13.10 Use the formula for mean free path :

$$\bar{l} = \frac{1}{\sqrt{2}\pi n d^2}$$

where d is the diameter of a molecule. For the given pressure and temperature $N/V = 5.10 \times 10^{25}$ m^{-3} and = 1.0×10^{-7} m. $v_{\text{rms}} = 5.1 \times 10^2$ m s^{-1}.

collisional frequency = $\frac{v_{\text{rms}}}{\bar{l}} = 5.1 \times 10^9 \text{ s}^{-1}$. Time taken for the collision = $d / v_{\text{rms}} = 4 \times 10^{-13}$ s.

Time taken between successive collisions = $l / v_{\text{rms}} = 2 \times 10^{-10}$ s. Thus the time taken between successive collisions is 500 times the time taken for a collision. Thus a molecule in a gas moves essentially free for most of the time.

13.11 Nearly 24 cm of mercury flows out, and the remaining 52 cm of mercury thread plus the 48 cm of air above it remain in equilibrium with the outside atmospheric pressure (We assume there is no change in temperature throughout).

13.12 Oxygen

13.14 Carbon[1.29 Å]; Gold [1.59 Å]; Liquid Nitrogen [1.77 Å]; Lithium [1.73 Å]; Liquid fluorine[1.88 Å]

Chapter 14

14.1 (b), (c)

14.2 (b) and (c): SHM; (a) and (d) represent periodic but not SHM [A polyatomic molecule has a number of natural frequencies; so in general, its vibration is a superposition of SHM's of a number of different frequencies. This superposition is periodic but not SHM].

14.3 (b) and (d) are periodic, each with a period of 2 s; (a) and (c) are not periodic. [Note in (c), repetition of merely one position is not enough for motion to be periodic; the entire motion during one period must be repeated successively].

14.4 (a) Simple harmonic, $T = (2\pi/\omega)$; (b) periodic, $T = (2\pi/\omega)$ but not simple harmonic; (c) simple harmonic, $T = (\pi/\omega)$; (d) periodic, $T = (2\pi/\omega)$ but not simple harmonic; (e) non-periodic; (f) non-periodic (physically not acceptable as the function $\to \infty$ as $t \to \infty$.

14.5 (a) 0, +, + ; (b) 0, –, – ; (c) –, 0,0 ; (d) –, –, – ; (e) +, +, + ; (f) –, –, –.

14.6 (c) represents a simple harmonic motion.

14.7 A = $\sqrt{2}$ cm, $\phi = 7\pi/4$; B = $\sqrt{2}$ cm, $a = \pi/4$.

14.8 219 N

14.9 Frequency 3.2 s^{-1}; maximum acceleration of the mass 8.0 m s^{-2}; maximum speed of the mass 0.4 m s^{-1}.

14.10 (a) $x = 2 \sin 20t$
(b) $x = 2 \cos 20t$
(c) $x = -2 \cos 20t$

where x is in cm. These functions differ neither in amplitude nor frequency. They differ in initial phase.

14.11 (a) $x = -3 \sin \pi t$ where x is in cm.

(b) $x = -2 \cos \dfrac{\pi}{2} t$ where x is in cm.

14.13 (a) F/k for both (a) and (b).

(b) $T = 2\pi\sqrt{\dfrac{m}{k}}$ for (a) and $2\pi\sqrt{\dfrac{m}{2k}}$ for (b)

14.14 100 m/min

14.15 8.4 s

14.16 (a) For a simple pendulum, k itself is proportional to m, so m cancels out.

(b) $\sin\theta < \theta$; if the restoring force, $mg \sin\theta$ is replaced by $mg\theta$, this amounts to effective reduction in angular acceleration [Eq.(14.27)] for large angles and hence an increase in time period T over that given by the formula $T = 2\pi\sqrt{\dfrac{l}{g}}$ where one assumes $\sin\theta = \theta$.

(c) Yes, the motion in the wristwatch depends on spring action and has nothing to do with acceleration due to gravity.

(d) Gravity disappears for a man under free fall, so frequency is zero.

14.17 $T = 2\pi\sqrt{\dfrac{l}{\sqrt{g^2 + v^4/R^2}}}$. Hint: Effective acceleration due to gravity will get reduced due to radial acceleration v^2/R acting in the horizontal plane.

14.18 In equilibrium, weight of the cork equals the up thrust. When the cork is depressed by an amount x, the net upward force is $Ax\rho_l g$. Thus the force constant $k = A\rho_l g$.

Using $m = Ah\rho$, and $T = 2\pi\sqrt{\dfrac{m}{k}}$ one gets the given expression.

14.19 When both the ends are open to the atmosphere, and the difference in levels of the liquid in the two arms is h, the net force on the liquid column is $Ah\rho g$ where A is the area of cross-section of the tube and ρ is the density of the liquid. Since restoring force is proportional to h, motion is simple harmonic.

14.20 $T = 2\pi\sqrt{\dfrac{Vm}{Ba^2}}$ where B is the bulk modulus of air. For isothermal changes $B = P$.

14.21 (a) 5×10^4 N m^{-1}; (b) 1344.6 kg s^{-1}

14.22 Hint: Average K.E. = $\dfrac{1}{T}\displaystyle\int_0^T \dfrac{1}{2}mv^2 dt$; Average P.E.= $\dfrac{1}{T}\displaystyle\int_0^T \dfrac{1}{2}kx^2 dt$

14.23 Hint: The time period of a torsional pendulum is given by $T = 2\pi\sqrt{\dfrac{I}{\alpha}}$, where I is the moment of inertia about the axis of rotation. In our case $I = \dfrac{1}{2}MR^2$, where M is the mass of the disk and R its radius. Substituting the given values, α = 2.0 N m rad^{-1}.

14.24 (a) $-5\pi^2$ m s^{-2} ; 0; (b) $-3\pi^2$ m s^{-2}; 0.4π m s^{-1}; (c) 0 ; $0.5\,\pi$ m s^{-1}

14.25 $\sqrt{\left(x_0^2 + \dfrac{v_0^2}{\omega^2}\right)}$

Chapter 15

15.1 0.5 s

15.2 8.7 s

15.3 2.06×10^4 N

15.4 Assume ideal gas law: $P = \dfrac{\rho RT}{M}$, where ρ is the density, M is the molecular mass, and T is the temperature of the gas. This gives $v = \sqrt{\dfrac{\gamma RT}{M}}$. This shows that v is:

(a) Independent of pressure.

(b) Increases as $\sqrt{T}$.

(c) The molecular mass of water (18) is less than that of N_2 (28) and O_2 (32).

Therefore as humidity increases, the effective molecular mass of air decreases and hence v increases.