Use the following values for constants.

Acceleration due to gravity on Earth	g	10.00 m·s^{-2}
Boltzmann constant	k_B	1.38×10^{-23} J·K^{-1}
Current Mass of the Sun	M_s	2.00×10^{30} kg
Current Radius of the Sun	R_s	7.00×10^{8} m
Magnitude of the electron charge	e	1.60×10^{-19} C
Mass of the electron	m_e	9.11×10^{-31} kg
Mass of the proton	m_p	1.67×10^{-27} kg
Atomic Mass Unit	u	931.50 MeV/c^2
Permeability of free space	μ_0	1.26×10^{-6} H·m^{-1}
Permittivity of free space	ϵ_0	8.85×10^{-12} F·m^{-1}
Planck's constant	h	6.63×10^{-34} J·s
Avogadro Constant	N_A	6.02×10^{23} mol^{-1}
Speed of light in vacuum	c	3.00×10^{8} m·s^{-1}
Stefan-Boltzmann constant	σ	5.67×10^{-8} W·m$^{-2} \cdot$ K^{-4}
Universal Gas constant	R	8.31 J·K$^{-1} \cdot$ mol^{-1}
Universal Gravitational constant	G	6.67×10^{-11} kg^{-1}·m$^{3} \cdot$ s^{-2}
Wien's constant	b	2.90×10^{-3} m·K
π	$\approx$	3.14
$\ln 2$	$\approx$	0.69
$\ln 3$	$\approx$	1.10
$\ln 10$	$\approx$	2.30
Base of the Napierian logarithm e	$\approx$	2.72

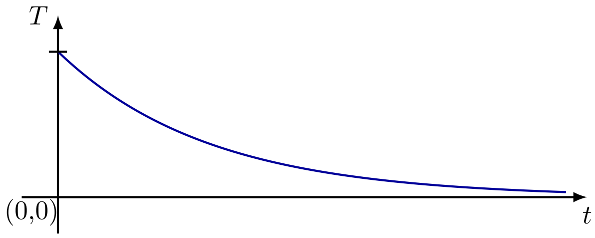
SET B

- The first 12 questions are multiple choice questions with only one answer correct. The candidate gets 2.5 marks for a correct answer and -1 for an incorrect answer.

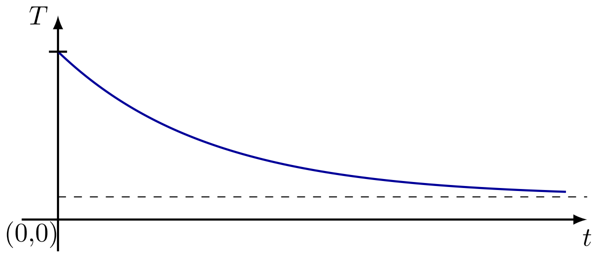
- Questions $13 - 17$ are multiple choice questions and more than one answer might be correct. The candidate gets 4 marks for selecting **all** the correct answers. There is no negative marking.

1. An arrow is released from a rigid bow at time $t = 0$. The magnitude of the tension (T) in the bowstring as a function of time is best desribed by

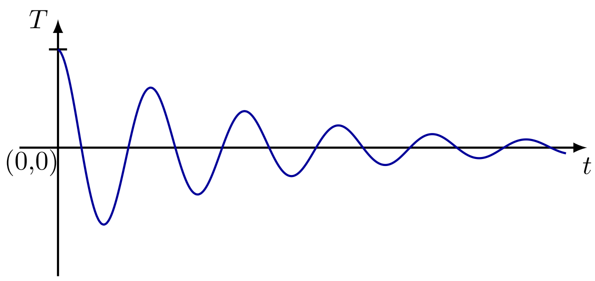
A.



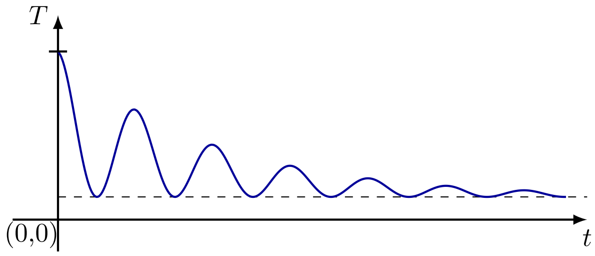
B.



C.



D.



2. Two air bubbles of equal initial volume rise from the bottom of a lake to the surface. One bubble ascends and expands adiabatically while the other bubble ascends and expands isothermally. Let V_A and V_T be the final volumes of the bubbles with adiabatic and isothermal expansions, respectively. Consider an ideal gas behaviour and note that γ is the adiabatic constant. Then,

   A. $V_A > V_T$

   B. $V_A < V_T$

   C. $V_A = V_T$

   D. $V_A = \gamma V_T$

3. A current I flows through a regular hexagonal loop of side length l. The magnitude of the magnetic field at the centre is

A. $\frac{\mu_0 I}{3\pi l}$

B. $\frac{\mu_0 I}{2\sqrt{3}\pi l}$

C. $\frac{\sqrt{3}\mu_0 I}{\pi l}$

D. $\frac{3\mu_0 I}{\pi l}$

4. A planet of mass m is orbiting around a non-rotating star of mass αm ($\alpha \gg 1$) with an orbital radius r. The star ejects mass λm ($\lambda \ll 1$) radially outwards in a spherically symmetric fashion. Neglecting any impact of ejected mass on the planet, the radius of new circular orbit of the planet is

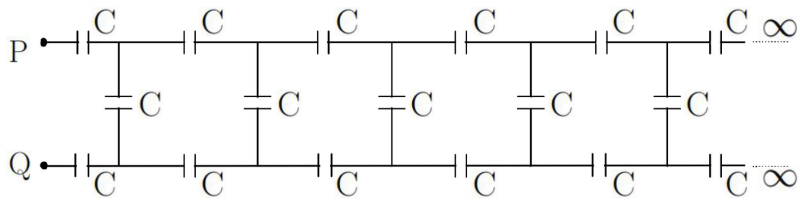
   A. $(1 + \frac{\lambda}{\alpha})^{-1} r$

   B. $(1 - \lambda\alpha)^{-1} r$

   C. $(1 + \lambda\alpha) r$

   D. $(1 - \frac{\lambda}{\alpha})^{-1} r$

5. The equivalent capacitance between P and Q for the infinite series of capacitors shown in the figure is



A. $\frac{C}{2}(\sqrt{3}+1)$

B. $\frac{C}{3}$

C. 3C

D. $\frac{\mathbf{C}}{2}(\sqrt{3}-1)$

6. The temperature and pressure at the summit of Mt. Everest is $-30°C$ and 0.27×10^5 N.m^{-2}, respectively. The corresponding values at sea-level are $27°C$ and 1×10^5 N.m^{-2}. Considering air to be an ideal gas, the ratio between the molecular number density at the summit of Mt. Everest to that at sea level is closest to

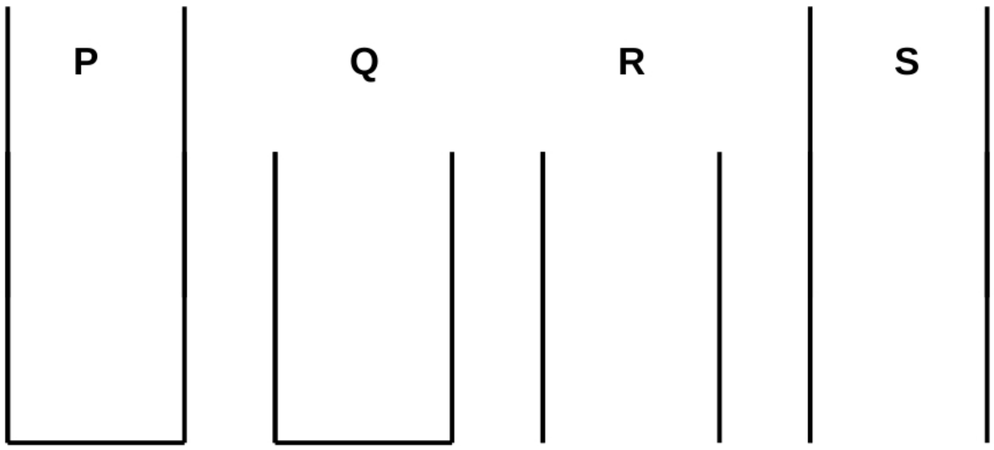
    A. 1:30

    B. 81:100

    C. 27:100

    D. 1:3

7. Consider the following four cylindrical tubes (P,Q,R,S) all of equal radii. The tubes Q and R are of length l. The tubes P and S are of length $1.5l$. If the fundamental frequencies are ν_P, ν_Q, ν_R and ν_S, respectively, then the correct option is



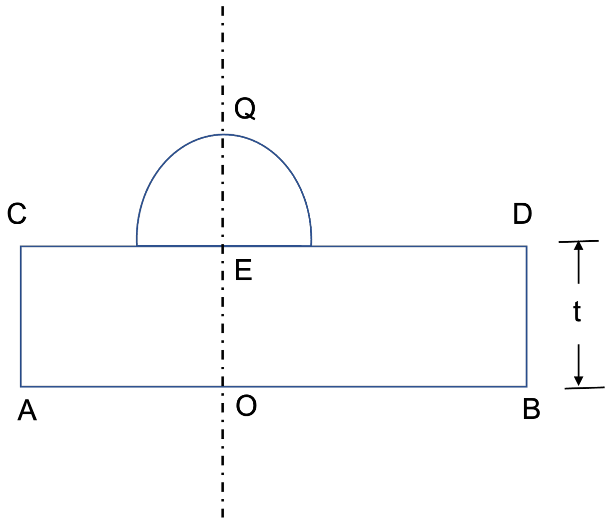
A. $\nu_R > \nu_S > \nu_P > \nu_Q$

B. $\nu_R > \nu_S > \nu_Q > \nu_P$

C. $\nu_S > \nu_R > \nu_Q > \nu_P$

D. $\nu_R > \nu_P > \nu_S > \nu_Q$

8. A transparent glass slab of thickness $t = 0.50$ cm is placed with its face AB on a horizontal table. A hemispherical water drop of radius $R = 0.33$ cm condenses on the glass slab as shown in figure. The refractive indices of the slab and the water drop are respectively 1.50 and 1.33. The image of the object at O on the face AB is viewed after refraction from the drop. Taking OEQ as the optical axis, the distance (cm) of the image from the point Q is



A. 1.40

B. 0.60

C. 0.72

D. 2.00

9. A beam of monochromatic light is incident on one face of a prism of angle 75°. If the angle of incidence is 60° and the refractive index of the prism is $\sqrt{3}$, then the correct option about the emergence of the beam from the opposite face is

   A. no emergence.

   B. grazing emergence.

   C. emergence with an angle of 60° from the normal.

   D. emergence with an angle of 30° from the normal.

10. In an isobaric process involving an ideal gas the mean distance between the molecules is quadrupled (four times). Then, the ratio of final to initial sound speeds is

   A. 1

   B. 2

   C. 8

   D. 4

11. Two radioactive samples X and Y have the same number of atoms initially $[N_X(t = 0) = N_Y(t = 0)]$. The half life $\tau^x_{1/2}$ of X is half the mean life of Y. Then the ratio $N_Y(t)/N_X(t)$ when $t = \tau^x_{1/2}$ is close to

A. 0.8

B. 1.0

C. 1.2

D. 1.4

12. Consider the Bohr model of the hydrogen atom. Suppose that the charge of the proton were $1.1e$ while the electron charge continued to be $-e$ but the masses for both remained unchanged. Then, the angular frequency of revolution ω_B of the electron would have

    A. remain unchanged.

    B. change to $\sqrt{1.1}\omega_B$.

    C. change to 1.1 ω_B.

    D. change to 1.21 ω_B**.**

The following questions may have more than one correct answer. Please select all the correct answers.

13. A heavy disc of radius R and mass M is placed horizontally. A small coin of mass m placed at a radial distance $R/2$ from the centre. The disc is now $(t = 0)$ given a constant angular acceleration of magnitude α rad $\cdot$ s^{-2} about a vertical axis passing through its centre . If μ_s and μ_d are the coefficients of static and dynamic friction, respectively, between the coin and the rotating disc, then

A. at $t > 0$, the force due to static friction acts radially inwards.

B. at $t > 0$, the magnitude of force due to static friction is always $F_s = \mu_s mg$.

C. the coin starts sliding at time $t = \frac{1}{\alpha}\sqrt{\frac{2\mu_s g}{R}}$.

D. the coin reaches the edge of the disc at time $t = \frac{2}{\alpha}\sqrt{\frac{(\mu_d - \mu_s)g}{R}}$.

14. An electromagnetic wave, travelling in vacuum, is represented by $\vec{E}=E_0\cos(kz-wt)\hat{y}$ where E_0 is the amplitude of the electric field. A square loop of side a ($a \ll 2\pi/k$) is placed in its path. Then, the correct option(s) is (are)

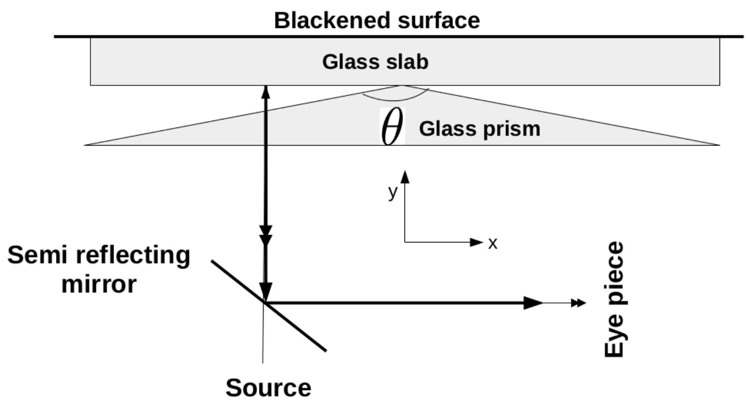
A. $\vec{B} = B_0\cos(kz - wt)\hat{x}$ **where** B_0=$-E_0/c$

B. The wave is travelling in the y-direction.

C. The induced emf is zero if the loop lies in the xz **plane.**

D. The induced emf is finite if the loop lies in the yz **plane.**

15. Consider the experimental set-up shown in the figure to observe the interference pattern. Note that the prism angle θ is close to π. The correct option(s) regarding this experiment is (are)



A. fringe width will increase with increasing angle θ.

B. fringe width will decrease with the refractive index of the lens.

C. fringe width will increase if the glass slab is lifted along y direction.

D. fringes will alternate between dark and bright if glass slab is lifted along y direction.

16. A current I is passing flowing through a thin copper slab placed on a diamond slab. The bottom surface of the diamond slab is maintained at 0° C and the remaining arrangment is thermally insulated from the surroundings. Note that diamond is an excellent thermal conductor but a poor electrical conductor. Then, the correct option(s) is(are)

   A. the steady-state temperature of the copper slab is directly proportional to the thickness of the diamond slab.

   B. the steady-state temperature of the copper slab depends upon the specific heat of the copper.

   C. if the current is supplied from a constant voltage source, the steady-state temperature of the copper slab will double when the its thickness is doubled.

   D. if the current is held constant, the steady-state temperature of the copper slab will be halved if its thickness is doubled.

17. The pair(s) with same dimensions is(are)

- **A. Pressure and Young's modulus**
- B. Power and energy flux
- **C. Gravitational potential and latent heat**
- **D. Rotational impulse and Planck's constant**