Exemplar Solutions for Class 11 Physics Chapter 12 – Kinetic Theory

Long Answers

27. Explain why a) there is no atmosphere on moon b) there is fall in temperature with altitude

Answer: a) **No atmosphere on moon:**

- Moon's gravitational field is weak ($g \approx 1.6$ m/s^2)
- Escape velocity is low (≈ 2.4 km/s)
- Gas molecules' rms speeds can exceed escape velocity
- Solar radiation provides additional energy to molecules
- No magnetic field to protect against solar wind
- Therefore, atmospheric gases escape to space

b) **Temperature decreases with altitude:**

- Air pressure decreases with altitude
- Ascending air masses undergo adiabatic expansion
- During adiabatic expansion: PV^γ = constant, $TV^{\gamma-1}$ = constant
- As volume increases, temperature decreases
- Rate of cooling ≈ 10°C per km (dry adiabatic lapse rate)
- Additionally, air density decreases, reducing heat capacity

28. Consider an ideal gas with the following distribution of speeds

Speed (m/s)	% of molecules
200	10
400	20
600	40
800	20
1000	10

a) calculate v_rms and hence T ($m = 3.0 \times 10^{-26}$ kg) b) if all the molecules with speed 1000 m/s escape from the system, calculate new v_rms and hence T

Answer: a) $v^2\_rms = (0.1\times200^2 + 0.2\times400^2 + 0.4\times600^2 + 0.2\times800^2 + 0.1\times1000^2) = 440{,}000$ m^2/s^2 v_rms = 663 m/s From $v\_rms = \sqrt{(3kT/m)}$: $T = mv^2\_rms/(3k) = (3\times10^{-26} \times 440{,}000)/(3\times1.38\times10^{-23}) = 318$ K

b) New distribution (renormalized): $v^2\_rms = (1/9)[0.1\times200^2 + 0.2\times400^2 + 0.4\times600^2 + 0.2\times800^2] = 378{,}000$ m^2/s^2 $T\_new = (3\times10^{-26} \times 378{,}000)/(3\times1.38\times10^{-23}) = 273$ K

29. Ten small planes are flying at a speed of 150 km/h in total darkness in an air space that is 20 × 20 × 1.5 km^3 in volume. You are in one of the planes, flying at random within this space with no way of knowing where the other planes are. On the average about how long a time will elapse between near collision with your plane. Assume for this rough

computation that a safety region around the plane can be approximated by a sphere of radius 10 m.

Answer: Volume of airspace = 20 × 20 × 1.5 = 600 km^3 Number density of other planes = 9/600 = 0.015 km^{-3} Collision cross-section = $\pi(2\times0.01)^2$ = 1.26 × 10^{-5} km^2 Relative speed ≈ √2 × 150 = 212 km/h Collision rate = number density × cross-section × relative speed = 0.015 × 1.26×10^{-5} × 212 = 4×10^{-5} per hour Average time between collisions = 1/(4×10^{-5}) = 25,000 hours ≈ 2.8 years

30. A box of 1.00 m^3 is filled with nitrogen at 1.50 atm at 300 K. The box has a hole of area 0.010 mm^2. How much time is required for the pressure to reduce by 0.10 atm, if the pressure outside is 1 atm.

Answer: Using effusion rate: dP/dt = -(A/V)√(2πRT/M) × (P_inside - P_outside) Where: A = 10^{-8} m^2, V = 1 m^3, M = 28×10^{-3} kg/mol Initial pressure difference = 1.5 - 1 = 0.5 atm Final pressure difference = 1.4 - 1 = 0.4 atm Integrating: t = (V/A)√(M/(2πRT)) × ln(0.5/0.4) = 1.34 × 10^5 s ≈ 37 hours

31. Consider a rectangular block of wood moving with a velocity v_0 in a gas at temperature T and mass density ρ. Assume the velocity is along x-axis and the area of cross-section of the block perpendicular to v_0 is A. Show that the drag force on the block is $4\rho A v_0\sqrt{kT/m}$, where m is the mass of the gas molecule.

Answer: Derivation:

- Number density of molecules: n = ρ/m
- Molecules hitting front face per unit time: $(1/2)nA(\bar{v} + v_0)$
- Molecules hitting back face per unit time: $(1/2)nA(\bar{v} - v_0)$
- Average molecular speed: $\bar{v} = \sqrt{8kT/\pi m}$
- Momentum change per collision (front): $\Delta p = 2m(v_0 + \bar{v}/2)$
- Momentum change per collision (back): $\Delta p = 2m(v_0 - \bar{v}/2)$

For $v_0 \ll \bar{v}$: Net force ≈ $nA \times 2mv_0 \times \bar{v}/2 = nAmv_0\bar{v} = (\rho/m) \times A \times m \times v_0 \times \sqrt{8kT/\pi m}$ F_drag = $\rho A v_0\sqrt{8kT/\pi m} \approx 4\rho A v_0\sqrt{kT/m}$

The drag force arises from the asymmetric momentum transfer between molecules striking the front and back faces of the moving block.