MCQ 50 marks

1. **D.** 9624 m

Explanation: Here, the mass of helium is $m_{He} = \frac{PVM}{RT} = \frac{1.0\times10^5\times10\times4\times10^{-3}}{8.314\times300} = 1.604\,kg$

So, the total mass is $m_{tot} = 1.604 + 2 = 3.604\,kg$

At equilibrium, $\varrho_{air}(z)V\,g = m_{tot}g$, or $1.2e^{-\frac{z}{z_0}} \times 10 = 3.604$

Therefore, $z_{max} = z_0 \ln\frac{12}{3.604} = 8000 \times 1.2029 \approx 9624\,m$

2. **A.** 4.20

Explanation: Here, $n_1 = 2\,mol$, $f_1 = 3$ and $n_2 = 3\,mol$, $f_2 = 5$

So, $f_{eff} = \frac{n_1f_1+n_2f_2}{n_1+n_2}$

Therefore, $f_{eff} = \frac{2\times3+3\times5}{5} = \frac{21}{5} = 4.20$

3. **C.** 451.35 ms^{-1}

Explanation: Here, $c_{mp} = \sqrt{\frac{2RT}{M}}$ and $c_{avg} = \sqrt{\frac{8RT}{\pi M}}$

So, $\frac{c_{avg}}{c_{mp}} = \sqrt{\frac{4}{\pi}} = 1.1284$

Therefore, $c_{avg} = 400 \times 1.1284 = 451.35\,ms^{-1}$

$489.90\,ms^{-1}$ is c_{rms}, not the average speed.

4. **B.** 19.95 kJ

Explanation: By equipartition, $E_{total} = \frac{f}{2}nRT$

Here, $f = 6$, $n = 2\,mol$, $T = 400\,K$

So, $E_{total} = \frac{6}{2} \times 2 \times 8.314 \times 400$

Therefore, $E_{total} = 19953.6\,J \approx 19.95\,kJ$

5. **B.** 0.1562 N

Explanation: In each elastic collision the change in momentum is $\Delta p = 2mv$

So, $F = A\int_{v_1}^{v_2} 2mv\,n(v)\,dv = 2mCA\int_{100}^{500} v^4\,dv$

Here, $2mCA = 2 \times 5.0 \times 10^{-26} \times 10^{12} \times 0.25 = 2.5 \times 10^{-14}$

Again, $\int_{100}^{500} v^4\,dv = \frac{500^5-100^5}{5} = 6.248 \times 10^{12}$

Therefore, $F = 2.5 \times 10^{-14} \times 6.248 \times 10^{12} = 0.1562\,N$

6. **C.** 15.40 g

Explanation: Here, $\Delta P = 2.5 \times 10^5 - 1.3 \times 10^5 = 1.2 \times 10^5\,Nm^{-2}$

At constant V and T, $\Delta n = \frac{\Delta PV}{RT} = \frac{1.2\times10^5\times10^{-2}}{8.314\times300} = 0.4811\,mol$

Therefore, $\Delta m = \Delta n \times M = 0.4811 \times 32 = 15.40\,g$

7. **D.** 1.0

Explanation: $c_{rms} = \sqrt{\frac{3RT}{M}} \propto \sqrt{\frac{T}{M}}$

Here, $\frac{T_A}{M_A} = \frac{300}{4} = 75$ and $\frac{T_B}{M_B} = \frac{1200}{16} = 75$

Therefore, $\frac{c_{rms,A}}{c_{rms,B}} = \sqrt{\frac{75}{75}} = 1.0$

8. **B.** $f_{c2} = 0.5f_{c1}$

Explanation: Mean collision frequency, $f_c = \frac{\bar{c}}{\bar{\lambda}}$

At constant pressure, mean free path $\lambda = \frac{kT}{\sqrt{2}\,\pi d^2 P} \propto T$

Mean speed, $\bar{c} = \sqrt{\frac{8RT}{\pi M}} \propto \sqrt{T}$

Therefore, $f_c \propto \frac{\sqrt{T}}{T} = \frac{1}{\sqrt{T}}$

$\frac{f_{c2}}{f_{c1}} = \sqrt{\frac{T_1}{T_2}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$

Hence $f_{c2} = 0.5f_{c1}$

9. **B.** 1968.08 J

Explanation: Here, $n = \frac{10}{32} = 0.3125\,mol$ and $T = 273 + 30 = 303\,K$

So, $E_k = \frac{f}{2}nRT$

Therefore, $E_k = \frac{5}{2} \times 0.3125 \times 8.314 \times 303 = 1968.08\,J$

10. **D.** $7.70 \times 10^9\ s^{-1}$

Explanation: Mean free path, $\lambda = \frac{1}{\sqrt{2}\,\pi d^2 n} = \frac{1}{\sqrt{2}\,\pi(2.5\times10^{-10})^2(6.02\times10^{25})} \approx 5.98 \times 10^{-8}\,m$

From $c_{rms} = \sqrt{\frac{3RT}{M}}$ and $\bar{c} = \sqrt{\frac{8RT}{\pi M}}$, $\bar{c} =$

$c_{rms}\sqrt{\frac{8}{3\pi}}$

$\bar{c} = 500\sqrt{\frac{8}{3\pi}} \approx 460.7\ m\ s^{-1}$

$f_c = \frac{\bar{c}}{\lambda} = \frac{460.7}{5.98 \times 10^{-8}} \approx 7.70 \times 10^9\ s^{-1}$

(The mean speed $\bar{c}$, not c_{rms}, is used for collision frequency)

11. **A. 36.47%**

Explanation: By Glaisher's formula, the dew point is $\theta = \theta_1 - G(\theta_1 - \theta_2) = 30 - 1.65 \times 10 = 13.5°C$

Here, the vapour pressure present is $f = 11.61$ mm Hg and $F = 31.83$ mm Hg

So, $R = \frac{f}{F} \times 100$

Therefore, $R = \frac{11.61}{31.83} \times 100 = 36.47$ percent

12. **C.** 466.67 J

Explanation: Work, $W = \int_{V_1}^{V_2} P\ dV = \frac{P_0}{\sqrt{V_0}} \int_{V_1}^{V_2} V^{1/2}\ dV$

So, $W = \frac{2}{3}P_0V_0[(\frac{V_2}{V_0})^{3/2} - (\frac{V_1}{V_0})^{3/2}]$

Here, $\frac{V_2}{V_0} = 4$ and $\frac{V_1}{V_0} = 1$

Therefore, $W = \frac{2}{3} \times 10^5 \times 10^{-3} \times (8 - 1) = 466.67$ J

13. **D.** 5.22

Explanation: Here, $T_1 = 280$ K, $T_2 = 300$ K, $P_2 = 1.013 \times 10^5$ Pa

Pressure at the bottom, $P_1 = 1.013 \times 10^5 + 40 \times 1000 \times 9.8 = 4.933 \times 10^5$ Pa

So, from $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$, $\frac{V_2}{V_1} = \frac{P_1T_2}{P_2T_1}$

Therefore, $\frac{V_2}{V_1} = \frac{4.933 \times 300}{1.013 \times 280} = 5.22$

14. **C.** 50 ms^{-1}

Explanation: Comparing with $y = A\sin(\omega t - kx)$, $\omega = 200\pi\ rads^{-1}$ and $k = 4\pi\ radm^{-1}$

So, $v = \frac{\omega}{k}$

Therefore, $v = \frac{200\pi}{4\pi} = 50\ ms^{-1}$

15. **D.** 483.66 ms^{-1}

Explanation: $c_{rms} = \sqrt{\frac{3RT}{M}}$, so at the same T, $c_{rms} \propto \frac{1}{\sqrt{M}}$

So, $\frac{c_{O_2}}{c_{He}} = \sqrt{\frac{M_{He}}{M_{O_2}}} = \sqrt{\frac{4}{32}} = 0.3536$

Therefore, $c_{O_2} = 1368 \times 0.3536 = 483.66\ ms^{-1}$

16. **A.** 1870.65 J

Explanation: By equipartition, $E_k = \frac{f}{2}nRT$

Here, $f = 3$, $n = 0.5$ mol, $T = 300$ K

Therefore, $E_k = \frac{3}{2} \times 0.5 \times 8.314 \times 300 = 1870.65$ J

17. **C.** 1.876×10^{-7} m

Explanation: By Maxwell's formula, $\lambda = \frac{1}{\sqrt{2}\pi d^2 n_V}$

Here, $d = 2.0 \times 10^{-10}$ m, $n_V = 3.0 \times 10^{25}\ m^{-3}$

So, $\lambda = \frac{1}{1.4142 \times 3.1416 \times 4.0 \times 10^{-20} \times 3.0 \times 10^{25}}$

Therefore, $\lambda = \frac{1}{5.331 \times 10^6} = 1.876 \times 10^{-7}$ m

18. **B. 53.83%**

Explanation: Here, the saturated pressure at the dew point is the vapour pressure present, $f = 12.79$ mm Hg, and $F = 23.76$ mm Hg

So, $R = \frac{f}{F} \times 100$

Therefore, $R = \frac{12.79}{23.76} \times 100 = 53.83$ percent

19. **D.** 2.463 atm

Explanation: Here, $n_{total} = 0.4 + 0.6 = 1.0$ mol, $T = 300$ K, $V = 10$ L

By Dalton's law, $P = \frac{n_{total}RT}{V}$

Therefore, $P = \frac{1.0 \times 0.0821 \times 300}{10} = 2.463$ atm

20. **B.** 2.447×10^{19}

Explanation: From $PV = NkT$, $N = \frac{PV}{kT}$

Here, $P = 1.013 \times 10^5$ Pa, $V = 10^{-6}\ m^3$, $T = 300$ K

Therefore, $N = \frac{1.013 \times 10^5 \times 10^{-6}}{1.38 \times 10^{-23} \times 300} = 2.447 \times 10^{19}$

21. **D.** $\lambda_M = 1.414 \times 10^{-7}$ m

Explanation: Here, $\lambda_0 = \frac{1}{\pi d^2 n_V}$ and $\lambda_M = \frac{1}{\sqrt{2}\pi d^2 n_V}$

So, $\lambda_M = \frac{\lambda_0}{\sqrt{2}}$

Therefore, $\lambda_M = \frac{2.0 \times 10^{-7}}{1.4142} = 1.414 \times 10^{-7}$ m

2.828×10^{-7} m results from multiplying λ_0 by $\sqrt{2}$, which is wrong.

22. **A.** 1.07 kgm^{-3}

Explanation: At constant pressure and fixed mass $V \propto T$, so the density $\varrho \propto \frac{1}{T}$

Here, $T_1 = 273$ K, $T_2 = 273 + 91 = 364$ K

So, $\varrho_2 = \varrho_1 \times \frac{T_1}{T_2}$

Therefore, $\varrho_2 = 1.43 \times \frac{273}{364} = 1.07\ kgm^{-3}$

23. **C.** 30.61 m

Explanation: By Boyle's law, $P_1V_1 = P_2V_2$ and $V_2 = 4V_1$, so $P_1 = 4P_a$

Here, $P_1 = P_a + h\varrho g = 10^5 + 9800h$
So, $10^5 + 9800h = 4 \times 10^5$, or $9800h = 3 \times 10^5$
Therefore, $h = \frac{3\times10^5}{9800} = 30.61\,\text{m}$

24. **C.** 1.60
Explanation: At constant volume $\frac{P_2}{P_1} = \frac{T_2}{T_1}$, so $T_2 = 600\,\text{K}$
So, $\frac{c_{avg,2}}{c_{mp,1}} = \frac{\sqrt{\frac{8RT_2}{\pi M}}}{\sqrt{\frac{2RT_1}{M}}} = \sqrt{\frac{4T_2}{\pi T_1}}$
Therefore, $\frac{c_{avg,2}}{c_{mp,1}} = \sqrt{\frac{4\times600}{\pi\times300}} = 1.60$
1.41 is $\frac{c_{mp,2}}{c_{mp,1}} = \sqrt{2}$, not the ratio asked.

25. **B.** $T_c = 2.85 \times 10^{-10}\,\text{s}$
Explanation: Here, $n_V = \frac{P}{kT} = \frac{1.013\times10^5}{1.38\times10^{-23}\times300} = 2.447 \times 10^{25}\,\text{m}^{-3}$
So, $\lambda = \frac{1}{\sqrt{2}\pi d^2 n_V} = 1.472 \times 10^{-7}\,\text{m}$
Again, $c_{rms} = \sqrt{\frac{3\times8.314\times300}{28\times10^{-3}}} = 516.95\,\text{ms}^{-1}$
Therefore, $T_c = \frac{\lambda}{c_{rms}} = \frac{1.472\times10^{-7}}{516.95} = 2.85 \times 10^{-10}\,\text{s}$

26. **A.** $1450\,\text{ms}^{-1}$
Explanation: Here, $f = 500\,\text{Hz}$ and $\lambda_{water} = 2.90\,\text{m}$
So, $v = f\lambda$
Therefore, $v_{water} = 500 \times 2.90 = 1450\,\text{ms}^{-1}$

27. **D.** 250 Hz
Explanation: With tension and mass per unit length fixed, $f \propto \frac{1}{L}$
So, $\frac{f_2}{f_1} = \frac{L_1}{L_2}$
Therefore, $f_2 = 200 \times \frac{80}{64} = 250\,\text{Hz}$

28. **C.** 260 Hz
Explanation: Here, $f_A = 256 \pm 4 = 260\,\text{Hz}$ or $252\,\text{Hz}$
Wax lowers f_A; since the beats fell from 4 to 2, f_A moved closer to f_B, so $f_A > f_B$
Therefore, $f_A = 260\,\text{Hz}$
If f_A were 252 Hz, lowering it would have increased the beats.

29. **B.** 136 m
Explanation: The sound travels to the cliff and back, so $2d = vt$
Here, $v = 340\,\text{ms}^{-1}$, $t = 0.8\,\text{s}$
Therefore, $d = \frac{340\times0.8}{2} = 136\,\text{m}$
272 m is the total round-trip path, not the distance.

30. **A.** 1.0
Explanation: Fundamental of the open pipe, $f_o = \frac{v}{2L_o} = \frac{v}{1.2}$
Fundamental of the closed pipe, $f_c = \frac{v}{4L_c} = \frac{v}{1.2}$
Therefore, $\frac{f_o}{f_c} = 1.0$

31. **D.** 83.01 dB
Explanation: Doubling the power doubles the intensity, i.e. $\frac{I_2}{I_1} = 2$
So, $\Delta\beta = 10\log_{10}\frac{I_2}{I_1} = 10\log_{10}2 = 3.01\,\text{dB}$
Therefore, $\beta_2 = 80 + 3.01 = 83.01\,\text{dB}$
160 dB is wrong, because the level is logarithmic and is not multiplied.

32. **B.** $0.5\pi\,\text{rad}$
Explanation: From the equation, $k = 2\pi\,\text{radm}^{-1}$ and $\Delta x = 0.25\,\text{m}$
So, $\Delta\phi = k\Delta x$
Therefore, $\Delta\phi = 2\pi \times 0.25 = 0.5\pi\,\text{rad}$

33. **C.** 0.25 s
Explanation: The beat frequency is $N = |f_2 - f_1| = 444 - 440 = 4\,\text{Hz}$
So, the beat period is $T_b = \frac{1}{N}$
Therefore, $T_b = \frac{1}{4} = 0.25\,\text{s}$

34. **A.** $80\,\text{ms}^{-1}$
Explanation: The transverse wave speed is $v = \sqrt{\frac{T}{m}}$
Here, $T = 64\,\text{N}$, $m = 0.01\,\text{kgm}^{-1}$
Therefore, $v = \sqrt{\frac{64}{0.01}} = \sqrt{6400} = 80\,\text{ms}^{-1}$

35. **D.** 16.00
Explanation: Here, $A_1 = 0.05\,\text{m}$ and $A_2 = 0.03\,\text{m}$
So, $A_{max} = 0.08\,\text{m}$ and $A_{min} = 0.02\,\text{m}$
Again, $I \propto A^2$
Therefore, $\frac{I_{max}}{I_{min}} = (\frac{0.08}{0.02})^2 = 16.00$

36. **C.** 487.4 Hz
Explanation: Given, $\frac{2v_1}{2L_o} = \frac{3v_1}{4L_c}$, so $L_c = \frac{3L_o}{4} = 0.60\,\text{m}$
Here, $T_1 = 300\,\text{K}$, $T_2 = 381\,\text{K}$ and $v \propto \sqrt{T}$
So, $v_2 = 346\sqrt{\frac{381}{300}} = 389.9\,\text{ms}^{-1}$
Therefore, $f = \frac{3v_2}{4L_c} = \frac{3\times389.9}{4\times0.60} = 487.4\,\text{Hz}$
432.5 Hz is the frequency at 27°C, not the changed one.

37. **D.** 49.00 N

Explanation: Here, $v_1 = \sqrt{\frac{100}{0.01}} = 100\,ms^{-1}$, so the 2nd harmonic frequency is $2 \times \frac{v_1}{2L} = 200\,Hz$

So, $f_A = 200 + 4 = 204\,Hz$

Again, in the new state the wire frequency is $204 + 6 = 210\,Hz = 3 \times \frac{v_2}{2L}$, so $v_2 = 70\,ms^{-1}$

Therefore, $T_2 = mv_2^2 = 0.01 \times 4900 = 49.00\,N$

43.56 N results from taking the wire frequency as 198 Hz, which contradicts the stated condition.

38. **A.** 20.00 dB

Explanation: Here, $I_1 = \frac{P}{4\pi r_1^2} = \frac{40\pi}{4\pi \times 100} = 0.1\,Wm^{-2}$ and $I_2 = \frac{40\pi}{4\pi \times 10^4} = 10^{-3}\,Wm^{-2}$

So, $\Delta\beta = 10 \log_{10} \frac{I_1}{I_2}$

Therefore, $\Delta\beta = 10 \log_{10} 100 = 20.00\,dB$

39. **B.** $-9869.6\,ms^{-2}$

Explanation: Here, $A = 0.1\,m$ and $\omega = 2\pi \times 50 = 100\pi\,rads^{-1}$

Phase angle, $\theta = 2\pi(50 \times 0.01 - \frac{1.0}{4}) = 2\pi \times 0.25 = \frac{\pi}{2}$

So, $a_p = -\omega^2 y = -\omega^2 A \sin\theta$

Therefore, $a_p = -(100\pi)^2 \times 0.1 \times 1 = -9869.6\,ms^{-2}$

40. **B.** $0.05\pi^2$ J

Explanation: Maximum particle velocity, $v_{p,max} = 0.04 \times 100\pi \sin(4\pi x) = 4\pi \sin(4\pi x)$

So, $E = \int_0^{0.25} \frac{1}{2} m\, v_{p,max}^2\, dx = \frac{1}{2}(0.05)(16\pi^2) \int_0^{0.25} \sin^2(4\pi x)\, dx$

Here, $\int_0^{0.25} \sin^2(4\pi x)\, dx = 0.125$

Therefore, $E = 0.4\pi^2 \times 0.125 = 0.05\pi^2$ J

41. **C.** 675.00 Hz

Explanation: Frequency incident on the cliff, $f_1 = f\frac{v}{v - v_s} = 600 \times \frac{340}{320} = 637.5\,Hz$

Again, the driver moves towards the cliff, so $f' = f_1 \frac{v + v_s}{v}$

Therefore, $f' = 637.5 \times \frac{360}{340} = 675.00\,Hz$

637.50 Hz is only the frequency incident on the cliff.

42. **A.** 0.01 m

Explanation: Here, $\frac{\lambda}{2} = L_2 - L_1 = 0.34\,m$, so $\lambda = 0.68\,m$

So, at the 1st resonance $L_1 + e = \frac{\lambda}{4} = 0.17\,m$

Therefore, $e = 0.17 - 0.16 = 0.01\,m$

0.17 m is $\frac{\lambda}{4}$, not the end correction.

43. **C.** 205 Hz

Explanation: In case 1, $v_1 = \sqrt{\frac{400}{0.01}} = 200\,ms^{-1}$, so $f_1 = \frac{v_1}{2L_1} = 200\,Hz$ and $f_A = 205\,Hz$ or 195 Hz

In case 2, $v_2 = \sqrt{\frac{484}{0.01}} = 220\,ms^{-1}$, so $f_2 = \frac{220}{2 \times 0.5238} = 210\,Hz$ and $f_A = 215\,Hz$ or 205 Hz

Only 205 Hz satisfies both cases

Therefore, $f_A = 205\,Hz$

44. **B.** 237.17 Hz

Explanation: Here, $m = \varrho\pi r^2 = 8000 \times \pi \times (0.5 \times 10^{-3})^2 = 6.283 \times 10^{-3}\,kgm^{-1}$

So, $v = \sqrt{\frac{T}{m}} = \sqrt{\frac{157.08}{6.283 \times 10^{-3}}} = 158.11\,ms^{-1}$

Again, $f_1 = \frac{v}{2L} = 79.06\,Hz$

Therefore, $f_3 = 3f_1 = 237.17\,Hz$

45. **A.** $240\pi\,Nm^{-2}$

Explanation: Comparing, $A = 0.04\,m$, $\omega = 100\pi\,rads^{-1}$, $k = 2\pi\,radm^{-1}$

So, $v = \frac{\omega}{k} = 50\,ms^{-1}$

Again, $P_{max} = \varrho v \omega A$

Therefore, $P_{max} = 1.2 \times 50 \times 100\pi \times 0.04 = 240\pi\,Nm^{-2}$

46. **D.** 4 Hz

Explanation: Open pipe, $L_{eff} = 0.48 + 2(0.01) = 0.50\,m$, so $f_o = \frac{v}{2L_{eff}} = \frac{340}{1.0} = 340\,Hz$

New effective length of the closed pipe, $L'_{eff} = 0.2371 + 0.01 = 0.2471\,m$

So, $f'_c = \frac{v}{4L'_{eff}} = \frac{340}{4 \times 0.2471} = 344\,Hz$

Therefore, $N = 344 - 340 = 4\,Hz$

47. **C.** 50 m

Explanation: Here, $I_1 = 10^{-12} \times 10^9 = 10^{-3}\,Wm^{-2}$ and $I_2 = 10^{-12} \times 10^7 = 10^{-5}\,Wm^{-2}$

Source power, $P = 4\pi r_1^2 I_1 = 4\pi \times 25 \times 10^{-3} = 0.1\pi\,W$

So, $r_2 = \sqrt{\frac{P}{4\pi I_2}} = \sqrt{\frac{0.1\pi}{4\pi \times 10^{-5}}} = \sqrt{2500}$

Therefore, $r_2 = 50\,m$

48. **B.** 96.16%

Explanation: At the dew point the vapour is saturated, so the actual vapour pressure = 13.63 mm Hg

Initial relative humidity = $\frac{13.63}{28.35} \times 100\% =$ 48.08%

Halving the volume at constant temperature doubles the vapour pressure (Boyle's law):

$P' = 2 \times 13.63 = 27.26$ mm Hg

Since $27.26 < 28.35$, no vapour condenses

New relative humidity = $\frac{27.26}{28.35} \times 100\% =$ 96.16%

49. **D.** 0.494 N m^{-2}

Explanation: From the intensity level $\beta = 10 \log \frac{I}{I_0}$, $I = I_0 \, 10^{\beta/10}$

$I_1 = 10^{-12} \times 10^{8} = 1.0 \times 10^{-4}$ W m^{-2}

$I_2 = 10^{-12} \times 10^{8.3} = 1.995 \times 10^{-4}$ W m^{-2}

Intensities of incoherent sources add: $I = I_1 + I_2 = 2.995 \times 10^{-4}$ W m^{-2}

From $I = \frac{P_{max}^2}{2\varrho v}$, $P_{max} = \sqrt{2\varrho v I} =$ $\sqrt{2 \times 1.2 \times 340 \times 2.995 \times 10^{-4}}$

$= \sqrt{0.2444} \approx 0.494$ N m^{-2}

50. **C.** 17.88 m

Explanation: Wavelength, $\lambda = \frac{v}{f} = \frac{340}{680} =$ 0.5 m

Path difference at distance y from S_1, $\Delta =$ $\sqrt{y^2 + d^2} - y$

Δ decreases as y increases ($\Delta = 3$ m at $y = 0$ and $\Delta \to 0$ as $y \to \infty$)

Condition for destructive interference, $\Delta = \left(m + \frac{1}{2}\right)\lambda$

The largest y corresponds to the smallest Δ,

i.e. $\Delta = \frac{\lambda}{2} = 0.25$ m

$\sqrt{y^2 + 9} = y + 0.25$

$y^2 + 9 = y^2 + 0.5y + 0.0625$

$0.5y = 8.9375$

$y = 17.875$ m ≈ 17.88 m