Engineering Daily 16 [Set 04] EV

Waves + Ideal Gas and Kinetic Theory of Gases

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

MCQ 50 marks

1. A balloon of skin mass 2 kg and volume 10 m^3 contains helium gas ($M = 4\ gmol^{-1}$) at 300 K. The atmospheric density varies with altitude z as $\varrho_{air}(z) = \varrho_0 e^{-\frac{z}{z_0}}$, where $\varrho_0 = 1.2\ kgm^{-3}$ and $z_0 = 8000$ m. If the surface pressure is 1.0×10^5 Pa, calculate the maximum equilibrium altitude z_{max}. (Take the balloon volume as fixed and the amount of helium inside as set at 1.0×10^5 Pa at the surface; $g = 9.8\ ms^{-2}$, $R = 8.314\ Jmol^{-1}K^{-1}$)

(A) 8000 m (B) 5400 m (C) 12000 m (D) 9624 m

2. A gas mixture contains 2 mol of a monatomic ideal gas (f = 3) and 3 mol of a rigid diatomic ideal gas (f = 5). What is the effective degree of freedom (f_{eff}) of the mixture?

(A) 4.20 (B) 4.00 (C) 3.80 (D) 4.50

3. In an ideal gas kept at temperature T, the most probable speed (c_{mp}) of the molecules is $400\ ms^{-1}$. What is the average speed (c_{avg}) of the molecules at the same temperature?

(A) $512.10\ ms^{-1}$ (B) $489.90\ ms^{-1}$
(C) $451.35\ ms^{-1}$ (D) $400.00\ ms^{-1}$

4. A container holds 2 mol of water vapour (H_2O, non-linear triatomic gas, f = 6) at 400 K. What is the total internal kinetic energy of the 2 mol of gas? ($R = 8.314\ Jmol^{-1}K^{-1}$)

(A) 29.93 kJ (B) 19.95 kJ (C) 39.91 kJ (D) 9.98 kJ

5. Ideal gas molecules undergo elastic collisions with a container wall of area 0.25 m^2. The number of molecules striking per unit area per second with speeds between v and v + dv is n(v) dv, where $n(v) = Cv^3$ and $C = 1.0 \times 10^{12}\ s^3m^{-6}$. For speeds ranging from $100\ ms^{-1}$ to $500\ ms^{-1}$, and with each molecule having mass $m = 5.0 \times 10^{-26}$ kg, calculate the total force F exerted on the wall.

(A) 0.2450 N (B) 0.1562 N (C) 0.0250 N (D) 0.1500 N

6. An oxygen cylinder of volume $1 \times 10^{-2}\ m^3$ contains oxygen gas at 300 K and a pressure of $2.5 \times 10^5\ Nm^{-2}$. Keeping the temperature constant, some oxygen is released until the pressure drops to $1.3 \times 10^5\ Nm^{-2}$. What mass of oxygen was released? (Molar mass of oxygen $M = 32\ gmol^{-1}$, $R = 8.314\ Jmol^{-1}K^{-1}$)

(A) 32.00 g (B) 8.50 g (C) 15.40 g (D) 24.12 g

7. Two ideal gases A ($M_A = 4\ gmol^{-1}$) and B ($M_B = 16\ gmol^{-1}$) are at temperatures $T_A = 300$ K and $T_B = 1200$ K respectively. What is the ratio of c_{rms} of gas A to c_{rms} of gas B ($\frac{c_{rms,A}}{c_{rms,B}}$)?

(A) 4.0 (B) 0.5 (C) 2.0 (D) 1.0

8. The absolute temperature T of an ideal gas kept at constant pressure (P = constant) is increased to four times ($T_2 = 4T_1$). What will the mean collision frequency (f_c) of the molecules be relative to its initial value f_{c1}?

(A) $f_{c2} = 0.25f_{c1}$ (B) $f_{c2} = 0.5f_{c1}$
(C) $f_{c2} = 2f_{c1}$ (D) $f_{c2} = 4f_{c1}$

9. If 10 g of oxygen gas ($M = 32\ gmol^{-1}$) is enclosed in a vessel at 30°C, what is the total internal kinetic energy of the molecules? (Since oxygen is a diatomic gas, f = 5, $R = 8.314\ Jmol^{-1}K^{-1}$)

(A) 1180.85 J (B) 1968.08 J
(C) 2361.70 J (D) 1476.06 J

10. At 300 K, the effective diameter of the molecules of an ideal gas is 2.5×10^{-10} m and the number of molecules per cubic metre is $6.02 \times 10^{25}\ m^{-3}$. If the root-mean-square speed of the molecules is $c_{rms} = 500\ m\ s^{-1}$, what is the mean collision frequency (f_c) of a molecule?

(A) $8.36 \times 10^9\ s^{-1}$ (B) $4.18 \times 10^9\ s^{-1}$
(C) $1.67 \times 10^{10}\ s^{-1}$ (D) $7.70 \times 10^9\ s^{-1}$

11. The dry and wet bulb temperatures of a room are 30°C and 20°C respectively. Glaisher's factor at 30°C is 1.65. If the saturated vapour pressures at 30°C and at the dew point temperature (13.5°C) are 31.83 mm Hg and 11.61 mm Hg respectively, what is the relative humidity of the room?

(A) 36.47% (B) 42.15% (C) 62.80% (D) 50.00%

12. 1 mol of a monatomic ideal gas expands from volume $V_1 = 1$ L ($1 \times 10^{-3}\ m^3$) to $V_2 = 4$ L ($4 \times 10^{-3}\ m^3$) following $P(V) = P_0(\frac{V}{V_0})^{1/2}$, where $P_0 = 1.0 \times 10^5$ Pa and $V_0 = 1 \times 10^{-3}\ m^3$. Calculate the total work done by the gas.

(A) 233.33 J (B) 300.00 J (C) 466.67 J (D) 700.00 J

13. An air bubble formed at the bottom of a 40 m deep lake (where the temperature is 7°C) rises to the surface (where the temperature is 27°C and the atmospheric pressure is 1.013×10^5 Pa). If the density of water is $1000\ kgm^{-3}$ and $g = 9.8\ ms^{-2}$, what is the ratio of the final volume to the initial volume ($\frac{V_2}{V_1}$) of the bubble on reaching the surface?

(A) 3.50 (B) 6.10 (C) 4.87 (D) 5.22

14. The displacement equation of a wave propagating in a medium in SI units is $y = 0.2\sin(200\pi t - 4\pi x)$, where x and y are in metres and t is in seconds. What is the propagation velocity of the wave?

(A) $25\ ms^{-1}$ (B) $100\ ms^{-1}$
(C) $50\ ms^{-1}$ (D) $12.5\ ms^{-1}$

15. In a closed container at an absolute temperature of 300 K, the root mean square speed of helium gas molecules is measured to be 1368 ms^{-1}. What will be the root mean square speed of oxygen gas molecules ($M = 32\ gmol^{-1}$) in another vessel of equal volume at the same temperature? (Molar mass of helium $M_{He} = 4\ gmol^{-1}$)

(A) 684.00 ms^{-1} (B) 241.83 ms^{-1}

(C) 342.00 ms^{-1} (D) 483.66 ms^{-1}

16. A cylinder kept at a constant temperature of 27°C contains 0.5 mol of a monatomic ideal gas. Considering only the translational kinetic energy of the molecules, with degrees of freedom f = 3, what is the total kinetic energy of the gas molecules? ($R = 8.314\ Jmol^{-1}K^{-1}$)

(A) 1870.65 J (B) 1247.10 J

(C) 3741.30 J (D) 2494.20 J

17. At a specific pressure and temperature, the effective diameter of ideal gas molecules is 2.0×10^{-10} m and the number of molecules per cubic metre is $3.0 \times 10^{25}\ m^{-3}$. Using Maxwell's molecular collision theory, calculate the mean free path between two consecutive collisions of the gas molecules.

(A) 5.305×10^{-7} m (B) 2.653×10^{-7} m

(C) 1.876×10^{-7} m (D) 1.326×10^{-7} m

18. At a weather observation station the daytime air temperature was recorded as 25°C, and the dew point of the air was found to be 15°C. If the saturated vapour pressures at 25°C and 15°C are 23.76 mm Hg and 12.79 mm Hg respectively, what is the relative humidity (in percent) of the air recorded at that station?

(A) 60.50% (B) 53.83% (C) 75.20% (D) 42.10%

19. A 10 L fixed-volume closed vessel contains a mixture of 0.4 mol of nitrogen (N_2) gas and 0.6 mol of oxygen (O_2) gas at 27°C. Assuming no chemical reaction occurs between the gases, what is the total pressure in the vessel by Dalton's law of partial pressures? ($R = 0.0821\ Latmmol^{-1}K^{-1}$)

(A) 4.926 atm (B) 3.695 atm

(C) 1.231 atm (D) 2.463 atm

20. How many gas molecules are present in a small glass vessel of volume 1 cm^3 at 27°C and a standard atmospheric pressure of 1.013×10^5 Pa? (Boltzmann constant $k = 1.38 \times 10^{-23}\ JK^{-1}$)

(A) 2.687×10^{19} (B) 2.447×10^{19}

(C) 1.223×10^{19} (D) 6.023×10^{23}

21. If the mean free path of a gas according to the elementary collision theory is $\lambda_0 = 2.0 \times 10^{-7}$ m, what is the mean free path λ_M of the same gas according to Maxwell's collision theory?

(A) $\lambda_M = 1.500 \times 10^{-7}$ m (B) $\lambda_M = 2.828 \times 10^{-7}$ m

(C) $\lambda_M = 1.000 \times 10^{-7}$ m (D) $\lambda_M = 1.414 \times 10^{-7}$ m

22. The density of a gas at standard temperature and pressure (STP) is 1.43 kgm^{-3}. The gas is transferred to a heated chamber at constant atmospheric pressure, raising its temperature to 91°C. Using Charles's law at constant pressure, calculate the new density of the gas.

(A) 1.07 kgm^{-3} (B) 0.85 kgm^{-3}

(C) 1.25 kgm^{-3} (D) 1.91 kgm^{-3}

23. An air bubble formed at the bottom of a deep lake expands to 4 times its initial volume on reaching the water surface. The atmospheric pressure at the surface is 10^5 Pa and the density of water is 1000 kgm^{-3}. Using Boyle's law and assuming constant temperature, calculate the depth of the lake. ($g = 9.8\ ms^{-2}$)

(A) 40.82 m (B) 10.20 m

(C) 30.61 m (D) 20.41 m

24. 2 mol of oxygen gas ($M = 32\ gmol^{-1}$, f = 5) is kept in a rigid vessel at an initial temperature $T_1 = 300$ K. Heat is supplied at constant volume until the pressure doubles ($P_2 = 2P_1$). What is the ratio $\frac{c_{avg,2}}{c_{mp,1}}$ of the average speed at the final temperature to the most probable speed at the initial temperature?

(A) 2.26 (B) 1.22 (C) 1.60 (D) 1.41

25. Nitrogen gas ($M = 28\ gmol^{-1}$, molecular diameter $d = 2.5 \times 10^{-10}$ m) is contained in a chamber at $T = 300$ K and $P = 1.013 \times 10^5$ Pa. Using Maxwell's mean free path λ and the rms speed c_{rms}, calculate the mean collision time between two collisions ($T_c = \frac{\lambda}{c_{rms}}$) for the nitrogen molecules. ($k = 1.38 \times 10^{-23}\ JK^{-1}$, $R = 8.314\ Jmol^{-1}K^{-1}$)

(A) $T_c = 1.42 \times 10^{-10}$ s (B) $T_c = 2.85 \times 10^{-10}$ s

(C) $T_c = 3.52 \times 10^{-10}$ s (D) $T_c = 5.68 \times 10^{-10}$ s

26. A tuning fork of frequency 500 Hz produces longitudinal waves separately in air and in water. If the wavelength of the wave produced in water is 2.90 m, what is the speed of sound in water?

(A) 1450 ms^{-1} (B) 1400 ms^{-1}

(C) 1160 ms^{-1} (D) 1500 ms^{-1}

27. The fundamental frequency of a stretched wire of length 80 cm under a fixed tension is measured to be 200 Hz. If the tension and the mass per unit length are kept unchanged and the length is reduced to 64 cm, what will be the new fundamental frequency?

(A) 225 Hz (B) 160 Hz (C) 300 Hz (D) 250 Hz

28. A known tuning fork B of frequency 256 Hz sounded together with an unknown tuning fork A produces 4 beats per second. When some wax is attached to a prong of A to increase its mass, the beat frequency decreases to 2 beats per second. What was the original fundamental frequency of fork A?

(A) 252 Hz (B) 248 Hz

(C) 260 Hz (D) 264 Hz

29. A person standing at some distance from a vertical cliff fires a gun from rest and hears a distinct echo exactly 0.8 s later. If the speed of sound in air is 340 ms^{-1}, how far was the person from the cliff?

Ⓐ 200 m Ⓑ 136 m Ⓒ 170 m Ⓓ 272 m

30. What is the ratio of the fundamental frequency of an open organ pipe of length 0.60 m to the fundamental frequency of a closed organ pipe of length 0.30 m, given that the speed of sound is the same in both pipes?

Ⓐ 1.0 Ⓑ 0.5 Ⓒ 1.5 Ⓓ 2.0

31. The initial sound intensity level from a sound source at a certain location is measured to be 80 dB. If the output power of the source is increased to exactly double, what will be the new intensity level at the same location?

Ⓐ 86.02 dB Ⓑ 160.00 dB

Ⓒ 81.50 dB Ⓓ 83.01 dB

32. The equation of a progressive wave in a medium in SI units is $y = 0.05\sin(100\pi t - 2\pi x)$. If two particles lying along the wave path are 0.25 m apart, what is the phase difference between them in radians?

Ⓐ 2π rad Ⓑ 0.5π rad

Ⓒ 0.25π rad Ⓓ π rad

33. Two sound waves of close frequencies 440 Hz and 444 Hz travel together in the same medium and superimpose. What is the time interval between two consecutive maximum intensities (the time period of the beats)?

Ⓐ 0.50 s Ⓑ 2.00 s

Ⓒ 0.25 s Ⓓ 0.125 s

34. What will be the velocity of transverse waves along a wire kept under a stretching force of $T = 64$ N and having a linear mass density of $m = 0.01\ kgm^{-1}$?

Ⓐ 80 ms^{-1} Ⓑ 100 ms^{-1}

Ⓒ 40 ms^{-1} Ⓓ 64 ms^{-1}

35. Two progressive waves travelling in the same direction are given by $y_1 = 0.05\sin(200\pi t - 4\pi x)$ and $y_2 = 0.03\sin(208\pi t - 4\pi x)$ (in SI units). What is the ratio of maximum to minimum intensity ($\frac{I_{max}}{I_{min}}$) produced by their superposition?

Ⓐ 8.00 Ⓑ 4.00

Ⓒ 64.00 Ⓓ 16.00

36. At 27°C the speed of sound in air is 346 ms^{-1}. The 2nd harmonic of an open organ pipe of length L_o = 0.8 m and the 3rd harmonic of a closed organ pipe of length L_c are in unison (same frequency). If the temperature rises to 108°C (the pipe lengths unchanged), what is the new frequency of the 3rd harmonic of the closed pipe?

Ⓐ 389.9 Hz Ⓑ 432.5 Hz

Ⓒ 487.4 Hz Ⓓ 325.0 Hz

37. A stretched wire of length $L = 0.5$ m and linear mass density $m = 0.01\ kgm^{-1}$ vibrating in its 2nd harmonic (1st overtone) under tension $T_1 = 100$ N produces 4 beats per second with a tuning fork A (the fork frequency is higher than the wire frequency). When the tension is changed to T_2, the wire vibrates in its 3rd harmonic (2nd overtone) and produces 6 beats per second with the same fork A (this time the wire frequency is higher than the fork frequency). What is the value of the new tension T_2?

Ⓐ 43.56 N Ⓑ 64.00 N

Ⓒ 100.00 N Ⓓ 49.00 N

38. A point sound source emits power $P = 40\pi$ W uniformly in all directions. What is the decrease in sound intensity level ($\Delta\beta$) when moving from 10 m to 100 m away from the source?

Ⓐ 20.00 dB Ⓑ 40.00 dB

Ⓒ 10.00 dB Ⓓ 30.00 dB

39. The equation of a progressive wave in SI units is $y = 0.1\sin[2\pi(50t - \frac{x}{4})]$. What is the acceleration (a_p) of the particle at $x_1 = 1.0$ m at time $t = 0.01$ s?

Ⓐ 0 ms^{-2} Ⓑ $-9869.6\ ms^{-2}$

Ⓒ $-98.70\ ms^{-2}$ Ⓓ $-4934.8\ ms^{-2}$

40. The equation of a stationary wave on a stretched string is $y = 0.04\sin(4\pi x)\cos(100\pi t)$ (in SI units). The linear mass density of the string is $m = 0.05\ kgm^{-1}$. What is the total mechanical energy (E) stored in a segment of length equal to half a wavelength ($\frac{\lambda}{2} = 0.25$ m)?

Ⓐ $0.025\pi^2$ J Ⓑ $0.05\pi^2$ J

Ⓒ $0.20\pi^2$ J Ⓓ $0.10\pi^2$ J

41. A train moving at 20 ms^{-1} towards a cliff sounds a whistle of frequency 600 Hz. The speed of sound in air is 340 ms^{-1}. At what frequency will the train driver hear the echo reflected from the cliff?

Ⓐ 637.50 Hz Ⓑ 750.00 Hz

Ⓒ 675.00 Hz Ⓓ 600.00 Hz

42. In a resonance tube experiment the speed of sound in air is 340 ms^{-1}. With a particular tuning fork the 1st and 2nd resonances are observed at air column lengths $L_1 = 0.16$ m and $L_2 = 0.50$ m respectively. What is the end correction (e) of the tube?

Ⓐ 0.01 m Ⓑ 0.17 m Ⓒ 0.02 m Ⓓ 0.34 m

43. A stretched wire of length $L_1 = 0.5$ m and linear mass density $m = 0.01\ kgm^{-1}$ vibrating in its fundamental mode under tension $T_1 = 400$ N produces 5 beats per second with a tuning fork A. When the tension is increased to $T_2 = 484$ N and the length changed to $L_2 = 0.5238$ m, it again produces 5 beats per second with the same fork A. What is the frequency of fork A?

Ⓐ 210 Hz Ⓑ 200 Hz Ⓒ 205 Hz Ⓓ 195 Hz

44. A metal wire of length $L = 1.0\ m$ and radius $r = 0.5\ mm$ has a material density $\varrho = 8000\ kgm^{-3}$. If the wire is stretched under a tension $T = 157.08\ N$, what is the frequency (f_3) of its 3rd harmonic (2nd overtone)?

Ⓐ 316.23 Hz Ⓑ 237.17 Hz

Ⓒ 474.34 Hz Ⓓ 150.00 Hz

45. The equation of a longitudinal sound wave in SI units is $y = 0.04\sin(100\pi t - 2\pi x)$. If the density of air is $\varrho = 1.2\ kgm^{-3}$, what is the sound pressure amplitude (P_{max})?

Ⓐ $240\pi\ Nm^{-2}$ Ⓑ $120\pi\ Nm^{-2}$

Ⓒ $480\pi\ Nm^{-2}$ Ⓓ $60\pi\ Nm^{-2}$

46. At 27°C the speed of sound in air is $340\ ms^{-1}$. An open organ pipe of length $L_o = 0.48\ m$ (end correction $e = 0.01\ m$ at each end) and a closed organ pipe of length $L_c = 0.24\ m$ (end correction $e = 0.01\ m$ at the open end) vibrate in their fundamental modes. If the length of the closed pipe is reduced to 0.2371 m, what is the number of beats per second (N) between the two pipes?

Ⓐ 8 Hz Ⓑ 0 Hz Ⓒ 14 Hz Ⓓ 4 Hz

47. A sound source emits spherical waves uniformly in all directions. At a distance $r_1 = 5\ m$ from the source the sound intensity level is $\beta_1 = 90\ dB$. At what distance (r_2) will the intensity level drop to 70 dB? ($I_0 = 10^{-12}\ Wm^{-2}$)

Ⓐ 500 m Ⓑ 100 m Ⓒ 50 m Ⓓ 25 m

48. The air in a closed container is at 28°C with a dew point of 16°C. The saturated vapour pressures of water at 28°C and 16°C are 28.35 mm Hg and 13.63 mm Hg respectively. If the volume of the container is halved at constant temperature without any water vapour escaping, what will the new relative humidity be?

Ⓐ 100.00% Ⓑ 96.16%

Ⓒ 48.08% Ⓓ 85.50%

49. At a certain point, the sound intensity levels from two independent incoherent sound sources are 80 dB and 83 dB respectively. If the density of air is $\varrho = 1.2\ kg\ m^{-3}$ and the speed of sound is $v = 340\ m\ s^{-1}$, what is the pressure amplitude (P_{max}) of the resultant sound at that point when both sources operate together? ($I_0 = 10^{-12}\ W\ m^{-2}$)

Ⓐ $0.350\ N\ m^{-2}$ Ⓑ $0.175\ N\ m^{-2}$

Ⓒ $0.700\ N\ m^{-2}$ Ⓓ $0.494\ N\ m^{-2}$

50. Two coherent point sources S_1 and S_2, separated by $d = 3\ m$, emit sound in phase at a frequency $f = 680\ Hz$. The speed of sound in air is $v = 340\ m\ s^{-1}$. An observer moves away from S_1 along the perpendicular to S_1S_2 drawn through S_1. At what maximum distance (y_{max}) from S_1 will the observer experience destructive interference (minimum intensity)?

Ⓐ 35.75 m Ⓑ 0.55 m

Ⓒ 17.88 m Ⓓ 8.94 m