Series BVM/4

Code No. 55/4/1

Roll No.

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

• कृपया जाँच कर लें कि इस प्रश्न-पत्र में मुद्रित पृष्ठ 19 हैं।
• प्रश्न-पत्र में दाहिने हाथ की ओर दिए गए कोड नंबर को छात्र उत्तर-पुस्तिका के मुख-पृष्ठ पर
लिखें।
• कृपया जाँच कर लें कि इस प्रश्न-पत्र में 27 प्रश्न हैं।
• कृपया प्रश्न का उत्तर लिखना शुरू करने से पहले, प्रश्न का क्रमांक अवश्य लिखें।
• इस प्रश्न-पत्र को पढ़ने के लिए 15 मिनट का समय दिया गया है। प्रश्न-पत्र का वितरण पूर्वांचल
में 10.15 बजे किया जाएगा। 10.15 बजे से 10.30 बजे तक छात्र केवल प्रश्न-पत्र को पढ़ने और इस
अवधि के दौरान वे उत्तर-पुस्तिका पर कोई उत्तर नहीं लिखें।
• Please check that this question paper contains 19 printed pages.
• Code number given on the right hand side of the question paper should be
written on the title page of the answer-book by the candidate.
• Please check that this question paper contains 27 questions.
• Please write down the Serial Number of the question before
attempting it.
• 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
students will read the question paper only and will not write any answer on
the answer-book during this period.

भौतिक विज्ञान (सैद्धांतिक)
PHYSICS (Theory)

निर्धारित समय : 3 घण्टे

Time allowed : 3 hours

अधिकतम अंक : 70

Maximum Marks : 70

55/4/1

P.T.O.
General Instructions:

(i) All questions are compulsory. There are 27 questions in all.
(ii) This question paper has four sections: Section A, Section B, Section C and Section D.
(iii) Section A contains five questions of one mark each, Section B contains seven questions of two marks each, Section C contains twelve questions of three marks each, Section D contains three questions of five marks each.
(iv) There is no overall choice. However, an internal choice(s) has been provided in two questions of one mark, two questions of two marks, four questions of three marks and three questions of five marks weightage. You have to attempt only one of the choices in such questions.
You may use the following values of physical constants wherever necessary:

\[
c = 3 \times 10^8 \text{ m/s}
\]
\[
h = 6.63 \times 10^{-34} \text{ Js}
\]
\[
e = 1.6 \times 10^{-19} \text{ C}
\]
\[
\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}
\]
\[
\varepsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}
\]
\[
\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}
\]

Mass of electron \((m_e)\) = 9.1 \times 10^{-31} \text{ kg}

Mass of neutron = 1.675 \times 10^{-27} \text{ kg}

Mass of proton = 1.673 \times 10^{-27} \text{ kg}

Avogadro’s number = 6.023 \times 10^{23} \text{ per gram mole}

Boltzmann constant = 1.38 \times 10^{-23} \text{ JK}^{-1}

**SECTION A**

1. Two identical conducting balls A and B have charges \(-Q\) and \(+3Q\) respectively. They are brought in contact with each other and then separated by a distance \(d\) apart. Find the nature of the Coulomb force between them.

**OR**

A metallic spherical shell has an inner radius \(R_1\) and outer radius \(R_2\). A charge \(Q\) is placed at the centre of the shell. What will be the surface charge density on the (i) inner surface, and (ii) outer surface of the shell?
2. Under what condition will the current in a wire be the same when connected in series and in parallel of n identical cells each having internal resistance \( r \) and external resistance \( R \)?

3. The small ozone layer on top of the stratosphere is crucial for human survival. Why?

OR

Illustrate by giving suitable examples, how you can show that electromagnetic waves carry both energy and momentum.

4. The figure shows the variation of stopping potential \( V_0 \) with the frequency \( v \) of the incident radiations for two photosensitive metals P and Q. Which metal has smaller threshold wavelength? Justify your answer.

5. Why is ground wave transmission of signals restricted to a frequency of 1500 kHz?
SECTION B

6. Gauss’s law can be used to show that the electric field outside a charged spherical shell is, as if the entire charge were concentrated at the centre.

\[ \text{Apply Gauss’s law to show that for a charged spherical shell, the electric field outside the shell is, as if the entire charge were concentrated at the centre.} \]

**OR**

Two large parallel plane sheets have uniform charge densities \( +\sigma \) and \( -\sigma \). Determine the electric field (i) between the sheets, and (ii) outside the sheets.

7. In a magnetic field, a proton moves with a velocity of \( 4 \times 10^6 \) m/s. The magnetic field exerts a force on the proton. Calculate the force and specify its direction.

![Diagram of a proton moving in a magnetic field](https://byjus.com)
8. A parallel plate capacitor of plate area $A$ each and separation $d$, is being charged by an ac source. Show that the displacement current inside the capacitor is the same as the current charging the capacitor.

9. A beam of light converges at a point $P$. Now a convex lens is placed in the path of the convergent beam at 15 cm from $P$. At what point does a beam converge if the convex lens has a focal length 10 cm ?

OR

An object is kept in front of a concave mirror of focal length 15 cm. The image formed is real and three times the size of the object. Calculate the distance of the object from the mirror.

10. Explain giving reason, how the resolving power of a compound microscope depends on the
(a) frequency of the incident light.
(b) focal length of the objective lens.

11. The distance of the object from the mirror is $SS_2 - SS_1 = \lambda/4$.

(a) Slightly off-kilter for the image to lie. 
(b) Fringe crossing for the image to emerge.
The figure shows a modified Young’s double slit experimental set-up. Here \( SS_2 - SS_1 = \lambda / 4 \).

(a) Write the condition for constructive interference.
(b) Obtain an expression for the fringe width.

12. किसी n-p-n ट्रांजिस्टर का उभयनिष्ठ उत्सर्जक निर्गत अभिलाखणिक आरेख में दर्शाए अनुसार है।

![](image)

(a) \( V_{CE} = 12.5 \text{ V} \) तथा \( I_b = 60 \mu \text{A} \) पर उत्सर्जक धारा, तथा
(b) इस बिन्दु पर वोल्टटा लच्छ ‘\( \beta \)’ ज्ञात कीजिए।

A certain n-p-n transistor has the common emitter output characteristics as shown in the figure.

![](image)

(a) Find the emitter current at \( V_{CE} = 12.5 \text{ V} \) and \( I_b = 60 \mu \text{A} \), and
(b) Current gain ‘\( \beta \)’ at this point.
SECTION C

13. (a) Draw a graph showing the variation of current versus voltage in an electrolyte when an external resistance is also connected.

(b) (i) The graph between resistance (R) and temperature (T) for Hg is shown in the figure (a). Explain the behaviour of Hg near 4 K.

(ii) The graph (b) shows the variation of current with voltage for an electrolyte. What is the significance of points A, B, and C on the graph?
(ii) In which region of the graph shown in the figure (b) is the resistance negative and why?

Figure (b)

14. (a) अरेख में दर्शाए गए परिपथ के लिए शून्य विक्षेप लम्बाई किस प्रकार प्रभावित होगी, यदि
(i) $R_1$ में कमी कर दी जाए,
(ii) $R_2$ में वृद्धि कर दी जाए,
जबकि परिपथ के अन्य सभी कारक अपरिवर्तित रहते हैं ? प्रत्येक प्रकरण में अपने उत्तर की पुष्टि कीजिए ।

(b) बोल्टमीटर की तुलना में पोटेंटियोमीटर को प्राथिकता क्यों दी जाती है ? कारण दीजिए ।

अथवा

मीटर सेट का कार्यकारी सिद्धांत लिखिए । परिपथ आरेख खींचिए और व्याख्या कीजिए कि इस विधि द्वारा किसी चालक का अज्ञात प्रतिरोध किस प्रकार निर्धारित किया जा सकता है ।
(a) For the circuit shown in the figure, how would the balancing length be affected, if
(i) \( R_1 \) is decreased,
(ii) \( R_2 \) is increased,
the other factors remaining the same in the circuit? Justify your answer in each case.

![Circuit Diagram]

(b) Why is a potentiometer preferred over a voltmeter? Give reason.

**OR**

State the underlying principle of meter bridge. Draw the circuit diagram and explain how the unknown resistance of a conductor can be determined by this method.

15. एक प्रोटॉन, एक ड्यूट्रॉन और एक ऐल्फा कण को समान विभंगन्त हाल तक त्वरित किया गया है और फिर इन पर इनकी गति की दिशा के लम्बवत एक एकसमान चुम्बकीय क्षेत्र \( B \) लगाया गया है। (i) इनकी गतिज ऊर्जाओं की तुलना कीजिए। यदि प्रोटॉन के वृत्तीय पथ की त्रिज्या 5 cm है, तो ड्यूट्रॉन तथा ऐल्फा कण के पथों की त्रिज्या निर्धारित कीजिए।

A proton, a deuteron and an alpha particle, are accelerated through the same potential difference and then subjected to a uniform magnetic field \( B \), perpendicular to the direction of their motions. Compare (i) their kinetic energies, and (ii) if the radius of the circular path described by proton is 5 cm, determine the radii of the paths described by deuteron and alpha particle.

16. (a) संक्षेप में व्याख्या कीजिए कि किसी गैल्वॉमीटर की एमीटर में किस प्रकार परिवर्तित किया जाता है।
(b) किसी गैल्वॉमीटर की कुंडली का प्रतिरोध 15 \( \Omega \) है तथा इसके पूर्ण प्राप्ति विश्वेषण की धारा 4 mA है। इसे 0 – 6 A परिसर के एमीटर में परिवर्तित कीजिए।

(अथवा)
(a) संक्षेप में व्याख्या कीजिए कि किसी गैल्वॉमीटर को वोल्टमीटर में किस प्रकार परिवर्तित किया जा सकता है।
(b) A galvanometer coil has a resistance of 15 Ω and it shows full scale deflection for a current of 4 mA. Convert it into an ammeter of range 0 to 6 A.

OR

(a) Briefly explain how a galvanometer is converted into a voltmeter.
(b) A voltmeter of a certain range is constructed by connecting a resistance of 980 Ω in series with a galvanometer. When the resistance of 470 Ω is connected in series, the range gets halved. Find the resistance of the galvanometer.

The figure shows a rectangular conducting frame MNOP of resistance R placed partly in a perpendicular magnetic field \( \vec{B} \) and moved with velocity \( \vec{v} \) as shown in the figure.
Obtain the expressions for the
(a) force acting on the arm ‘ON’ and its direction, and
(b) power required to move the frame to get a steady emf induced
between the arms MN and PO.

18. अपवर्ती दूरदर्शक द्वारा किसी दरस्थ बिंब का प्रतिबिंब बनना दर्शाने के लिए किरण आरेख
खींचिए। उपयोग किए गए लेंसों की फोकस दूरी के पदों में कोणीय आवर्धन के लिए व्यंजक
लिखिए। अधिक विवेधन प्राप्त करने के लिए आवश्यक महत्त्वपूर्ण तथ्यों और उनकी
परिणामी सीमाओं का उल्लेख कीजिए। 
अथवा
(a) किसी विभुजाकार प्रिज्म के लिए आपतन कोण के साथ विचलन कोण के विचरण को
दर्शाने के लिए ग्राफ खींचिए।
(b) न्यूनतम विचलन कोण और प्रिज्म कोण के पदों में प्रिज्म के पदार्थ के अपवर्तनांक के
लिए संबंध व्युतप्त कीजिए।

Draw a ray diagram to show the image formation of a distant object by a
refracting telescope. Write the expression for its angular magnification in
terms of the focal lengths of the lenses used. State the important
considerations required to achieve large resolution and their consequent
limitations.

OR

(a) Plot a graph for angle of deviation as a function of angle of
incidence for a triangular prism.
(b) Derive the relation for the refractive index of the prism in terms of
the angle of minimum deviation and angle of prism.

19. (a) संक्षेप में उल्लेख कीजिए कि डेबिसन और जर्मार के प्रयोग का प्रयोजन क्या था और
इससे क्या निष्कर्ष निकला।
(b) किसी प्रोटॉन और किसी α-कण को त्वरित करने वाले उन त्वरक विभवों के अनुपात
के लिए व्यंजक प्राप्त कीजिए जिनसे संबंध दे-ब्रॉगली तरंगदैर्घ्य समान हों।
अथवा
(a) किसी इलेक्ट्रॉन और किसी प्रोटॉन को समान विभव तक त्वरित किया गया है। इनमें
से किसके लिए
(i) संबंध दे-ब्रॉगली तरंगदैर्घ्य का मान अधिक होगा, तथा
(ii) संवेग कम होगा?
प्रत्येक प्रकरण में अपने उत्तर की पुष्टि कीजिए।
(b) किसी कण का संवेग उसकी दे-ब्रॉगली तरंगदैर्घ्य से किस प्रकार संबंधित होता है?
ग्राफ द्वारा विचरण दर्शाइए।
(a) State briefly, with what purpose was Davisson and Germer experiment performed and what inference was drawn from this.

(b) Obtain an expression for the ratio of the accelerating potentials required to accelerate a proton and an \( \alpha \)-particle to have the same de-Broglie wavelength associated with them.

**OR**

(a) An electron and a proton are accelerated through the same potential. Which one of the two has

(i) greater value of de-Broglie wavelength associated with it, and

(ii) lesser momentum?

Justify your answer in each case.

(b) How is the momentum of a particle related with its de-Broglie wavelength? Show the variation on a graph.

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20. (a) बोहर के अभिगृहीतों का उपयोग करते हुए हाइड्रोजन परमाणु की \( n \)वीं कक्षा में गतिमान इलेक्ट्रॉन के कक्षीय काल के लिए व्यंजक व्युत्पत्ति कीजिए।

(b) हाइड्रोजन परमाणु के स्पेक्ट्रम की स्पेक्ट्रल रेखाओं की तरंगदैर्घ्यों के लिए रिडर्बर्ग सूत्र लिखिए। उल्लेख कीजिए कि हाइड्रोजन के उल्सरी स्पेक्ट्रम की किस श्रेणी से \( H_\alpha \) लाइन संबंधित है।

(a) Using Bohr’s postulates, derive the expression for the orbital period of the electron moving in the \( n \)th orbit of hydrogen atom.

(b) Write Rydberg’s formula for wavelengths of the spectral lines of hydrogen atom spectrum. Mention to which series in the emission spectrum of hydrogen, \( H_\alpha \) line belongs.

21. विभिन्न नाभिकीय विविधताओं की त्रुटिमान संख्या के साथ बंधन ऊर्जा प्रति न्यूक्लियाम के विचरण को दर्शाने के लिए ग्राफ खींचिए। इस वक्र के किन्हीं दो विशिष्ट लक्षणों को लिखिए। यह वक्र नाभिकीय विविधता और नाभिकीय संलयन दोनों ही प्रक्रियाओं में ऊर्जा मुक्त होने की व्याख्या किस प्रकार करता है?

Draw a graph showing the variation of binding energy per nucleon with mass number of different nuclei. Write any two salient features of the curve. How does this curve explain the release of energy both in the processes of nuclear fission and fusion?
22. Draw the energy band diagram of (i) n-type, and (ii) p-type semiconductors at temperature $T > 0$ K.

In the case of n-type Si-semiconductor, the donor energy level is slightly below the bottom of conduction band whereas in p-type semiconductor, the acceptor energy level is slightly above the top of valence band. Explain, giving examples, what role do these energy levels play in conduction and valence bands.

23. With what considerations in view is a photodiode fabricated? Explain its working with the help of a suitable diagram. With the help of V-I characteristics, state how photodiode is used to detect optical signals.

24. (a) What is amplitude modulation? Draw a diagram showing an amplitude modulated wave obtained by modulation of a carrier sinusoidal wave on a modulating signal.

(b) Define the terms (i) modulation index, and (ii) side bands. Mention the significance of side bands.
SECTION D

25. (a) When a parallel plate capacitor is connected across a dc battery, explain briefly how the capacitor gets charged.

(b) A parallel plate capacitor of capacitance ‘C’ is charged to ‘V’ volt by a battery. After some time the battery is disconnected and the distance between the plates is doubled. Now a slab of dielectric constant $1 < k < 2$ is introduced to fill the space between the plates. How will the following be affected?

(i) The electric field between the plates of the capacitor.

(ii) The energy stored in the capacitor.

Justify your answer in each case.
(c) The electric potential as a function of distance ‘x’ is shown in the figure. Draw a graph of the electric field E as a function of x.

OR

(a) Derive an expression for the potential energy of an electric dipole in a uniform electric field. Explain conditions for stable and unstable equilibrium.

(b) Is the electrostatic potential necessarily zero at a point where the electric field is zero? Give an example to support your answer.
(a) What do you understand by ‘sharpness of resonance’ for a series LCR resonant circuit? How is it related with the quality factor ‘Q’ of the circuit? Using the graphs given in the diagram, explain the factors which affect it. For which graph is the resistance (R) minimum?

(b) A 2 μF capacitor, 100 Ω resistor and 8 H inductor are connected in series with an ac source. Find the frequency of the ac source for which the current drawn in the circuit is maximum.

If the peak value of emf of the source is 200 V, calculate the (i) maximum current, and (ii) inductive and capacitive reactance of the circuit at resonance.

OR
(a) Draw a schematic diagram of an ac generator. Explain its working and obtain the expression for the instantaneous value of the emf in terms of the magnetic field $B$, number of turns $N$ of the coil of area $A$ rotating with angular frequency $\omega$. Show how an alternating emf is generated by a loop of wire rotating in a magnetic field.

(b) A circular coil of radius 10 cm and 20 turns is rotated about its vertical diameter with angular speed of 50 rad s\(^{-1}\) in a uniform horizontal magnetic field of $3.0 \times 10^{-2}$ T.

(i) Calculate the maximum and average emf induced in the coil.

(ii) If the coil forms a closed loop of resistance 10 $\Omega$, calculate the maximum current in the coil and the average power loss due to Joule heating.

27. (a)

\[ \frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}. \]

(b) A circular coil of radius 10 cm and 20 turns is rotated about its vertical diameter with angular speed of 50 rad s\(^{-1}\) in a uniform horizontal magnetic field of $3.0 \times 10^{-2}$ T.

(i) Calculate the maximum and average emf induced in the coil.

(ii) If the coil forms a closed loop of resistance 10 $\Omega$, calculate the maximum current in the coil and the average power loss due to Joule heating.
(a) Using the ray diagram for a system of two lenses of focal lengths \( f_1 \) and \( f_2 \) in contact with each other, show that the two lens system can be regarded as equivalent to a single lens of focal length \( f \), where

\[
\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}.
\]

Also write the relation for the equivalent power of the lens combination.

(b) Determine the position of the image formed by the lens combination given in the figure.

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O

\[ f = +10, -10, +30 \text{ cm} \]
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OR

(a) Explain, using a suitable diagram, how unpolarized light gets linearly polarized by scattering.

(b) Describe briefly the variation of the intensity of transmitted light when a polaroid sheet kept between two crossed polaroids is rotated. Draw the graph depicting the variation of intensity with the angle of rotation. How many maxima and minima would be observed when \( \theta \) varies from 0 to \( \pi \)?