Series : R5QPS

SET~1

प्रश्न-पत्र कोड
Q.P. Code **55/5/1**

रोल नं.
Roll No.

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

(I) कृपया जाँच कर लें कि इस प्रश्न-पत्र में मुद्रित पृष्ठ 31 हैं।

(II) प्रश्न-पत्र में दाहिने हाथ की ओर दिए गए प्रश्न-पत्र कोड को परीक्षार्थी उत्तर-पुस्तिका के मुख-पृष्ठ पर लिखें।

(III) कृपया जाँच कर लें कि इस प्रश्न-पत्र में 33 प्रश्न हैं।

(IV) **कृपया प्रश्न का उत्तर लिखना शुरू करने से पहले, उत्तर-पुस्तिका में यथा स्थान पर प्रश्न का क्रमांक अवश्य लिखें।**

(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।

NOTE

(I) *Please check that this question paper contains 31 printed pages.*

(II) *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.*

(III) *Please check that this question paper contains 33 questions.*

(IV) *Please write down the Serial Number of the question in the answer-book at the given place before attempting it.*

(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

1. Two small identical metallic balls having charges q and – 2q are kept far at a separation r. They are brought in contact and then separated at distance $\frac{r}{2}$. Compared to the initial force F, they will now :

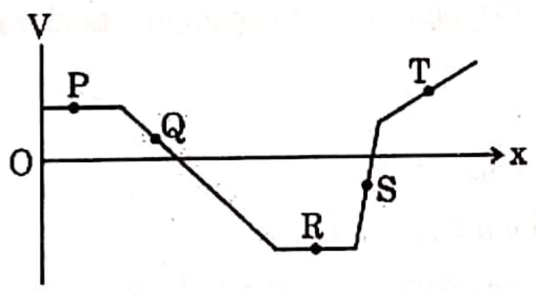
   (A) attract with a force $\frac{F}{2}$

   (B) repel with a force $\frac{F}{2}$

   (C) repel with a force F

   (D) attract with a force F

2. The figure represents the variation of the electric potential V at a point in a region of space as a function of its position along the x-axis. A charged particle will experience the maximum force at :



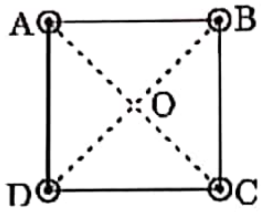
   (A) P

   (B) Q

   (C) R

   (D) S

3. Four long straight thin wires are held vertically at the corners A, B, C and D of a square of side 'a', kept on a table and carry equal current 'I'. The wire at A carries current in upward direction whereas the current in the remaining wires flows in downward direction. The net magnetic field at the centre of the square will have the magnitude :



(A) $\frac{\mu_0 I}{\pi a}$ and directed along OC

(B) $\frac{\mu_0 I}{\pi a \sqrt{2}}$ and directed along OD

(C) $\frac{\mu_0 I \sqrt{2}}{\pi a}$ and directed along OB

(D) $\frac{2 \mu_0 I}{\pi a}$ and directed along OA

4. The magnetic flux through a loop placed in a magnetic field can be changed by changing :

(A) area of the loop only

(B) the value of magnetic field only

(C) orientation of the loop in the magnetic field only

(D) any one or more of the factors given in (A), (B) and (C)

5. Which of the following statements is ***not*** true for electric energy in ac form compared to that in dc form ?

(A) Production of ac is economical.

(B) ac can be easily and efficiently converted from one voltage to the other.

(C) ac can be transmitted economically over long distances.

(D) ac is less dangerous.

6. The magnetic field in a plane electromagnetic wave travelling in glass (n = 1·5) is given by

$$B_y = (2 \times 10^{-7}\ T) \sin(\alpha x + 1{\cdot}5 \times 10^{11}\ t)$$

where x is in metres and t is in seconds. The value of α is :

(A) $0{\cdot}5 \times 10^3\ m^{-1}$

(B) $6{\cdot}0 \times 10^2\ m^{-1}$

(C) $7{\cdot}5 \times 10^2\ m^{-1}$

(D) $1{\cdot}5 \times 10^3\ m^{-1}$

7. Light of which of the following colours will have the maximum energy in a photon associated with it ?

(A) Red light (B) Yellow light

(C) Green light (D) Blue light

8. Nuclides with the same number of neutrons are called :

(A) Isobars (B) Isotones

(C) Isotopes (D) Isomers

9. The radius of a nucleus of mass number 125 is

(A) 6·0 fm

(B) 30 fm

(C) 72 fm

(D) 150 fm

10. The energy of an electron in an orbit in hydrogen atom is – 3·4 eV. Its angular momentum in the orbit will be :

(A) $\frac{3h}{2\pi}$ (B) $\frac{2h}{\pi}$

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

11. A good diode checked by a multimeter should indicate :

(A) high resistance in reverse bias and a low resistance in forward bias

(B) high resistance in both forward bias and reverse bias

(C) low resistance in both reverse bias and forward bias

(D) high resistance in forward bias and low resistance in reverse bias

12. The rms and the average value of an ac voltage $V = V_0 \sin \omega t$ volt over a cycle respectively will be :

(A) $\frac{V_0}{2}, \frac{V_0}{\sqrt{2}}$

(B) $\frac{V_0}{\pi}, \frac{V_0}{2}$

(C) $\frac{V_0}{\sqrt{2}}, 0$

(D) $V_0, \frac{V_0}{\sqrt{2}}$

Questions number ***13*** *to* ***16*** *are Assertion (A) and Reason (R) type questions. Two statements are given — one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer from the codes (A), (B), (C) and (D) as given below.*

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

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is ***not*** the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Both Assertion (A) and Reason (R) are false.

13. *Assertion (A) :* Induced emf produced in a coil will be more when the magnetic flux linked with the coil is more.

Reason (R) : Induced emf produced is directly proportional to the magnetic flux.

14. *Assertion (A) :* In Young's double-slit experiment, the fringe width for dark and bright fringes is the same.

Reason (R) : Fringe width is given by $\beta = \frac{\lambda D}{d}$, where symbols have their usual meanings.

15. *Assertion (A) :* Energy is released when heavy nuclei undergo fission or light nuclei undergo fusion.

Reason (R) : For heavy nuclei, binding energy per nucleon increases with increasing Z while for light nuclei, it decreases with increasing Z.

16. *Assertion (A) :* Photoelectric effect is a spontaneous phenomenon.

Reason (R) : According to the wave picture of radiation, an electron would take hours/days to absorb sufficient energy to overcome the work function and come out from a metal surface.

SECTION B

17. (a) An electric iron rated 2·2 kW, 220 V is operated at 110 V supply. Find : 2

(i) its resistance, and

(ii) heat produced by it in 10 minutes.

OR

(b) A current of 4·0 A flows through a wire of length 1 m and cross-sectional area 1·0 mm^2, when potential difference of 2 V is applied across its ends.

Calculate the resistivity of the material of the wire. 2

18. A plane circular coil is rotated about its vertical diameter with a constant angular speed ω in a uniform horizontal magnetic field. Initially the plane of the coil is parallel to the magnetic field. Draw plots showing the variation of the following physical quantities as the function of ωt, where t represents time elapsed :

(a) Magnetic flux ϕ linked with the coil, and 2

(b) emf induced in the coil.

19. A tank is filled with a liquid to a height of 12·5 m. The apparent depth of a needle lying at the bottom of the tank is measured to be 9·0 m. Calculate the speed of light in the liquid. 2

20. Two thin lenses of focal length f_1 and f_2 are placed in contact with each other coaxially. Prove that the focal length f of the combination is given by $f = \dfrac{f_1 f_2}{f_1 + f_2}$. 2

21. Suppose a pure Si crystal has 5×10^{28} atoms per m^3. It is doped with 5×10^{22} atoms per m^3 of Arsenic. Calculate the majority and minority carrier concentration in the doped silicon. (Given : $n_i = 1{\cdot}5 \times 10^{16}\ m^{-3}$) 2

SECTION C

22. Two parallel plate capacitors X and Y are connected in series to a 6 V battery. They have the same plate area and same plate separation but capacitor X has air between its plates, whereas capacitor Y contains a material of dielectric constant 4.

(a) Calculate the capacitances of X and Y, if the equivalent capacitance of the combination of X and Y is 4 μF.

(b) Calculate the potential difference across the plates of X and Y. 3

23. Write the expression for the magnetic field due to a current element in vector form. Consider a 1 cm segment of a wire, centered at the origin, carrying a current of 10 A in positive x-direction. Calculate the magnetic field $\vec{B}$ at a point (1 m, 1 m, 0). 3

24. A long solenoid of length L and radius r_1 having N_1 turns is surrounded symmetrically by a coil of radius r_2 ($> r_1$) having N_2 turns ($N_2 << N_1$) around its mid-point. Derive an expression for the mutual inductance of solenoid and coil. Is $M_{12} = M_{21}$ valid in this case ? *3*

25. What is displacement current (i_d) ? Considering the case of charging of a capacitor, show that $i_d = \varepsilon_0 \frac{d\phi_E}{dt}$. What is the value of i_d for a conductor across which a constant voltage is applied ? *3*

26. (a) (i) Write any two features of nuclear forces.

(ii) If both the number of protons and the neutrons are conserved in each nuclear reaction, in what way is mass converted into energy (or vice versa) in a nuclear reaction ? Explain. *3*

OR

(b) (i) Draw the number of scattered particles versus the scattering angle graph for scattering of alpha particles by a thin foil. Write two important conclusions that can be drawn from this plot.

(ii) If Bohr's quantization postulate (angular momentum = $\frac{nh}{2\pi}$) is a basic law of nature, it should be equally valid for the case of planetary motion also. Why, then, do we never speak of quantization of orbits of planets around the Sun ? Explain. *3*

27. Photoemission of electrons occurs from a metal ($\phi_0 = 1{\cdot}96$ eV) when light of frequency $6{\cdot}4 \times 10^{14}$ Hz is incident on it. Calculate : *3*

(a) Energy of a photon in the incident light,

(b) The maximum kinetic energy of the emitted electrons, and

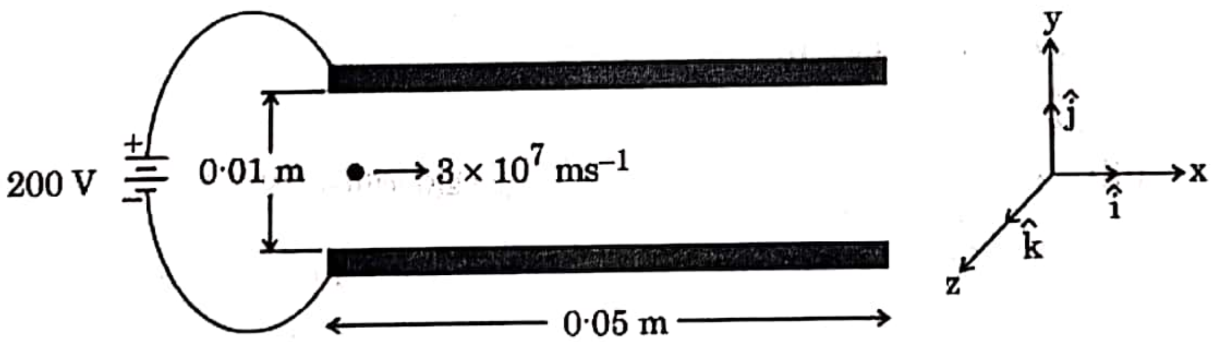
(c) The stopping potential.

28. Draw a circuit diagram of a full-wave rectifier using p-n junction diodes. Explain its working and show the input-output waveforms. *3*

SECTION D

*Questions number **29** and **30** are Case Study-based questions. Read the following paragraphs and answer the questions that follow.*

29. The electric potential (V) and electric field (E) are closely related concepts in electrostatics. The electric field is a vector quantity that represents the force per unit charge at a given point in space, whereas electric potential is a scalar quantity that represents the potential energy per unit charge at a given point in space. Electric field and electric potential are related by the equations $E_r = \frac{-dV}{dr}$ and $\vec{E} = E_r \hat{r}$, i.e., electric field is the negative gradient of the electric potential. This means that electric field points in the direction of decreasing potential and its magnitude is the rate of change of potential with distance. The electric field is the force that drives a unit charge to move from higher potential region to lower potential region and electric potential difference between the two points determines the work done in moving a unit charge from one point to the other point.



A pair of square conducting plates having sides of length 0·05 m are arranged parallel to each other in x-y plane. They are 0·01 m apart along z-axis and are connected to a 200 V power supply as shown in the figure. An electron enters with a speed of $3 \times 10^7 \ ms^{-1}$ horizontally and symmetrically in the space between the two plates. Neglect the effect of gravity on the electron.

(i) The electric field $\vec{E}$ in the region between the plates is : *1*

(A) $\left(2 \times 10^2 \frac{V}{m}\right)\hat{k}$

(B) $-\left(2 \times 10^2 \frac{V}{m}\right)\hat{k}$

(C) $\left(2 \times 10^4 \frac{V}{m}\right)\hat{k}$

(D) $-\left(2 \times 10^4 \frac{V}{m}\right)\hat{k}$

(ii) In the region between the plates, the electron moves with an acceleration $\vec{a}$ given by : *1*

(A) $-(3{\cdot}5 \times 10^{15}\ ms^{-2})\ \hat{k}$

(B) $(3{\cdot}5 \times 10^{15}\ ms^{-2})\ \hat{k}$

(C) $(3{\cdot}5 \times 10^{13}\ ms^{-2})\ \hat{i}$

(D) $-(3{\cdot}5 \times 10^{13}\ ms^{-2})\ \hat{i}$

(iii) (a) Time interval during which an electron moves through the region between the plates is : *1*

(A) $9{\cdot}0 \times 10^{-9}$ s (B) $1{\cdot}67 \times 10^{-8}$ s

(C) $1{\cdot}67 \times 10^{-9}$ s (D) $2{\cdot}17 \times 10^{-9}$ s

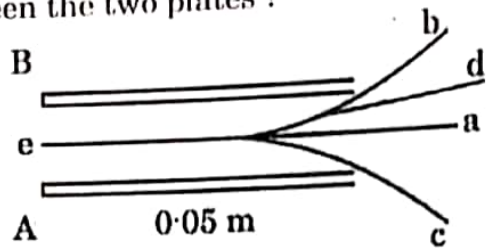
OR

(b) The vertical displacement of the electron which travels through the region between the plates is : *1*

(A) 10 mm (B) 4·9 mm

(C) 5·9 mm (D) 3·0 mm

(iv) Which one of the following is the path traced by the electron in between the two plates ? *1*

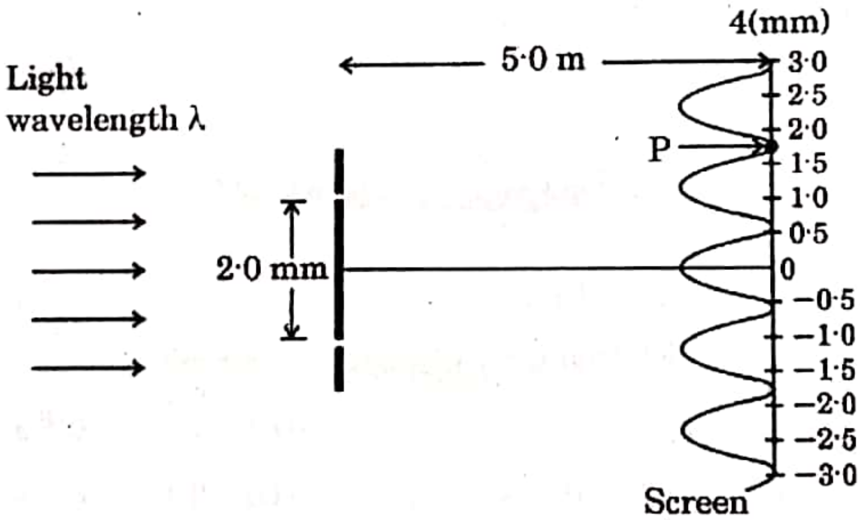


(A) a (B) b

(C) c (D) d

30. In a Young's double-slit experiment, the two slits behave as coherent sources. When coherent light waves superpose over each other they create an interference pattern of successive bright and dark regions due to constructive and destructive interference.

Two slits 2 mm apart are illuminated by a source of monochromatic light and the interference pattern is observed on a screen 5·0 m away from the slits as shown in the figure.



(i) What property of light does this interference experiment demonstrate ? *1*

(A) Wave nature of light

(B) Particle nature of light

(C) Transverse nature of light

(D) Both wave nature and transverse nature of light

(ii) (a) The wavelength of light used in this experiment is : *1*

(A) 720 nm

(B) 590 nm

(C) 480 nm

(D) 364 nm

OR

(b) The fringe width in the interference pattern formed on the screen is : *1*

(A) 1·2 mm

(B) 0·2 mm

(C) 4·2 mm

(D) 6·8 mm

(iii) The path difference between the two waves meeting at point P, where there is a minimum in the interference pattern is : *1*

(A) $8{\cdot}1 \times 10^{-7}$ m

(B) $7{\cdot}2 \times 10^{-7}$ m

(C) $6{\cdot}5 \times 10^{-7}$ m

(D) $6{\cdot}0 \times 10^{-7}$ m

(iv) When the experiment is performed in a liquid of refractive index greater than 1, then fringe pattern will : *1*

(A) disappear

(B) become blurred

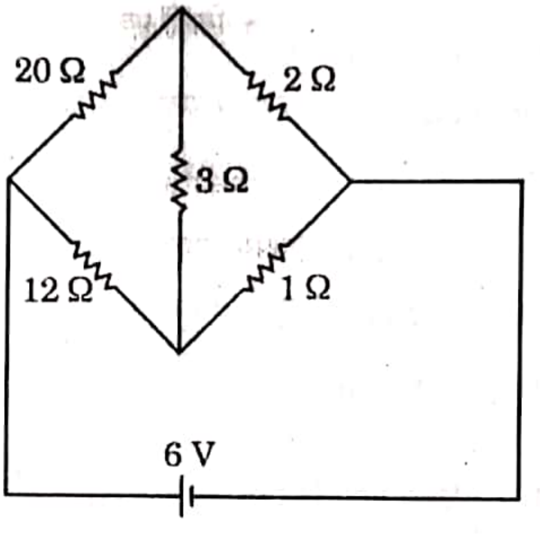
(C) be widened

(D) be compressed

SECTION E

31. (a) (i) Derive the condition for which a Wheatstone Bridge is balanced.

(ii) Determine the current in 3 Ω branch of a Wheatstone Bridge in the circuit shown in the figure. 5



OR

(b) (i) Consider a cylindrical conductor of length l and area of cross-section A. Current I is maintained in the conductor and electrons drift with velocity v_d $\left(|\vec{v}_d| = \frac{e|\vec{E}|}{m}\tau\right)$, (where symbols have their usual meanings). Show that the conductivity σ of the material of the conductor is given by $\sigma = \frac{ne^2}{m}\tau$.

(ii) The resistance of a metal wire at 20°C is 1·05 Ω and at 100°C is 1·38 Ω. Determine the temperature coefficient of resistivity of this metal. 5

32. (a) (i) A rectangular loop of sides a and b carrying current I is placed in a magnetic field $\vec{B}$ such that its area vector $\vec{A}$ makes an angle θ with $\vec{B}$. With the help of a suitable diagram, show that the torque $\vec{\tau}$ acting on the loop is given by $\vec{\tau} = \vec{m} \times \vec{B}$, where $\vec{m}$ (= I $\vec{A}$) is the magnetic dipole moment of the loop.

(ii) A circular coil of 100 turns and radius $\left(\frac{10}{\sqrt{\pi}}\right)$ cm carrying current of 5·0 A is suspended vertically in a uniform horizontal magnetic field of 2·0 T. The field makes an angle 30° with the normal to the coil. Calculate :

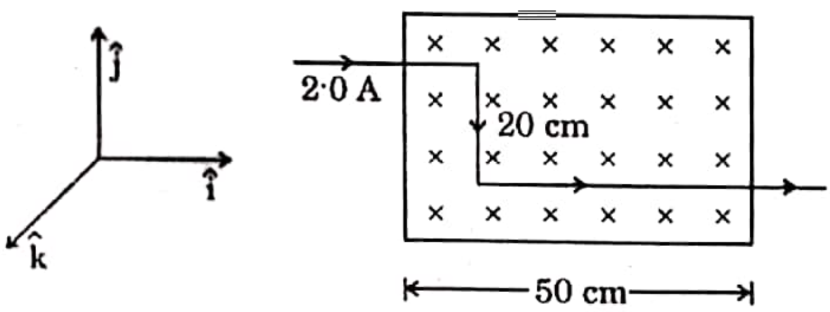
(I) the magnetic dipole moment of the coil, and

(II) the magnitude of the counter torque that must be applied to prevent the coil from turning. 5

OR

(b) (i) Derive an expression for the force $\vec{F}$ acting on a conductor of length L and area of cross-section A carrying current I and placed in a magnetic field $\vec{B}$.

(ii) A part of a wire carrying 2·0 A current and bent at 90° at two points is placed in a region of uniform magnetic field $\vec{B} = -(0{\cdot}50\ T)\ \hat{k}$, as shown in the figure. Calculate the magnitude of the net force acting on the wire. 5



33. (a) (i) A parallel beam of monochromatic light falls normally on a single slit of width 'a' and a diffraction pattern is observed on a screen placed at distance D from the slits. Explain :

(I) the formation of maxima and minima in the diffraction pattern, and

(II) why the maxima go on becoming weaker and weaker with its increasing number (n).

(ii) Write any two points of difference between interference pattern due to double-slit and diffraction pattern due to single-slit. *5*

OR

(b) (i) With the help of a ray diagram, describe the construction and working of a compound microscope.

(ii) (I) The real image of an object placed between f and 2f from a convex lens can be seen on a screen placed at the image location. If the screen is removed, is the image still there ? Explain.

(II) Plane and convex mirrors produce virtual images of objects. Can they produce real images under some circumstances ? Explain. *5*