पत्र कोड को उत्तर-पुस्तिका के मुख-पृष्ठ पर अवश्य लिखें ।
Candidates must write the Q.P. Code on the title page of the answer-book.

भौतिक विज्ञान (सैद्धान्तिक)
PHYSICS (Theory)

निर्धारित समय : 3 घण्टे *अधिकतम अंक : 70*

Time allowed : 3 hours *Maximum Marks : 70*

नोट	NOTE
(I) कृपया जाँच कर लें कि इस प्रश्न-पत्र में मुद्रित पृष्ठ **23** हैं ।	(I) Please check that this question paper contains **23** printed pages.
(II) कृपया जाँच कर लें कि इस प्रश्न-पत्र में **33** प्रश्न हैं ।	(II) Please check that this question paper contains **33** questions.
(III) प्रश्न-पत्र में दाहिने हाथ की ओर दिए गए प्रश्न-पत्र कोड को परीक्षार्थी उत्तर-पुस्तिका के मुख-पृष्ठ पर लिखें ।	(III) Q.P. Code given on the right hand side of the question paper should be written on the title page of the answer-book by the candidate.
(IV) **कृपया प्रश्न का उत्तर लिखना शुरू करने से पहले, उत्तर-पुस्तिका में प्रश्न का क्रमांक अवश्य लिखें ।**	(IV) **Please write down the serial number of the question in the answer-book before attempting it.**
(V) इस प्रश्न-पत्र को पढ़ने के लिए 15 मिनट का समय दिया गया है । प्रश्न-पत्र का वितरण पूर्वाह्न में 10.15 बजे किया जाएगा । 10.15 बजे से 10.30 बजे तक परीक्षार्थी केवल प्रश्न-पत्र को पढ़ेंगे और इस अवधि के दौरान वे उत्तर-पुस्तिका पर कोई उत्तर नहीं लिखेंगे ।	(V) 15 minute time has been allotted to read this question paper. The question paper will be distributed at 10.15 a.m. From 10.15 a.m. to 10.30 a.m., the candidates will read the question paper only and will not write any answer on the answer-book during this period.

SECTION – A

$16 \times 1 = 16$

1. An electric dipole of dipole moment $\vec{p}$ is kept in a uniform electric field $\vec{E}$. The amount of work done to rotate it from the position of stable equilibrium to that of unstable equilibrium will be 1

(A) 2 pE
(B) -2 pE
(C) pE
(D) zero

2. An infinite long straight wire having a charge density λ is kept along y'y axis in x-y plane. The Coulomb force on a point charge q at a point P $(x, 0)$ will be 1

(A) attractive and $\frac{q\lambda}{2\pi\varepsilon_0 x}$
(B) repulsive and $\frac{q\lambda}{2\pi\varepsilon_0 x}$
(C) attractive and $\frac{q\lambda}{\pi\varepsilon_0 x}$
(D) repulsive and $\frac{q\lambda}{\pi\varepsilon_0 x}$

3. The phase difference between electric field $\vec{E}$ and magnetic field $\vec{B}$ in an electromagnetic wave propagating along z-axis is – 1

(A) zero
(B) π
(C) $\frac{\pi}{2}$
(D) $\frac{\pi}{4}$

4. In Balmer series of hydrogen atom, as the wavelength of spectral lines decreases, they appear 1

(A) equally spaced and equally intense.
(B) further apart and stronger in intensity.
(C) closer together and stronger in intensity.
(D) closer together and weaker in intensity.

5. Two long straight parallel conductors A and B, kept at a distance r, carry current I in opposite directions. A third identical conductor C, kept at a distance $\left(\frac{r}{3}\right)$ from A carry current I_1 in the same direction as in A. The net magnetic force on unit length of C is 1

(A) $\frac{3\mu_0 I I_1}{2\pi r}$, towards A
(B) $\frac{3\mu_0 I I_1}{2\pi r}$, towards B
(C) $\frac{3\mu_0 I I_1}{4\pi r}$, towards A
(D) $\frac{3\mu_0 I I_1}{4\pi r}$, towards B

6. A coil of N turns is placed in a magnetic field $\vec{B}$ such that $\vec{B}$ is perpendicular to the plane of the coil. $\vec{B}$ changes with time as $B = B_0 \cos\left(\frac{2\pi}{T}t\right)$ where T is time period. The magnitude of emf induced in the coil will be maximum at 1

(A) $t = \frac{nT}{8}$ (B) $t = \frac{nT}{4}$

(C) $t = \frac{nT}{2}$ (D) $t = nT$

Here, n = 1, 2, 3, 4, ...

7. A circular loop A of radius R carries a current I. Another circular loop B of radius $r\left(=\frac{R}{20}\right)$ is placed concentrically in the plane of A. The magnetic flux linked with loop B is proportional to 1

(A) R (B) $\sqrt{R}$

(C) $R^{\frac{3}{2}}$ (D) R^2

8. A galvanometer of resistance 100 Ω is converted into an ammeter of range (0 – 1 A) using a resistance of 0.1 Ω. The ammeter will show full scale deflection for a current of about 1

(A) 0.1 mA (B) 1 mA

(C) 10 mA (D) 0.1 A

9. The r.m.s. value of a current given by $i = (i_1 \cos \omega t + i_2 \sin \omega t)$ is –

(A) $\frac{1}{\sqrt{2}}(i_1 + i_2)$ (B) $\frac{1}{\sqrt{2}}(i_1 - i_2)$

(C) $\frac{1}{\sqrt{2}}\sqrt{(i_1^2 + i_2^2)}$ (D) $\frac{1}{\sqrt{2}}(i_1^2 + i_2^2)$

10. The quantum nature of light explains the observations on photoelectric effect as – 1

(A) there is a minimum frequency of incident radiation below which no electrons are emitted.

(B) the maximum kinetic energy of photoelectrons depends only on the frequency of incident radiation.

(C) when the metal surface is illuminated, electrons are ejected from the surface after sometime.

(D) the photoelectric current is independent of the intensity of incident radiation.

11. The magnetic susceptibility for a diamagnetic material is 1

(A) small and negative (B) small and positive

(C) large and negative (D) large and positive

12. The radius (r_n) of n^{th} orbit in Bohr model of hydrogen atom varies with n as 1

(A) $r_n \propto n$ (B) $r_n \propto \frac{1}{n}$

(C) $r_n \propto n^2$ (D) $r_n \propto \frac{1}{n^2}$

Note : For questions number **13** to **16**, two statements are given – one labelled **Assertion (A)** and the other labelled **Reason (R)**. Select the correct answer to these questions from the codes **(A)**, **(B)**, **(C)** and **(D)** as given below :

(A) If both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).

(B) If both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of Assertion (A).

(C) If Assertion (A) is true and Reason (R) is false.

(D) If both Assertion (A) and Reason (R) are false.

13. **Assertion (A) :** When electrons drift in a conductor, it does not mean that all free electrons in the conductor are moving in the same direction.

Reason (R) : The drift velocity is superposed over large random velocities of electrons. 1

14. **Assertion (A) :** In interference and diffraction of light, light energy reduces in one region producing a dark fringe. It increases in another region and produces a bright fringe.

Reason (R) : This happens because energy is not conserved in the phenomena of interference and diffraction. 1

15. **Assertion (A) :** The temperature coefficient of resistance is positive for metals and negative for p-type semiconductors.

Reason (R) : The charge carriers in metals are negatively charged, whereas the majority charge carriers in p-type semiconductors are positively charged. 1

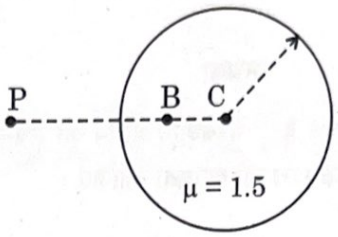
16. **Assertion (A) :** Electrons are ejected from the surface of zinc when it is irradiated by yellow light.

Reason (R) : Energy associated with a photon of yellow light is more than the work function of zinc. 1

SECTION – B

$5 \times 2 = 10$

17. (a) An air bubble is trapped at point B (CB = 20 cm) in a glass sphere of radius 40 cm and refractive index 1.5 as shown in figure. Find the nature and position of the image of the bubble as seen by an observer at point P. **2**



OR

(b) In normal adjustment, for a refracting telescope, the distance between objective and eye piece lens is 1.00 m. If the magnifying power of the telescope is 19, find the focal length of the objective and the eyepiece lens. **2**

18. The ratio of de Broglie wavelengths of a proton and a deuteron accelerated by potential V_p and V_d respectively, $\left(\frac{\lambda_p}{\lambda_d}\right)$ is $\frac{1}{2}$. Find $\frac{V_p}{V_d}$. **2**

19. A ray of light is incident normally on one face of an equilateral glass prism of refractive index μ. When the prism is completely immersed in a transparent medium, it is observed that the emergent ray just grazes the adjacent face. Find the refractive index of the medium. **2**

20. Find the temperature at which the resistance of a conductor increases by 25% of its value at 27 °C. The temperature coefficient of resistance of the conductor is $2.0 \times 10^{-4}\ °C^{-1}$. **2**

21. Draw the circuit diagram of a p-n junction diode in (i) forward biasing and (ii) reverse biasing. Also draw its I-V characteristics in the two cases. **2**

SECTION – C

$7 \times 3 = 21$

22. (a) (i) Define mutual inductance. Write its SI unit. 3

(ii) Derive an expression for the mutual inductance of a system of two long coaxial solenoids of same length l, having turns N_1 and N_2 and of radii r_1 and r_2 ($> r_1$).

OR

(b) What are ferromagnetic materials ? Explain ferromagnetism with the help of suitable diagrams, using the concept of magnetic domain. 3

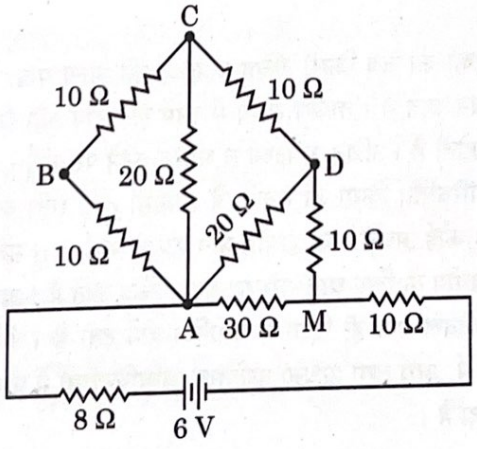
23. Two conducting spherical shells A and B of radii R and 2R are kept far apart and charged to the same charge density σ. They are connected by a wire. Obtain an expression for final potential of shell A. 3

24. Draw the graph showing variation of scattered particles detected (N) with the scattering angle (θ) in Geiger-Marsden experiment. Write two conclusions that you can draw from this graph. Obtain the expression for the distance of closest approach in this experiment. 3

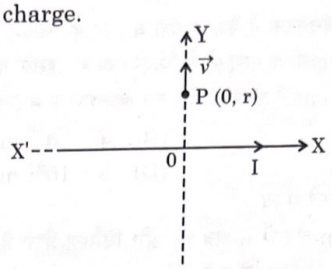
25. In the given network, calculate :

(i) effective resistance between points A and M, and

(ii) power supplied by the battery. 3



26. An infinite straight conductor is kept along X′X axis and carries a current I. A charge q at point P(0, r) starts moving with velocity $\vec{v} = v_0 \hat{j}$ as shown in figure. Find the direction and magnitude of force initially experienced by the charge. 3



27. Explain the following giving reasons :
    (i) 'Electromagnetic waves differ considerably in their mode of interaction with matter'.
    (ii) 'Food items to be heated in microwave oven must contain water'.
    (iii) 'Welders wear face mask with glasses during welding'. 3

28. (a) Differentiate between nuclear fission and fusion. 3
    (b) The fission properties of $_{94}Pu^{239}$ are very similar to those of $_{92}U^{235}$. How much energy (in MeV), is released if all the atoms in 1 g of pure $_{94}Pu^{239}$ undergo fission ? The average energy released per fission is 180 MeV.

SECTION – D

$2 \times 4 = 8$

Note : Questions number **29** to **30** are Case Study based questions. Read the following paragraph and answer the questions that follow.

29. A pure semiconductor like Ge or Si, when doped with a small amount of suitable impurity, becomes an extrinsic semiconductor. In thermal equilibrium, the electron and hole concentration in it are related to the concentration of intrinsic charge carriers. A p-type or n-type semiconductor can be converted into a p-n junction by doping it with suitable impurity. Two processes, diffusion and drift take place during formation of a p-n junction. A semiconductor diode is basically a p-n junction with metallic contacts provided at the ends for the application of an external voltage. A p-n junction diode allows currents to pass only in one direction when it is forward biased. Due to this property, a diode is widely used to rectify alternating voltages, in half-wave or full wave configuration.

$4 \times 1 = 4$

(i) When Ge is doped with pentavalent impurity, the energy required to free the weakly bound electron from the dopant is about

(A) 0.001 eV (B) 0.01 eV

(C) 0.72 eV (D) 1.1 eV

(ii) At a given temperature, the number of intrinsic charge carriers in a semiconductor is 2.0×10^{10} cm^{-3}. It is doped with pentavalent impurity atoms. As a result, the number of holes in it becomes 8×10^{3} cm^{-3}. The number of electrons in the semiconductor is

(A) 2×10^{24} m^{-3} (B) 4×10^{23} m^{-3}

(C) 1×10^{22} m^{-3} (D) 5×10^{22} m^{-3}

(iii) (a) During the formation of a p-n junction –

(A) electrons diffuse from p-region into n-region and holes diffuse from n-region into p-region.

(B) both electrons and holes diffuse from n-region into p-region.

(C) electrons diffuse from n-region into p-region and holes diffuse from p-region into n-region.

(D) both electrons and holes diffuse from p-region into n-region.

OR

(iii) (b) Initially during the formation of a p-n junction –

(A) diffusion current is large and drift current is small.

(B) diffusion current is small and drift current is large.

(C) both the diffusion and the drift currents are large.

(D) both the diffusion and the drift currents are small.

(iv) An ac voltage V = 0.5 sin (100 πt) volt is applied, in turn, across a half-wave rectifier and a full-wave rectifier. The frequency of the output voltage across them respectively will be

(A) 25 Hz, 50 Hz (B) 25 Hz, 100 Hz

(C) 50 Hz, 50 Hz (D) 50 Hz, 100 Hz

30. A lens is a transparent optical medium bounded by two surfaces; at least one of which should be spherical. Applying the formula of image formation by a single spherical surface successively at the two surfaces of a thin lens, a formula known as lens maker's formula and hence the basic lens formula can be obtained. The focal length (or power) of a lens depends on the radii of its surfaces and the refractive index of its material with respect to the surrounding medium. The refractive index of a material depends on the wavelength of light used. Combination of lenses helps us to obtain diverging or converging lenses of desired power and magnification. $4 \times 1 = 4$

(i) A thin converging lens of focal length 20 cm and a thin diverging lens of focal length 15 cm are placed coaxially in contact. The power of the combination is

(A) $\frac{-5}{6}$D (B) $\frac{-5}{3}$D

(C) $\frac{4}{3}$ D (D) $\frac{3}{2}$ D

(ii) The radii of curvature of two surfaces of a convex lens are R and 2R. If the focal length of this lens is $\left(\frac{4}{3}\right)$R, the refractive index of the material of the lens is :

(A) $\frac{5}{3}$ (B) $\frac{4}{3}$

(C) $\frac{3}{2}$ (D) $\frac{7}{5}$

(iii) The focal length of an equiconvex lens

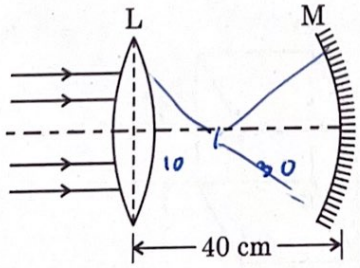
(A) increases when the lens is dipped in water.

(B) increases when the wavelength of incident light decreases.

(C) increases with decrease in radius of curvature of its surface.

(D) decreases when the lens is cut into two identical parts along its principal axis.

(iv) (a) A thin convex lens L of focal length 10 cm and a concave mirror M of focal length 15 cm are placed coaxially 40 cm apart as shown in figure. A beam of light coming parallel to the principal axis is incident on the lens. The final image will be formed at a distance of



(A) 10 cm, left of lens (B) 10 cm, right of lens

(C) 20 cm, left of lens (D) 20 cm, right of lens

OR

(iv) (b) A beam of light coming parallel to the principal axis of a convex lens L_1 of focal length 16 cm is incident on it. Another convex lens L_2 of focal length 12 cm is placed coaxially at a distance 40 cm from L_1. The nature and distance of the final image from L_2 will be

(A) real, 24 cm (B) virtual, 12 cm

(C) real, 32 cm (D) virtual, 18 cm

SECTION – E

$3 \times 5 = 15$

31. (a) (i) A dielectric slab of dielectric constant 'K' and thickness 't' is inserted between plates of a parallel plate capacitor of plate separation d and plate area A. Obtain an expression for its capacitance.

(ii) Two capacitors of different capacitances are connected first (1) in series and then (2) in parallel across a dc source of 100 V. If the total energy stored in the combination in the two cases are 40 mJ and 250 mJ respectively, find the capacitance of the capacitors. 5

OR

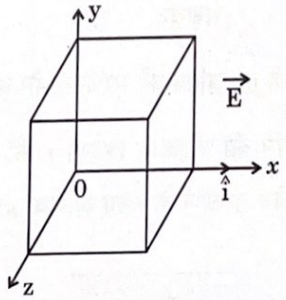
(b) (i) Using Gauss's law, show that the electric field $\vec{E}$ at a point due to a uniformly charged infinite plane sheet is given by $\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$ where symbols have their usual meanings.

(ii) Electric field $\vec{E}$ in a region is given by

$\vec{E} = (5x^2 + 2)\hat{i}$

where E is in N/C and x is in meters.

A cube of side 10 cm is placed in the region as shown in figure.



Calculate (1) the electric flux through the cube, and (2) the net charge enclosed by the cube. 5

32. (a) (i) Draw a ray diagram for the formation of the image of an object by a convex mirror. Hence, obtain the mirror equation.

(ii) Why are multi-component lenses used for both the objective and the eyepiece in optical instruments ?

(iii) The magnification of a small object produced by a compound microscope is 200. The focal length of the eyepiece is 2 cm and the final image is formed at infinity. Find the magnification produced by the objective. **5**

OR

(b) (i) Differentiate between a wavefront and a ray.

(ii) State Huygen's principle and verify laws of reflection using suitable diagram.

(iii) In Young's double slit experiment, the slits S_1 and S_2 are 3 mm apart and the screen is placed 1.0 m away from the slits. It is observed that the fourth bright fringe is at a distance of 5 mm from the second dark fringe. Find the wavelength of light used. **5**

33. (a) (i) Mention the factors on which the resonant frequency of a series LCR circuit depends. Plot a graph showing variation of impedance of a series LCR circuit with the frequency of the applied a.c. source.

(ii) With the help of a suitable diagram, explain the working of a step-up transformer.

(iii) Write two causes of energy loss in a real transformer. **5**

OR

(b) (i) With the help of a diagram, briefly explain the construction and working of ac generator.

(ii) An electron is revolving around a proton in an orbit of radius r with a speed v. Obtain expression for magnetic moment associated with the electron. **5**
