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QUESTION PAPER SERIES CODE
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Registration No. : ☐☐☐☐☐

Centre of Exam. : ____________________

Name of Candidate : ____________________

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Signature of Invigilator

ENTRANCE EXAMINATION, 2018

M.Sc. PHYSICS

[Field of Study Code : SPSM (226)]

Time Allowed : 3 hours

Maximum Marks : 100

INSTRUCTIONS FOR CANDIDATES

Candidates must read carefully the following instructions before attempting the Question Paper :

(i) Write your Name and Registration Number in the space provided for the purpose on the top of this Question Paper and in the Answer Sheet.

(ii) **Please darken the appropriate Circle of Question Paper Series Code on the Answer Sheet.**

(iii) **All** questions are compulsory. For each question, **one and only one** of the four choices given is the correct answer.

(iv) Answer all 25 questions in the Answer Sheet provided for the purpose by darkening the correct choice, i.e., (a) or (b) or (c) or (d) with BALLPOINT PEN only against the corresponding Circle. Any overwriting or alteration will be treated as wrong answer.

(v) Each correct answer carries **4** marks. **There will be negative marking and 1 mark will be deducted for each wrong answer.**

(vi) Answer written by the candidates inside the Question Paper will not be evaluated.

(vii) Calculators may be used.

(viii) Please use the space provided for Rough Work.

(ix) Return the Question Paper and Answer Sheet to the Invigilator at the end of the Entrance Examination. **DO NOT FOLD THE ANSWER SHEET.**

INSTRUCTIONS FOR MARKING ANSWERS

1. Use only Blue/Black Ballpoint Pen (do not use pencil) to darken the appropriate Circle.
2. Please darken the whole Circle.
3. Darken ONLY ONE CIRCLE for each question as shown in the example below :

Wrong	Wrong	Wrong	Wrong	Correct
● ⓑ ⓒ ●	⊗ ⓑ ⓒ ⓓ	⊗ ⓑ ⓒ ⊘	◉ ⓑ ⓒ ●	ⓐ ⓑ ⓒ ●

4. Once marked, no change in the answer is allowed.
5. Please do not make any stray marks on the Answer Sheet.
6. Please do not do any rough work on the Answer Sheet.
7. Mark your answer only in the appropriate space against the number corresponding to the question.
8. **Ensure that you have darkened the appropriate Circle of Question Paper Series Code on the Answer Sheet.**

Useful Physical Constants :

Acceleration due to gravity, $g = 9 \cdot 81$ m/s^2

Avogadro number, $N_A = 6 \cdot 022 \times 10^{23}$ /mol

Boltzmann constant, $k_B = 1 \cdot 38 \times 10^{-23}$ J/K

Charge of electron, $e = 1 \cdot 6 \times 10^{-19}$ C

Gravitational constant, $G = 6 \cdot 67 \times 10^{-11}$ N-m^2/kg^2

Mean radius of the earth, $R_e = 6 \cdot 37 \times 10^6$ m

Permittivity of vacuum, $\varepsilon_0 = 8 \cdot 85 \times 10^{-12}$ F/m

Permeability of vacuum, $\mu_0 = 4\pi \times 10^{-7}$ H-m^{-1}

Planck constant, $h = 6 \cdot 63 \times 10^{-34}$ J-s

Rest mass of electron, $m_e = 9 \cdot 11 \times 10^{-31}$ kg

Rest mass of neutron, $m_n = 1 \cdot 67 \times 10^{-27}$ kg

Rest mass of proton, $m_p = 1 \cdot 67 \times 10^{-27}$ kg

Speed of light in vacuum, $c = 3 \times 10^8$ m/s

Stefan-Boltzmann constant, $\sigma = 5 \cdot 67 \times 10^{-8}$ W/m^2-K^4

Universal gas constant, $R = 8 \cdot 31$ J/mol-K

Conversion Factors :

1 calorie = $4 \cdot 2$ J

1 eV = $1 \cdot 6 \times 10^{-19}$ J

1. Given the points $P(0, 0, 0)$, $Q(1, 1, 1)$, $R(1, 1, 0)$ and $S(0, 1, 1)$ in three-dimensional space, what is the shortest distance between lines PQ and RS?

   (a) 1

   (b) $1/\sqrt{3}$

   (c) $1/\sqrt{5}$

   (d) $1/\sqrt{6}$

2. The exponential function $e^{i\theta A}$ of matrix $A = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$ is given by which one of the following matrices? Here θ is an arbitrary real number.

   (a) $\begin{pmatrix} 0 & e^{i\theta} \\ e^{i\theta} & 0 \end{pmatrix}$

   (b) $\begin{pmatrix} 1 & e^{i\theta} \\ e^{-i\theta} & 1 \end{pmatrix}$

   (c) $\begin{pmatrix} \cos\theta & i\sin\theta \\ -i\sin\theta & \cos\theta \end{pmatrix}$

   (d) $\begin{pmatrix} \cos\theta & -i\sin\theta \\ i\sin\theta & \cos\theta \end{pmatrix}$

3. What is the solution of the differential equation $y'' + y' = bx$, with the boundary conditions $y(0) = 1$ and $y'(0) = 0$? Here b is a constant, $y' = dy/dx$ and $y'' = d^2y/dx^2$.

   (a) $y(x) = (1-b) + \frac{b}{2}x(x+2) + be^{-x}$

   (b) $y(x) = (1-b) - \frac{b}{2}x(x-2) + be^{-x}$

   (c) $y(x) = (1+b) - \frac{b}{2}x(x+2) - be^{-x}$

   (d) $y(x) = (1+b) + \frac{b}{2}x(x-2) - be^{-x}$

4. What is the value of the following complex integral?

$$\int_C z^2 e^{1/z} dz$$

Here C denotes the unit circle $|z| = 1$ traversed counter-clockwise.

(a) $2\pi i$

(b) πi

(c) $2\pi i / 5$

(d) $\pi i / 3$

5. A point particle of mass m is placed on the inner surface of a frictionless bowl which has the shape of a paraboloid of revolution given by the equation $z = a(x^2 + y^2)$. The gravity g is acting vertically downwards (along the negative z direction). At what angular speed should the bowl be rotated about the vertical axis so that the particle remains stationary?

(a) $\sqrt{2ag}$

(b) $\sqrt{ag}$

(c) $\sqrt{2g/a}$

(d) $1/\sqrt{2ag}$

6. The stiffness k_c of a spring when compressed from its equilibrium length is given to be different from its stiffness k_s when stretched. The potential energy $V(x)$, stored in this spring for an arbitrary compression or stretching x, is given by $V(x) = k_c x^2 /2$ for $x < 0$ and $V(x) = k_s x^2 /2$ for $x \geq 0$. A particle of mass m is attached to the one end of this spring, while the other end is fixed. The mass of the spring is negligible. Starting at time $t = 0$, with the compressed spring and the particle at rest at $x(0) = -1$, this system undergoes an oscillatory motion. What is the angular frequency of its oscillation?

(a) $\sqrt{\dfrac{k_c + k_s}{2m}}$

(b) $\dfrac{2}{\sqrt{m}} \dfrac{\sqrt{k_c k_s}}{\sqrt{k_c} + \sqrt{k_s}}$

(c) $\dfrac{1}{2}\left[\sqrt{\dfrac{k_c}{m}} + \sqrt{\dfrac{k_s}{m}}\right]$

(d) $\sqrt{\dfrac{2k_c k_s}{m(k_c + k_s)}}$

7. A uniform string of length 2 m and mass 10 g is under a tension of 8 N, with both ends fixed. If the string is plucked transversely and then touched at a point 80 cm away from one end, the vibrational modes of what frequencies will persist?

(a) All integer multiples of 10 Hz

(b) All integer multiples of 20 Hz

(c) All integer multiples of 25 Hz

(d) All integer multiples of 50 Hz

8. A concave-convex lens of negligible thickness has refractive index of 1·5, and its radii of curvature are 10 cm (for the convex surface) and 20 cm (for the concave surface). The lens is placed horizontally with concave surface facing upwards which is filled with an oil of refractive index 1·6. What is the focal length of this lens filled with oil?

(a) 18·18 cm

(b) 40·12 cm

(c) 20·5 cm

(d) 6·3 cm

9. Consider the fringes produced with monochromatic light of wavelength 5880 Å in a Young's double-slit experiment. When a thin glass plate of refractive index 1·5 is placed normally in front of one of the slits, the central bright fringe is shifted to a position where the third bright fringe from the centre was before the plate was placed. What is the thickness of this glass plate?

(a) 1·176 μm

(b) 1·764 μm

(c) 2·941 μm

(d) 3·528 μm

10. Consider a solid cube with a uniform charge density. Let the electrostatic potential be V_1 at its centre, and V_2 at any corner of the cube. The potential is zero at infinity. What is V_1/V_2?

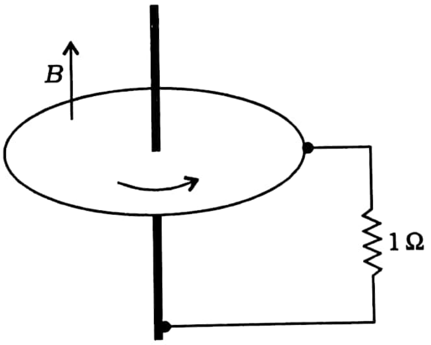
(a) 2

(b) $2/\sqrt{3}$

(c) 1/2

(d) 8

11. A metallic disc of radius 0·1 m rotates about its vertical axis with a rotational speed of 10 revolutions per second in a uniform magnetic field (B) of 0·1 tesla. If a 1 Ω resistor is connected between the axle and the outer edge of the disc, then the current flowing through the resistor is



(a) 5 mA

(b) 31·4 mA

(c) 15·7 mA

(d) 10 mA

12. The photoelectric effect can be demonstrated by shining light on a metallic surface in an evacuated chamber which results in a current of photoelectrons. To stop the photoelectric current (i_p), a negative voltage is applied between cathode and anode using a variable voltage source (V), and the corresponding stopping potential (V_s) is determined. In a typical experiment, the photoelectric current is measured by varying V with fixed intensity (I) and frequency (ν) of the incident light. Based on the resultant findings sketched in graphs [(A), (B), (C)] below, which of the following conclusions are correct?

(i) The work function of tungsten (W) is more than that of potassium (K).

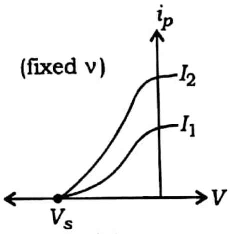
(ii) The saturation current is independent of the frequency of light for a fixed I.

(iii) The V_s depends on the intensity of light.

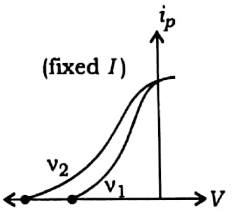
(iv) The Planck constant can be estimated from graph (C).

(v) The graph (C) is explainable by classical electrodynamics.

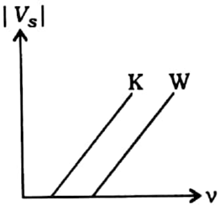
(vi) In graph (B), $\nu_1 > \nu_2$.



(A)



(B)



(C)

(a) (i), (ii) and (iv) are the correct conclusions

(b) (i), (iv) and (v) are the correct conclusions

(c) (ii), (iii), (v) and (vi) are the correct conclusions

(d) (i), (ii), (iv) and (vi) are the correct conclusions

13. A particle in one dimension is given to be in the quantum state $\psi(x) = e^{(a+ib)x-\frac{1}{2}x^2}$, where a and b are real-valued constants. What are the position and momentum expectation values, $\langle x\rangle$ and $\langle p\rangle$ respectively, of the particle in this state?

(a) $\langle x\rangle = a$ and $\langle p\rangle = \hbar/2a$

(b) $\langle x\rangle = a$ and $\langle p\rangle = \hbar b$

(c) $\langle x\rangle = ae^{a^2}\sqrt{\pi}$ and $\langle p\rangle = \hbar be^{-b^2}\sqrt{\pi}$

(d) $\langle x\rangle = ae^{a^2}\sqrt{\pi}$ and $\langle p\rangle = \hbar be^{a^2}\sqrt{\pi}$

17. Consider a three-level atom with energy levels 0, ε_1 and ε_2. What is the probability of finding the atom in the energy level ε_2 at temperature T (with $\beta = 1/k_B T$)?

(a) 0

(b) $e^{-\beta\varepsilon_2}$

(c) $e^{-\beta\varepsilon_1} / (1 + e^{-\beta\varepsilon_1} + e^{-\beta\varepsilon_2})$

(d) $e^{-\beta\varepsilon_2} / (1 + e^{-\beta\varepsilon_1} + e^{-\beta\varepsilon_2})$

18. For a gas at fixed temperature, pressure and particle number (T, P, N), the natural thermodynamic potential is $G = U - TS + PV$, where U is the internal energy, V is volume and S is entropy. Which of the following is the corresponding potential for a gas at fixed (T, V, μ)? Here μ is the chemical potential.

(a) $G + TS$

(b) $G - PV$

(c) $G - PV + \mu N$

(d) $G - PV - \mu N$

19. Two moles of an ideal gas is kept at a temperature of 300 K in a container of 1 m^3 volume. At this temperature, particle number and volume, what is the rate of change of its entropy with pressure in SI units?

(a) 300

(b) -600

(c) $-1/300$

(d) $1/600$

20. What is the number of lattice points contained in a primitive unit cell of the f.c.c. (face-centred cubic) lattice?

(a) 1

(b) 2

(c) 3

(d) 4

21. Which one of the following is not true for the specific heat (C_v) of solids?

(a) The C_v decreases as temperature (T) decreases

(b) According to Debye model, $C_v \propto T^3$ at low temperatures

(c) The Einstein model accounts for the contribution to C_v from the acoustic modes of lattice vibrations

(d) The Debye model accounts for the contribution to C_v from the acoustic modes of lattice vibrations

22. What is the concentration of electrons and holes at a temperature of 300 K in an intrinsic semiconductor with band gap 1·1 eV ? In this semiconductor, the effective mass of electrons is given to be $0 \cdot 7 m_e$ and the effective mass of holes is m_e. Here m_e denotes the rest mass of a free electron.

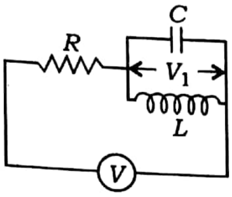
(a) $2 \cdot 1 \times 10^{17}$ m^{-3}

(b) $8 \cdot 5 \times 10^{16}$ m^{-3}

(c) $1 \cdot 1 \times 10^{16}$ m^{-3}

(d) $1 \cdot 1 \times 10^{15}$ m^{-3}

23. Consider the circuit drawn below of a resistor (R), capacitor (C) and inductor (L) with an applied time-dependent voltage $V(t)$. Let V_1 be the resultant voltage at any time t across the inductor. Which one of the following differential equations correctly applies to this circuit? Here $\dot{V}_1 = dV_1/dt$ and $\ddot{V}_1 = d^2V_1/dt^2$.



(a) $RC\ddot{V}_1 + \dot{V}_1 + (R/L)V_1 = \dot{V}(t)$

(b) $RC\ddot{V}_1 + \dot{V}_1 - (R/L)V_1 = \dot{V}(t)$

(c) $RC\ddot{V}_1 + (R/L)\dot{V}_1 + V_1 = V(t)$

(d) $RC\ddot{V}_1 - (R/L)\dot{V}_1 + V_1 = V(t)$

24. The Boolean expression $B\cdot(A+B)+A\cdot(\overline{B}+A)$ can be realized using a minimum number of

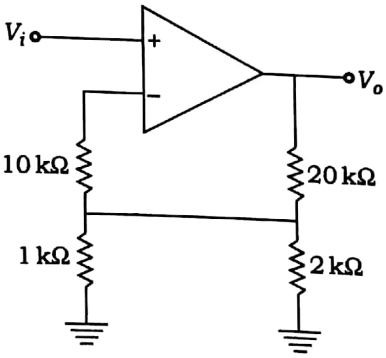
(a) 1 NAND gate

(b) 2 AND gates

(c) 1 OR gate

(d) 1 NOR gate

25. For an input voltage $V_i = 1$ mV, what is the output voltage V_o in the following circuit of an ideal OP-AMP (operational amplifier)?



(a) −10 mV

(b) 62 mV

(c) 31 mV

(d) 11 mV

14. The unstable oxygen nuclei ${}^{14}_{8}O$ and ${}^{19}_{8}O$ undergo beta decay. Which of the following do you expect to happen?

(a) ${}^{14}_{8}O$ undergoes positive beta decay and ${}^{19}_{8}O$ undergoes negative beta decay

(b) ${}^{14}_{8}O$ undergoes negative beta decay and ${}^{19}_{8}O$ undergoes positive beta decay

(c) Both ${}^{14}_{8}O$ and ${}^{19}_{8}O$ undergo positive beta decay

(d) Both ${}^{14}_{8}O$ and ${}^{19}_{8}O$ undergo negative beta decay

15. An X-ray tube operates at an applied voltage of 15000 V. What is the shortest wavelength of the X-ray emitted by this tube?

(a) 0·83 Å

(b) 0·66 Å

(c) 1·2 Å

(d) 2·1 Å

16. The work (in mega electron volts) that must be done to increase the speed of an electron from $0{\cdot}4c$ to $0{\cdot}8c$ (where c is the speed of light) is approximately

(a) 0·1 MeV

(b) 0·3 MeV

(c) 0·5 MeV

(d) 0·7 MeV