

**ENTRANCE EXAMINATION, 2017**

**M.Sc. PHYSICS**

[ Field of Study Code : SPSM (226) ]

*Time Allowed : 3 hours*

*Maximum Marks : 100*

**INSTRUCTIONS FOR CANDIDATES**

- (i) All questions are compulsory.
- (ii) For each question one and only one of the five choices given is the correct answer.
- (iii) For each question **answer must be given in the space provided in the Answer Table**. Answer given in any other place will not be evaluated.
- (iv) Each correct answer will be given +4 points.
- (v) Each wrong answer will be given -1 point.
- (vi) Use of calculators is permitted.
- (vii) Extra pages are attached at the end of the question paper for rough work.

**ENTRANCE EXAMINATION, 2017**

**M.Sc. PHYSICS**

SUBJECT .....  
(Field of Study/Language)

FIELD OF STUDY CODE .....

NAME OF THE CANDIDATE .....

REGISTRATION NO.

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CENTRE OF EXAMINATION .....

DATE. ....

.....  
*(Signature of Candidate)*

.....  
*(Signature of Invigilator)*

.....  
*(Signature and Seal of  
Presiding Officer)*



**Useful Physical Constants :**

Acceleration due to gravity,  $g = 9.81 \text{ m/s}^2$

Avogadro number,  $N_A = 6.022 \times 10^{23} / \text{mol}$

Boltzmann constant,  $k_B = 1.38 \times 10^{-23} \text{ J/K}$

Charge of electron,  $e = 1.6 \times 10^{-19} \text{ C}$

Gravitational constant,  $G = 6.67 \times 10^{-11} \text{ N-m}^2/\text{kg}^2$

Mean radius of the earth,  $R_e = 6.37 \times 10^6 \text{ m}$

Permittivity of vacuum,  $\epsilon_0 = 8.85 \times 10^{-12} \text{ F/m}$

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

Planck constant,  $h = 6.63 \times 10^{-34} \text{ J-s}$

Rest mass of electron,  $m_e = 9.11 \times 10^{-31} \text{ kg}$

Rest mass of neutron,  $m_n = 1.67 \times 10^{-27} \text{ kg}$

Rest mass of proton,  $m_p = 1.67 \times 10^{-27} \text{ kg}$

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

Stefan-Boltzmann constant,  $\sigma = 5.67 \times 10^{-8} \text{ W/m}^2\text{-K}^4$

Universal gas constant,  $R = 8.31 \text{ J/mol-K}$

**Conversion Factors :**

1 calorie = 4.2 J

1 eV =  $1.6 \times 10^{-19}$  J

**Relativistic expressions for momentum and total energy :**

$$\text{Total energy, } E = \frac{mc^2}{\sqrt{1 - (v/c)^2}}$$

$$\text{Momentum, } \mathbf{p} = \frac{m\mathbf{v}}{\sqrt{1 - (v/c)^2}}$$

ANSWER TABLE

Question No.	Answer	Question No.	Answer	Question No.	Answer
1.		2.		3.	
4.		5.		6.	
7.		8.		9.	
10.		11.		12.	
13.		14.		15.	
16.		17.		18.	
19.		20.		21.	
22.		23.		24.	
25.					

1. One hydrogen atom collides with a second hydrogen atom which is initially at rest in the laboratory. Both the atoms are in the ground state before the collision. What should be the minimum kinetic energy (in the laboratory frame) of the incident hydrogen atom so that one of the two atoms can be in its first excited state after the collision?
- (a) 3.4 eV
  - (b) 5.1 eV
  - (c) 10.2 eV
  - (d) 13.6 eV
  - (e) 20.4 eV
2. A proton of kinetic energy 1880 MeV is moving in a circular orbit in a plane perpendicular to a uniform magnetic field of strength 5 Tesla. What is the radius of the orbit?
- (a) 75.6 m
  - (b) 3.1 m
  - (c) 5.3 m
  - (d) 1.8 m
  - (e) 24.3 m
3. Consider a planet, of radius 5000 km, which is entirely in the liquid state and has a uniform density of  $5 \text{ gm/cm}^3$ . The planet is in equilibrium under the action of gravitational forces and hydrostatic pressure. The pressure at the centre of the planet is
- (a)  $90 \times 10^9 \text{ N/m}^2$
  - (b)  $360 \times 10^9 \text{ N/m}^2$
  - (c)  $180 \times 10^9 \text{ N/m}^2$
  - (d)  $270 \times 10^9 \text{ N/m}^2$
  - (e)  $540 \times 10^9 \text{ N/m}^2$

[Hint : (i) Consider the equilibrium of a small volume element at a distance  $r$  from the centre and (ii) pressure on the surface is zero.]

4. Two events occur in the space time continuum. Event  $A$  has coordinates (1 m, 2 m, 3 m, 0 s) and event  $B$  occurs at (2 m, 3 m, 4 m,  $\frac{10^{-8}}{3}$  s), where the 4th coordinate gives the time in seconds. The proper distance between these two events is given by

- (a) 2 m
- (b)  $\sqrt{3}$  m
- (c)  $\sqrt{2}$  m
- (d) 3 m
- (e) 1 m

5. An idealized ping-pong ball of mass  $m$  is bouncing on a recoilless table in one dimension. The energy of the ball is given by

$$E = mg \left( \frac{m^2 g}{h^2} \right)^\alpha$$

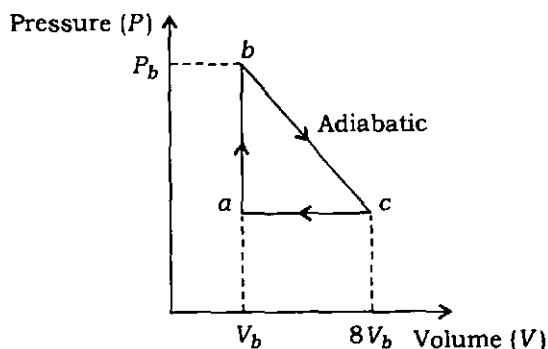
where  $g$  is the acceleration due to gravity and  $h$  is the Planck's constant. From dimensional analysis, the value of  $\alpha$  is given by

- (a)  $-\frac{1}{3}$
- (b)  $-1$
- (c) 3
- (d)  $\frac{2}{3}$
- (e) 0

6. Newton's rings are formed between two biconvex lenses of equal radii of curvature by reflected light of wavelength 5000 Å. If the distance between the 5th and the 15th dark rings is 0.085 cm, what is the radius of either lens?

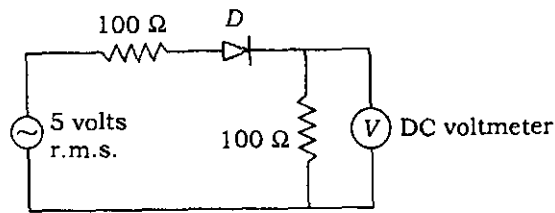
- (a) 109.7 cm
- (b) 71.29 cm
- (c) 107.9 cm
- (d) 75.6 cm
- (e) 105.4 cm

7. The visible spectrum has wavelength in the range of 400 nm to 700 nm. The angular spread of the first-order visible spectrum produced by a plane diffraction grating having  $6000 \text{ lines cm}^{-1}$ , when the light is incident normal to the grating is
- $8.9^\circ$
  - $9.9^\circ$
  - $10.9^\circ$
  - $11.9^\circ$
  - $12.9^\circ$
8. One mole of a monoatomic ideal gas is taken through the reversible cycle shown below. The path  $b \rightarrow c$  is an adiabatic expansion process with  $P_b = 10 \text{ atm}$  and  $V_b = 1 \times 10^{-3} \text{ m}^3$  :



- The efficiency of this cycle is closest to
- 0.75
  - 0.83
  - 0.41
  - 0.39
  - 0.62
9. Two reversible engines are connected in series. The first one receives heat at  $T^\circ \text{ K}$  and rejects heat at  $1527^\circ \text{ C}$ . The second one receives the heat rejected by the first at  $1527^\circ \text{ C}$  and then expels heat at  $527^\circ \text{ C}$ . Find the temperature  $T$  for equal efficiencies of the two engines.
- $3240^\circ \text{ K}$
  - $2800^\circ \text{ K}$
  - $2054^\circ \text{ K}$
  - $1000^\circ \text{ K}$
  - $3100^\circ \text{ K}$

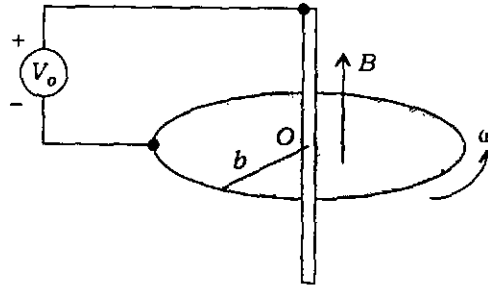
10. In the following circuit, the diode  $D$  is ideal. What is the reading in the DC voltmeter?



- (a) 3.18 volts  
 (b) 2.25 volts  
 (c) 4.50 volts  
 (d) 1.59 volts  
 (e) 1.85 volts
11. Let  $\vec{a}_1 = \hat{x}$  and  $\vec{a}_2 = (\sqrt{3}\hat{x} + \hat{y})/2$  be the primitive vectors of a two-dimensional lattice, where  $\hat{x}$  and  $\hat{y}$  are orthogonal unit vectors. If one of the corresponding reciprocal vectors is  $\vec{b}_2 = 4\pi\hat{y}$ , then the other one is
- (a)  $\vec{b}_1 = 2\pi(\hat{x} + \sqrt{3}\hat{y})$   
 (b)  $\vec{b}_1 = 2\pi(-\hat{x} + \sqrt{3}\hat{y})$   
 (c)  $\vec{b}_1 = 2\pi\hat{x}$   
 (d)  $\vec{b}_1 = 2\pi(\hat{x} - \sqrt{3}\hat{y})$   
 (e)  $\vec{b}_1 = 2\pi\sqrt{3}\hat{y}$
12. In the Debye model of the specific heat of solids, which of the following holds true?
- (a) The phonon frequencies are treated as independent of the wave vector and the low temperature specific heat behaves as  $C_v \propto T^3$   
 (b) Electron-electron repulsion is the key ingredient and the low temperature specific heat behaves as  $C_v \propto T$   
 (c) The phonon frequencies are taken to have the sound wave like dispersion and the low temperature specific heat behaves as  $C_v \propto T^3$   
 (d) The specific heat due to lattice vibrations is temperature independent  
 (e) The phonon frequencies are treated as independent of the wave vector and the low temperature specific heat behaves as  $C_v \propto T$

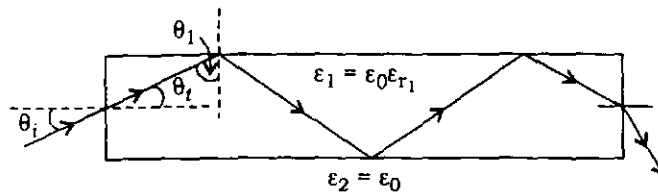


13. A circular metal disk (Faraday disk generator) is rotating with a constant angular velocity  $\omega$  in a uniform and constant magnetic field of flux density  $\vec{B} = \hat{a}_z B_0$  that is parallel to the axis of rotation. Determine the open-circuit voltage ( $V_o$ ) of the generator if the radius of the disk is  $b$ .



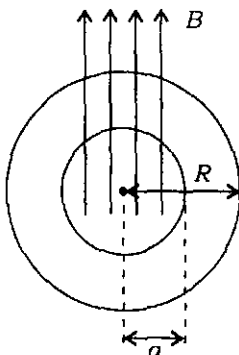
- (a)  $-\frac{\omega B_0 b^2}{2}$
- (b)  $\frac{\omega B_0 b^2}{2}$
- (c)  $\frac{\pi \omega B_0 b^2}{2}$
- (d)  $\pi \omega B_0 b^2$
- (e)  $-\frac{\omega B_0 b^2}{2\pi}$

14. A dielectric rod of a transparent material can be used to guide light under the condition of total internal reflection. What is the minimum dielectric constant of the guiding medium so that a wave incident on one end at any angle will be confined within the rod until it emerges from the other end?

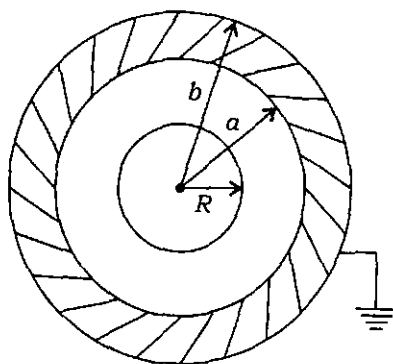


- (a)  $\sqrt{2}$
- (b) 1
- (c) 2
- (d) 1.5
- (e) 1.75

15. A wire carrying line-charge density  $\lambda$  is converted into a circular loop of radius  $R$ . Then it is suspended horizontally (with nonconducting spokes) so that it is free to rotate in the horizontal plane. A uniform magnetic field  $\vec{B}$  is applied in the central region (pointing up) out to radius  $a$  ( $R > a$ ). The angular momentum imparted to the loop when the field is turned off is given by



- (a)  $\pi B a^2$  (b) 0  
 (c)  $\pi R^2 \lambda a$  (d)  $\pi \lambda a^2 R b$   
 (e)  $\pi B \lambda^2$
16. A metal sphere of radius  $R$  with charge  $q$  is surrounded by a thick concentric spherical shell of inner radius  $a$  and outer radius  $b$ . The shell is grounded. The potential at the center of the sphere (with infinity as reference point) is given by



- (a)  $\frac{1}{4\pi\epsilon_0} \left( \frac{q}{b} + \frac{q}{R} - \frac{q}{a} \right)$  (b)  $\frac{1}{4\pi\epsilon_0} \left( \frac{q}{R} \right)$   
 (c)  $\frac{1}{4\pi\epsilon_0} \left( \frac{q}{b} - \frac{q}{R} \right)$  (d)  $\frac{1}{4\pi\epsilon_0} \left( \frac{q}{R} - \frac{q}{a} \right)$   
 (e)  $\frac{1}{4\pi\epsilon_0} \left( \frac{q}{R} + \frac{q}{a} \right)$

17. A dust particle of mass  $10^{-8}$  kg is at room temperature (300 K). Its de Broglie wavelength is nearest to
- (a)  $10^{-19}$  m
  - (b)  $10^{-15}$  m
  - (c)  $10^{-6}$  m
  - (d)  $10^{-9}$  m
  - (e)  $10^{-23}$  m
18. A quantum particle is confined in a one-dimensional box defined by the potential,  $V(x) = 0$  for  $0 < x < L$ , and  $+\infty$  otherwise. The particle is in the ground state. What is the probability ( $P_+$ ) that an experimenter will find it moving along the positive- $x$  direction? What would be the magnitude of momentum ( $p$ ) of that motion?
- (a)  $P_+ = 0$  and  $p = 0$
  - (b)  $P_+ = 1/2$  and  $p = \pi/L$
  - (c)  $P_+ = 1/2L$  and  $p = \pi/L$
  - (d)  $P_+ = 1/2$  and  $p = 0$
  - (e)  $P_+ = 0$  and  $p = \pi/L$
19. Let  $\Delta E_n$  be the energy difference between two adjacent energy levels ( $E_n$  and  $E_{n+1}$ ) for an electron confined to an one-dimensional infinite potential well. The ratio  $\frac{\Delta E_n}{E_n}$  in the limit of large quantum number  $n$  is given by
- (a)  $2/n$
  - (b)  $1/n$
  - (c)  $1/n^2$
  - (d) 0
  - (e)  $2n^2$

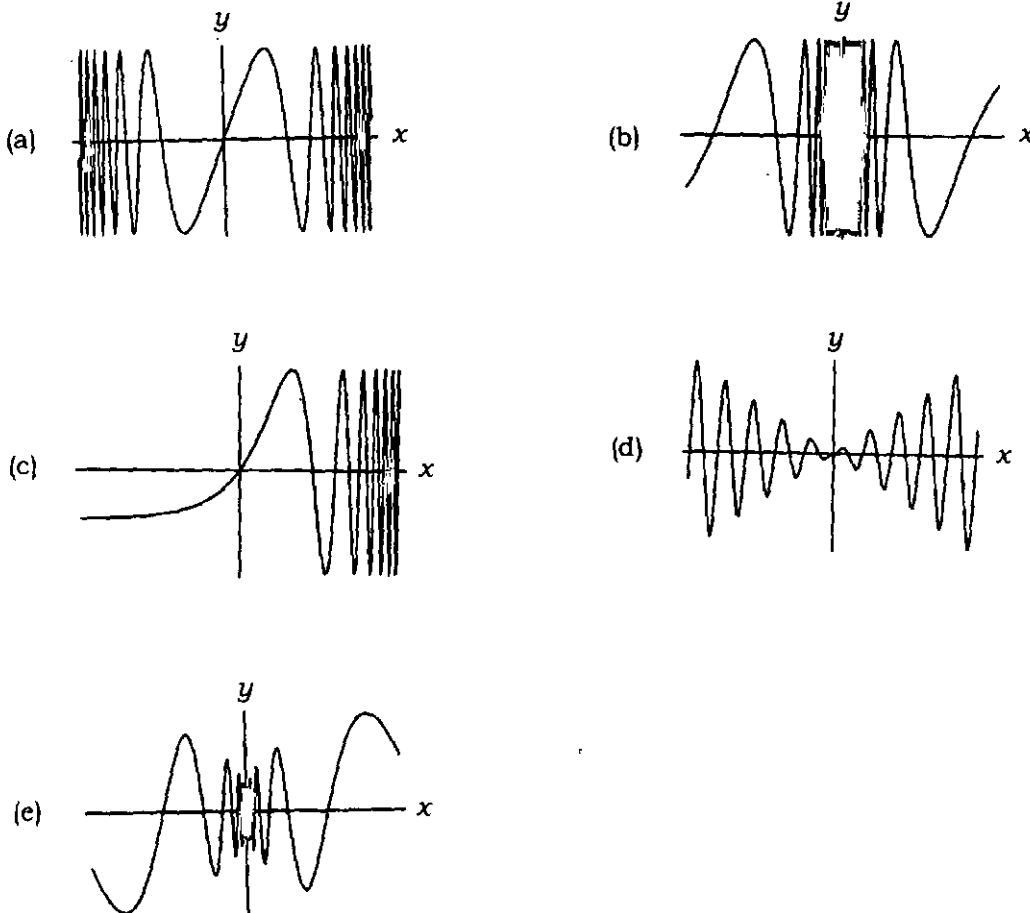
20. A photon is Compton-scattered off a stationary electron through an angle of  $45^\circ$ . If its final energy is half the initial energy, the value of the initial energy in MeV is closest to
- (a) 1.75
  - (b) 1.94
  - (c) 2.46
  - (d) 0.18
  - (e) 0.62
21. The line integral  $I = \int_{\Gamma} \mathbf{F} \cdot d\mathbf{x}$  of the vector field  $\mathbf{F} = yz\mathbf{i} + zx\mathbf{j} + xy\mathbf{k}$  is evaluated along the curve  $\Gamma$  parametrized by  $(x = a\sin t, y = b\cos t, z = c)$ , where  $a, b$  and  $c$  are constants. The value of  $I$  for  $\frac{\pi}{4} \leq t \leq \frac{3\pi}{4}$  is
- (a)  $abc$
  - (b)  $ab$
  - (c)  $bc$
  - (d)  $ac$
  - (e) 0
22. The general solution of the ordinary differential equation,  $\frac{d^2y}{dx^2} + y + 1 = 0$  is ( $A$  and  $B$  being constants)
- (a)  $x^2 + Ax + B$
  - (b)  $A(x - 1)^3 + B$
  - (c)  $A \sin x$
  - (d)  $A \sin(x + B)$
  - (e)  $A \cos x + B \sin x - 1$
23. What is the residue of the complex function  $f(z) = \exp(1/z)$  at  $z = 0$ ?
- (a) 1
  - (b) 0
  - (c) Undefined
  - (d)  $e$
  - (e)  $\infty$

24. Consider a monoatomic ideal (Boltzmann) gas in which the atoms carry magnetic moment  $\mu$ . The gas is placed in a magnetic field  $B\hat{z}$  pointing up. At a given temperature  $T$ , what is the average energy per atom due to the interaction with the magnetic field?

[Hint : Take into account that a certain fraction of atoms will have magnetic moment pointing up and a certain fraction will have them pointing down.]

- (a)  $-\mu B \tanh\left(\frac{\mu B}{k_B T}\right)$                       (b)  $\mu B \tanh\left(\frac{\mu B}{k_B T}\right)$
- (c)  $-\mu B \sinh\left(\frac{\mu B}{k_B T}\right)$                       (d)  $\mu B \sinh\left(\frac{\mu B}{k_B T}\right)$
- (e)  $-\mu B \tan\left(\frac{\mu B}{k_B T}\right)$

25. Which of the following graphs gives the best schematic representation of the real-valued function  $y = \sin(\sinh x)$  in an interval around  $x = 0$ ?



SPACE FOR ROUGH WORK

SPACE FOR ROUGH WORK

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