Engineering Daily 16 [Set 03] EV

Waves + Ideal Gas and Kinetic Theory of Gases

Total Marks: 50 **Negative Marks:** 0.25 **Time:** 1 Hour

MCQ 50 marks

1. An air bubble rising from the bottom of a lake to the surface expands to 5 times its initial volume. The water temperature at the bottom is 4°C and at the surface is 20°C. If the atmospheric pressure is 1.013×10^5 Pa and the density of water is 0.998×10^3 kgm^{-3}, what is the depth of the lake?

(A) 42.15 m (B) 40.82 m (C) 38.60 m (D) 38.03 m

2. Two glass bulbs of volumes 500 cc and 100 cc are connected by a narrow tube of negligible volume. Initially, the internal temperature is 20°C and the pressure is 70 cm Hg. If the 100 cc bulb is kept at 20°C and the 500 cc bulb is heated to 100°C, what will be the final internal pressure of the system?

(A) 85.23 cm Hg (B) 80.00 cm Hg
(C) 72.60 cm Hg (D) 90.15 cm Hg

3. A partially inflated balloon contains 500 m^3 of helium gas at 27°C and 1 atm pressure. What will be the volume of the helium gas at an altitude of 3000 m, where the pressure is 0.5 atm and the temperature is −3°C?

(A) 850 m^3 (B) 790 m^3 (C) 910 m^3 (D) 900 m^3

4. The temperature of an open room of volume 30 m^3 increases from 17°C to 27°C due to sunshine. If the atmospheric pressure in the room remains constant at 1×10^5 Pa, what will be the change in the number of molecules in the room ($n_i - n_f$) before and after heating?

(A) -2.5×10^{25} (B) 2.5×10^{25}
(C) -1.61×10^{23} (D) 1.38×10^{23}

5. At what temperature will the c_{rms} of SO_2 be equal to the c_{rms} of O_2 at 28°C?

(A) 602°C (B) 329 K (C) 329°C (D) 301 K

6. At what temperature will the root mean square speed of nitrogen molecules in the Earth's atmosphere be equal to the escape velocity of an object from the Earth's surface? Given: mass of an N_2 molecule = 4.65×10^{-26} kg, mean radius of the Earth = 6370 km, g = 980 cms^{-2} and Boltzmann constant = 1.37×10^{-16} ergK^{-1}

(A) 98520.40 K (B) 105230.15 K
(C) 250100.20 K (D) 141255.91 K

7. A vessel contains 1 mol of monatomic helium gas (f = 3) and 2 mol of diatomic oxygen gas (f = 5) mixed at 27°C. What is the total kinetic energy of the gas mixture?

(A) 2.49×10^4 J (B) 1.62×10^4 J
(C) 3.74×10^3 J (D) 1.25×10^4 J

8. If the absolute temperature is doubled ($T_2 = 2T_1$) and the pressure is tripled ($P_2 = 3P_1$), what will be the mean free path (λ_2) of an ideal gas relative to its initial value λ_1?

(A) $\lambda_2 = \frac{1}{6}\lambda_1$ (B) $\lambda_2 = 6\lambda_1$ (C) $\lambda_2 = \frac{2}{3}\lambda_1$ (D) $\lambda_2 = \frac{3}{2}\lambda_1$

9. The velocities of three particles are 24 ms^{-1}, 104 ms^{-1} and 114 ms^{-1} respectively. Which of the following statements is correct?

(A) The root mean square speed will be 9.5 ms^{-1} greater than the average speed
(B) The root mean square speed and the average speed will be equal
(C) The root mean square speed will be 24 ms^{-1} greater than the average speed
(D) The average speed will be 14 ms^{-1} greater than the root mean square speed

10. If the mean free path of gas molecules is 2.4×10^{-6} cm and the molecular diameter is 2.0×10^{-8} cm, what is the number of molecules per cubic centimetre?

(A) 3.5×10^{20} cm^{-3} (B) 3.2×10^{22} cm^{-3}
(C) 2.345×10^{26} cm^{-3} (D) 2.344×10^{20} cm^{-3}

11. At a place, the dry and wet bulb temperatures of a hygrometer are 30°C and 20°C respectively. If Glaisher's factor at 30°C is 1.65, what is the dew point of that place?

(A) 10.5°C (B) 13.5°C
(C) 15.0°C (D) 20.909°C

12. A person in Feni measured the tyre gauge pressure of his car as 1.8×10^5 Pa. At that time the temperature in that city was 30°C and the atmospheric pressure was 1.0×10^5 Pa. He then went to Bandarban, where the temperature was 15°C and the atmospheric pressure was 6.0×10^4 Pa. If the volume of the tyre remains unchanged in both places, what will be the tyre gauge pressure in Bandarban?

(A) 2.66×10^5 Pa (B) 1.50×10^5 Pa
(C) 1.80×10^5 Pa (D) 2.06×10^5 Pa

13. In an oxygen gas sample ($M = 32$ gmol^{-1}) the molecules have root mean square speed (c_{rms}), average speed (c_{avg}) and most probable speed (c_{mp}). If the absolute temperature of the container increases with time as $T(t) = T_0(1 + \alpha t)$, where $T_0 = 300$ K and $\alpha = 0.02$ s^{-1}, what is the rate of change $\frac{d}{dt}(c_{rms} \cdot c_{avg} \cdot c_{mp})$ at t = 25 s? (R = 8.314 Jmol^{-1}K^{-1})

(A) 3.125×10^6 m^{3}s^{-4} (B) 1.562×10^8 m^{3}s^{-4}
(C) 2.455×10^4 m^{3}s^{-4} (D) 5.208×10^5 m^{3}s^{-4}

14. A vertical cylinder of height $H = 10\ m$ and cross-sectional area $A = 0.1\ m^2$ contains an ideal gas at constant pressure ($P = 1 \times 10^5\ Pa$). The temperature inside varies with height z as $T(z) = T_0(1 + \alpha z)$, where $T_0 = 300\ K$ and $\alpha = 0.1\ m^{-1}$. By integrating the molar density along the height, find the total number of moles n of the gas.

(A) 27.79 mol (B) 15.20 mol

(C) 40.09 mol (D) 50.00 mol

15. At 20°C the relative humidity of a room is 50%. If the saturated vapour pressures at 20°C, 10°C and 9°C are 17.5 mm Hg, 9.2 mm Hg and 8.6 mm Hg respectively, what is the dew point of the room?

(A) 10.00°C (B) 9.50°C

(C) 9.25°C (D) 8.75°C

16. 1 mol of a monatomic ideal gas undergoes a non-isothermal process in which the pressure varies with volume as $P = P_0 - \alpha V^2$. Here $P_0 = 4 \times 10^5\ Pa$ and $\alpha = 1 \times 10^5\ Pam^{-6}$. Calculate the maximum temperature T_{max} reached by the gas during this process.

(A) 18500.50 K (B) 48120.15 K

(C) 25000.00 K (D) 37036.34 K

17. 1 mol of monatomic helium gas at 67°C is mixed with 1 mol of monatomic argon gas at 37°C. If there is no heat exchange with the surroundings, what will be the final equilibrium temperature of the mixture?

(A) 57°C (B) 325°C (C) 52°C (D) 47°C

18. On a winter day the air temperature inside a room is 0°C and the room contains 250 mol of diatomic air molecules. A closed cylinder inside the room contains 5 mol of monatomic helium gas at 60°C. If the cylinder suddenly bursts and all the helium spreads into the room with no heat exchange with the surroundings, what will be the final temperature of the mixture?

(A) 0.71°C (B) 0.00°C

(C) 1.20°C (D) 2.50°C

19. The temperature of a room is 30°C and its dew point is 15°C. If Glaisher's factor at 30°C is 1.65, what is the wet bulb temperature of the hygrometer? Furthermore, if the saturated vapour pressures at 30°C and 26°C are 31.83 mm Hg and 25.25 mm Hg respectively, and the relative humidity of the outdoor air at 26°C is 65%, in which direction will water vapour flow when the window is opened? The relative humidity of the room at 30°C is 50%.

(A) 15.00°C, there will be no flow.

(B) 20.91°C, vapour will flow from outside into the room.

(C) 18.50°C, vapour will flow from outside into the room.

(D) 20.91°C, vapour will flow from the room to the outside.

20. Two vessels of equal volume contain 48 g of oxygen (O_2) and 8 g of helium (He) gas respectively. The temperatures of the vessels are 60°C and 20°C respectively. If they are connected by a tube of negligible volume, what will be the final equilibrium temperature of the whole system?

(A) 42.22°C (B) 38.72°C

(C) 50.00°C (D) 28.50°C

21. A tuning fork of a specific frequency produces waves in air at a speed of $345\ ms^{-1}$ and in water at $1425\ ms^{-1}$. If the difference in wavelength between water and air is 3.375 m, what is the frequency of the tuning fork?

(A) 280 Hz (B) 320 Hz (C) 400 Hz (D) 350 Hz

22. A person standing between two vertical cliffs fires a gun. He hears the first echo after 1.5 s and the second echo after 2.5 s. If the speed of sound in air is $340\ ms^{-1}$, what is the distance between the two cliffs, and how long after the second echo will the third echo be heard?

(A) 680 m, 1.0 s (B) 1360 m, 2.0 s

(C) 510 m, 1.0 s (D) 680 m, 1.5 s

23. The equation of a progressive wave in SI units is $y = 0.05 \sin(100\pi t - 2\pi x)$. What is the ratio of the maximum particle velocity to the wave velocity?

(A) 0.1π (B) 0.5π

(C) 1.0π (D) 0.2π

24. The equation of a progressive wave is $y = 0.1 \sin \pi(200t - 4x)$ (all quantities in MKS units). What will be the displacement and velocity of a particle at position $x = 0.5\ m$ at time $t = 0.02\ s$?

(A) 0.1 m, 0 ms^{-1} (B) 0.05 m, 10 ms^{-1}

(C) 0 m, 20π ms^{-1} (D) 0 m, 0 ms^{-1}

25. The equation of a progressive wave on a stretched string in SI units is $y = 0.05 \sin(100\pi t - 2\pi x)$. If the density of the string material is $\rho = 8000\ kgm^{-3}$ and the wave velocity is $v = 50\ ms^{-1}$, what are the maximum particle acceleration ($a_{p,max}$) and the intensity (I) carried by the wave?

(A) $500\pi^2\ ms^{-2}$, $10^7\pi^2\ Wm^{-2}$

(B) $500\pi^2\ ms^{-2}$, $5 \times 10^6\pi^2\ Wm^{-2}$

(C) $250\pi^2\ ms^{-2}$, $2.5 \times 10^6\pi^2\ Wm^{-2}$

(D) $100\pi^2\ ms^{-2}$, $5 \times 10^6\pi^2\ Wm^{-2}$

26. A stretched wire of length $L = 0.5\ m$ and linear mass density $m = 0.01\ kgm^{-1}$ produces its fundamental note under a tension $T_1 = 400\ N$. Increasing the tension by a small amount ΔT raises the fundamental frequency by 2 Hz. Using differentiation, determine the change in tension ΔT and the initial wave velocity.

(A) 8 N, 100 ms^{-1} (B) 16 N, 400 ms^{-1}

(C) 4 N, 200 ms^{-1} (D) 8 N, 200 ms^{-1}

27. The equation of a stationary wave on a stretched string is $y = 0.04\sin(2\pi x)\cos(100\pi t)$ (in SI units). If the linear mass density of the string is $m = 0.02\ \text{kgm}^{-1}$, what is the total mechanical energy stored in a segment of length equal to one wavelength (λ), found by integration?

(A) $0.08\pi^2$ J (B) $0.32\pi^2$ J

(C) $0.16\pi^2$ J (D) $0.04\pi^2$ J

28. The power emitted by a sound source is $P_{source} = 40\pi$ W. If the density of air is $\varrho = 1.29\ \text{kgm}^{-3}$ and the speed of sound is $v = 350\ \text{ms}^{-1}$, at what distance from the source will the sound intensity level be 100 dB, and what is the effective (root mean square) sound pressure (P_{rms}) at that point?

(A) 100.00 m, 1.290 Nm^{-2} (B) 10.00 m, 4.250 Nm^{-2}

(C) 31.62 m, 2.125 Nm^{-2} (D) 31.62 m, 4.515 Nm^{-2}

29. Two progressive waves of the same frequency, $y_1 = 0.03\sin(100\pi t)$ and $y_2 = 0.04\cos(100\pi t)$ (in SI units), superimpose on the same particle. What are the resultant amplitude (A) and, by differentiation, the maximum particle velocity ($v_{p,max}$) and maximum particle acceleration ($a_{p,max}$)?

(A) 0.01 m, $\pi\ \text{ms}^{-1}$, $100\pi^2\ \text{ms}^{-2}$

(B) 0.05 m, $5\pi\ \text{ms}^{-1}$, $500\pi^2\ \text{ms}^{-2}$

(C) 0.05 m, $2.5\pi\ \text{ms}^{-1}$, $250\pi^2\ \text{ms}^{-2}$

(D) 0.07 m, $7\pi\ \text{ms}^{-1}$, $700\pi^2\ \text{ms}^{-2}$

30. The sound intensity level at a distance of 10 m from a loudspeaker is 80 dB. If 9 identical loudspeakers of the same power are placed together at the same spot, what will be the new sound intensity level at a distance of 30 m from the source?

(A) 90 dB (B) 70.46 dB (C) 89.54 dB (D) 80 dB

31. If the density of air is $\varrho = 1.2\ \text{kgm}^{-3}$ and the speed of sound in air is $v = 330\ \text{ms}^{-1}$, what is the pressure amplitude (P_{max}) of sound at an intensity level of 100 dB?

(A) 2.814 Nm^{-2} (B) 7.920 Nm^{-2}

(C) 1.980 Nm^{-2} (D) 3.960 Nm^{-2}

32. A stretched wire of length $L_1 = 0.8$ m under tension $T_1 = 100$ N has a fundamental frequency $f_1 = 200$ Hz. If the tension is increased by 44% and the length is decreased by 20%, what will be the new fundamental frequency f_2?

(A) 400 Hz (B) 360 Hz (C) 300 Hz (D) 240 Hz

33. 24 tuning forks are arranged in order of increasing frequency. Any two consecutive forks produce 4 beats per second when sounded together. If the frequency of the last fork is double that of the first, what are the frequencies of the 1st and 24th forks respectively?

(A) 88 Hz, 176 Hz (B) 92 Hz, 196 Hz

(C) 92 Hz, 184 Hz (D) 96 Hz, 192 Hz

34. The equation of a progressive wave in SI units is $y = 0.02\sin\pi(100t - 2x)$. If the density of the medium through which the wave travels is $\varrho = 1.2\ \text{kgm}^{-3}$, what is the energy density (u) of the wave in the medium?

(A) 23.69 Jm^{-3} (B) 47.37 Jm^{-3}

(C) 5.92 Jm^{-3} (D) 11.84 Jm^{-3}

35. The fundamental frequency of an open organ pipe of length L_o is equal to the third harmonic (1st overtone) of a closed organ pipe of length L_c. What is the ratio of their lengths $\frac{L_o}{L_c}$?

(A) 1.500 (B) 0.667 (C) 1.333 (D) 0.750

36. A metal wire of density $\varrho = 8000\ \text{kgm}^{-3}$ and radius $r = 0.5$ mm is stretched under a tension of $T = 157$ N. What is the velocity of transverse waves along the wire?

(A) 312.40 ms^{-1} (B) 100.00 ms^{-1}

(C) 225.50 ms^{-1} (D) 158.07 ms^{-1}

37. A loudspeaker placed in an open field emits sound of power 100 W. If a listener at a distance of 10 m from the source moves back to a distance of 50 m, what will be the decrease in sound intensity level ($\Delta\beta$) and the new sound intensity (I_2)?

(A) 6.99 dB, $1.59 \times 10^{-3}\ \text{Wm}^{-2}$

(B) 13.98 dB, $3.18 \times 10^{-3}\ \text{Wm}^{-2}$

(C) 20.00 dB, $3.18 \times 10^{-3}\ \text{Wm}^{-2}$

(D) 13.98 dB, $7.96 \times 10^{-2}\ \text{Wm}^{-2}$

38. Two wires of lengths $L_1 = 0.5$ m and $L_2 = 0.5$ m with linear mass densities $m_1 = 0.01\ \text{kgm}^{-1}$ and $m_2 = 0.04\ \text{kgm}^{-1}$ are joined end to end to form a compound wire of total length 1.0 m. The wire is under a tension $T = 100$ N. If a stationary wave is formed with a node at the junction, what is its minimum frequency?

(A) 50 Hz (B) 150 Hz (C) 100 Hz (D) 200 Hz

39. A vibrating tuning fork is held at the open end of a closed organ pipe. The equation of the wave produced is $y = 0.1\sin(3500\pi t - 10\pi x)$ (SI units). Which of the following can be the length of the pipe for resonance, and what is the wave velocity in the medium?

(A) 0.65 m, 175 ms^{-1} (B) 0.65 m, 350 ms^{-1}

(C) 0.40 m, 700 ms^{-1} (D) 0.50 m, 350 ms^{-1}

40. A balloon of fixed volume can carry a maximum mass of 175 kg at sea level at pressure $P_1 = 1.0 \times 10^5$ Pa and temperature $T_1 = 300$ K. Neglecting the mass of the balloon and of the gas inside it, the carrying capacity is taken to be proportional to the density of the surrounding air. What maximum mass can the balloon carry at $P_2 = 0.75 \times 10^5$ Pa and $T_2 = 330$ K?

(A) 119.3 kg (B) 159.1 kg

(C) 144.4 kg (D) 131.3 kg

41. A person standing at some distance from a cliff claps at regular intervals. When the clapping rate is 40 claps per minute, he does not hear distinct echoes (each echo coincides with the next clap). After moving 90 m closer to the cliff and clapping at 60 claps per minute, he again does not hear distinct echoes. What were the person's initial distance from the cliff and the speed of sound in air?

(A) 180 m, 340 ms^{-1} (B) 360 m, 330 ms^{-1}

(C) 240 m, 320 ms^{-1} (D) 270 m, 360 ms^{-1}

42. The equation of a stationary wave is $y = 5\sin(\frac{\pi x}{3})\cos(40\pi t)$ (where x, y are in cm and t is in s). What are the amplitude and wave velocity of each of the two progressive waves whose superposition forms this stationary wave, and what is the distance between two adjacent nodes?

(A) 2.5 cm, 40 cms^{-1}, 3 cm

(B) 5.0 cm, 120 cms^{-1}, 6 cm

(C) 5.0 cm, 40 cms^{-1}, 1.5 cm

(D) 2.5 cm, 120 cms^{-1}, 3 cm

43. A rocket launches vertically upward from a launchpad at a constant speed of 150 ms^{-1}. At the moment of launch, Elon and Jeff start walking towards the launchpad from opposite sides at speeds of 30 ms^{-1} and 35 ms^{-1} respectively. The rocket explodes 5 s after launch, and the sound produced is described by $y = 0.05\sin(69.53\pi t + 0.6283x)$ (SI units). If Elon and Jeff hear the sound 5 s and 7 s after the explosion respectively, what was the distance between them at the instant Jeff heard the sound?

(A) 3.823 km (B) 3.883 km

(C) 4.603 km (D) 3.953 km

44. A tuning fork B of frequency 256 Hz produces 8 beats per second with the fundamental note of an open organ pipe. Attaching wax to B decreases the beat frequency. If the speed of sound in air is 285.25 ms^{-1}, what is the initial length of the pipe, and by how much must its length be changed to bring it into resonance with the unwaxed fork B?

(A) 57.51 cm, the length must be decreased by 1.80 cm

(B) 57.51 cm, the length must be increased by 1.80 cm

(C) 55.71 cm, the length must be decreased by 1.80 cm

(D) 54.00 cm, the length must be increased by 1.71 cm

45. The intensity level of a sound wave travelling in air is 100 dB. If the density of air is 1.29 kgm^{-3} and the speed of sound is 350 ms^{-1}, what are the pressure amplitude (P_{max}) of the sound wave and the total energy flowing per second through an area of 2 m^2 perpendicular to the direction of propagation?

(A) 2.124 Nm^{-2}, 0.01 W (B) 3.005 Nm^{-2}, 0.04 W

(C) 3.005 Nm^{-2}, 0.02 W (D) 4.248 Nm^{-2}, 0.04 W

46. A 40 cm long wire stretched by a load of 2 kg is in resonance with a tuning fork in its fundamental mode. If the load is increased to 2.5 kg, by how much must the length of the wire be changed so that it remains in unison with the same tuning fork?

(A) +2.36 cm (B) +4.72 cm

(C) −4.72 cm (D) +5.00 cm

47. At 26°C, the relative humidity of a place is 70%. The saturated vapour pressure of water at this temperature is 25.21 mm Hg. The air is cooled at constant volume to 18°C. If the saturated vapour pressure at 18°C is 15.48 mm Hg, what percentage of the initial water vapour will condense?

(A) 12.28% (B) 7.62%

(C) 9.87% (D) 15.48%

48. At standard temperature and pressure (STP), the mean free path of oxygen molecules is 9.5×10^{-8} m. What is the mean time between two successive collisions? ($M = 32$ g mol^{-1}, $R = 8.314$ J $mol^{-1}K^{-1}$)

(A) 2.24×10^{-10} s (B) 2.06×10^{-10} s

(C) 4.12×10^{-10} s (D) 1.50×10^{-8} s

49. A planet has a temperature of 527°C and a mean density of 5.5×10^3 kg m^{-3}. Taking the root-mean-square speed c_{rms} of oxygen molecules equal to the planet's escape velocity v_{esc} as the limiting condition, what is the minimum radius of the planet? ($G = 6.67 \times 10^{-11}$ N m^2kg^{-2}, $M = 32$ g mol^{-1}, $R = 8.31$ J $mol^{-1}K^{-1}$)

(A) 6370 km (B) 850 km

(C) 320 km (D) 450 km

50. At 27°C, the total pressure of a mixture of dry air and saturated water vapour in a closed container is 1.07×10^5 N m^{-2}. The saturated vapour pressure at that temperature is 3.7×10^3 N m^{-2}. If the container is heated to 40°C, what will be the final total pressure inside? (Assume there is no liquid water in the container and the vapour behaves as an ideal gas.)

(A) 1.25×10^5 N m^{-2} (B) 1.12×10^5 N m^{-2}

(C) 0.98×10^5 N m^{-2} (D) 1.07×10^5 N m^{-2}