ANSWERS

Chapter 9

9.1 1.8

9.2 (a) From the given graph for a stress of 150×10^6 N m^{-2} the strain is 0.002

(b) Approximate yield strength of the material is 3×10^8 N m^{-2}

9.3 (a) Material A

(b) Strength of a material is determined by the amount of stress required to cause fracture: material A is stronger than material B.

9.4 (a) False (b) True

9.5 1.5×10^{-4} m (steel); 1.3×10^{-4} m (brass)

9.6 Deflection = 4×10^{-6} m

9.7 2.8×10^{-6}

9.8 0.127

9.9 7.07×10^4 N

9.10 $D_{copper}/D_{iron} = 1.25$

9.11 1.539×10^{-4} m

9.12 2.026×10^9 Pa

9.13 1.034×10^3 kg/m^3

9.14 0.0027

9.15 0.058 cm^3

9.16 2.2×10^6 N/m^2

9.17 Pressure at the tip of anvil is 2.5×10^{11} Pa

9.18 (a) 0.7 m (b) 0.43 m from steel wire

9.19 Approximately 0.01 m

9.20 260 kN

9.21 2.51×10^{-4} m^3

Chapter 10

10.3 (a) decreases (b) η of gases increases, η of liquid decreases with temperature (c) shear strain, rate of shear strain (d) conservation of mass, Bernoulli's equation (e) greater.

10.5 6.2×10^6 Pa

10.6 10.5 m

10.7 Pressure at that depth in the sea is about 3×10^7 Pa. The structure is suitable since it can withstand far greater pressure or stress.

10.8 6.92×10^5 Pa

10.9 0.800

10.10 Mercury will rise in the arm containing spirit; the difference in levels of mercury will be 0.221 cm.

10.11 No, Bernoulli's principle applies to streamline flow only.

10.12 No, unless the atmospheric pressures at the two points where Bernoulli's equation is applied are significantly different.

10.13 9.8×10^2 Pa (The Reynolds number is about 0.3 so the flow is laminar).

10.14 1.5×10^3 N

10.15 Fig (a) is incorrect [Reason: at a constriction (i.e. where the area of cross-section of the tube is smaller), flow speed is larger due to mass conservation. Consequently pressure there is smaller according to Bernoulli's equation. We assume the fluid to be incompressible].

10.16 0.64 m s^{-1}

10.17 2.5×10^{-2} N m^{-1}

10.18 4.5×10^{-2} N for (b) and (c), the same as in (a).

10.19 Excess pressure = 310 Pa, total pressure = 1.0131×10^5 Pa. However, since data are correct to three significant figures, we should write total pressure inside the drop as 1.01×10^5 Pa.

10.20 Excess pressure inside the soap bubble = 20.0 Pa; excess pressure inside the air bubble in soap solution = 10.0 Pa. Outside pressure for air bubble = $1.01 \times 10^5 + 0.4 \times 10^3 \times 9.8 \times 1.2 = 1.06 \times 10^5$ Pa. The excess pressure is so small that up to three significant figures, total pressure inside the air bubble is 1.06×10^5 Pa.

10.21 55 N (Note, the base area does not affect the answer)

10.22 (a) absolute pressure = 96 cm of Hg; gauge pressure = 20 cm of Hg for (a), absolute pressure = 58 cm of Hg, gauge pressure = -18 cm of Hg for (b); (b) mercury would rise in the left limb such that the difference in its levels in the two limbs becomes19 cm.

10.23 Pressure (and therefore force) on the two equal base areas are identical. But force is exerted by water on the sides of the vessels also, which has a nonzero vertical component when the sides of the vessel are not perfectly normal to the base. This net vertical component of force by water on sides of the vessel is greater for the first vessel than the second. Hence the vessels weigh different even when the force on the base is the same in the two cases.

10.24 0.2 m

10.25 (a) The pressure drop is greater (b) More important with increasing flow velocity.

10.26 (a) 0.98 m s^{-1}; (b) 1.24×10^{-5} m^3 s^{-1}

10.27 4393 kg

10.28 5.8 cm s^{-1}, 3.9×10^{-10} N

10.29 5.34 mm

10.30 For the first bore, pressure difference (between the concave and convex side) = $2 \times 7.3 \times 10^{-2} / 3 \times 10^{-3}$ = 48.7 Pa. Similarly for the second bore, pressure difference = 97.3 Pa. Consequently, the level difference in the two bores is [48.7 / ($10^3 \times 9.8$)] m = 5.0 mm.

The level in the narrower bore is higher. (Note, for zero angle of contact, the radius of the meniscus equals radius of the bore. The concave side of the surface in each bore is at 1 atm).

10.31 (b) 8 km. If we consider the variation of g with altitude the height is somewhat more, about 8.2 km.

Chapter 11

11.1 Neon: – 248.58 °C = – 415.44 °F;

CO_2: – 56.60 °C = – 69.88 °F

(use $t_F = \frac{9}{5}t_c + 32$)

11.2 $T_A = (4/7)\ T_B$

11.3 384.8 K

11.4 (a) Triple-point has a *unique* temperature; fusion point and boiling point temperatures depend on pressure; (b) The other fixed point is the absolute zero itself; (c) Triple-point is 0.01°C, not 0 °C; (d) 491.69.

11.5 (a) T_A = 392.69 K, T_B = 391.98 K; (b) The discrepancy arises because the gases are not perfectly ideal. To reduce the discrepancy, readings should be taken for lower and lower pressures and the plot between temperature measured versus absolute pressure of the gas at triple point should be extrapolated to obtain temperature in the limit pressure tends to zero, when the gases approach ideal gas behaviour.

11.6 Actual length of the rod at 45.0 °C = (63.0 + 0.0136) cm = 63.0136 cm. (However, we should say that change in length up to three significant figures is 0.0136 cm, but the total length is 63.0 cm, up to three significant places. Length of the same rod at 27.0 °C = 63.0 cm.

11.7 When the shaft is cooled to temperature – 69^{0}C the wheel can slip on the shaft.

11.8 The diameter increases by an amount = 1.44×10^{-2} cm.

11.9 3.8×10^2 N

11.10 Since the ends of the combined rod are not clamped, each rod expands freely.

Δl_{brass} = 0.21 cm, Δl_{steel} = 0.126 cm = 0.13 cm

Total change in length = 0.34 cm. No 'thermal stress' is developed at the junction since the rods freely expand.

11.11 0.0147 = 1.5×10^{-2}

11.12 103 °C

11.13 1.5 kg

11.14 0.43 J g^{-1} K^{-1} ; smaller

11.15 The gases are diatomic, and have other degrees of freedom (i.e. have other modes of motion) possible besides the translational degrees of freedom. To raise the temperature of the gas by a certain amount, heat is to be supplied to increase the average energy of all the modes. Consequently, molar specific heat of diatomic gases is more than that of monatomic gases. It can be shown that if only rotational modes of motion are considered, the molar specific heat of diatomic gases is nearly (5/2) R which agrees with the observations for all the gases listed in the table, except chlorine. The higher value of molar specific heat of chlorine indicates that besides rotational modes, vibrational modes are also present in chlorine at room temperature.

11.16 4.3 g/min

11.17 3.7 kg

11.18 238 °C

11.20 9 min

11.21 (a) At the triple point temperature = – 56.6 °C and pressure = 5.11 atm.

(b) Both the boiling point and freezing point of CO_2 decrease if pressure decreases.

(c) The critical temperature and pressure of CO_2 are 31.1 °C and 73.0 atm, respectively. Above this temperature, CO_2 will not liquefy even if compressed to high pressures.

(d) (a) vapour (b) solid (c) liquid

11.22 (a) No, vapour condenses to solid directly.

(b) It condenses to solid directly without passing through the liquid phase.

(c) It turns to liquid phase and then to vapour phase. The fusion and boiling points are where the horizontal line on $P-T$ diagram at the constant pressure of 10 atm intersects the fusion and vaporisation curves.

(d) It will not exhibit any clear transition to the liquid phase, but will depart more and more from ideal gas behaviour as its pressure increases.

Chapter 12

12.1 16 g per min

12.2 934 J

12.4 2.64

12.5 16.9 J

12.6 (a) 0.5 atm (b) zero (c) zero (assuming the gas to be ideal) (d) No, since the process (called free expansion) is rapid and cannot be controlled. The intermediate states are non-equilibrium states and do not satisfy the gas equation. In due course, the gas does return to an equilibrium state.

12.7 15%, 3.1×10^9 J

12.8 25 W

12.9 450 J

12.10 10.4

Chapter 13

13.1 4×10^{-4}

13.3 (a) The dotted plot corresponds to 'ideal' gas behaviour; (b) $T_1 > T_2$; (c) 0.26 J K^{-1}; (d) No, 6.3×10^{-5} kg of H_2 would yield the same value

13.4 0.14 kg

13.5 5.3×10^{-6} m^3

13.6 6.10×10^{26}

13.7 (a) 6.2×10^{-21} J (b) 1.24×10^{-19} J (c) 2.1×10^{-16} J

13.8 Yes, according to Avogadro's law. No, v_{rms} is largest for the lightest of the three gases; neon.

13.9 2.52×10^3 K

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 $= 1.0 \times 10^{-7}$ m. $v_{rms} = 5.1 \times 10^2$ m s^{-1}.

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

Time taken between successive collisions $= l / v_{rms} = 2 \times 10^{-10}$ 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) $x = -2 \cos \frac{\pi}{2} t$ where x is in cm.

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

(b) $T = 2\pi\sqrt{\frac{m}{k}}$ for (a) and $2\pi\sqrt{\frac{m}{2k}}$ 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 $T = 2\pi\sqrt{\frac{l}{g}}$ 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 $T = 2\pi\sqrt{\frac{l}{\sqrt{g^2 + v^4/R^2}}}$. 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 $T = 2\pi\sqrt{\frac{m}{k}}$ 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 $T = 2\pi\sqrt{\frac{Vm}{Ba^2}}$ where B is the bulk modulus of air. For isothermal changes $B = P$.

14.21 (a) $5 \times 10^4 \text{N m}^{-1}$; (b) 1344.6 kg s^{-1}

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

14.23 Hint: The time period of a torsional pendulum is given by $T = 2\pi\sqrt{\frac{I}{\alpha}}$, where I is the moment of inertia about the axis of rotation. In our case $I = \frac{1}{2}MR^2$, 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 $\sqrt{\left(x_0^2 + \frac{v_0^2}{\omega^2}\right)}$

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: $P = \frac{\rho RT}{M}$, where ρ is the density, M is the molecular mass, and T is the temperature of the gas. This gives $v = \sqrt{\frac{\gamma RT}{M}}$. 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.

15.5 The converse is not true. An obvious requirement for an acceptable function for a travelling wave is that it should be finite everywhere and at all times. Only function (c) satisfies this condition, the remaining functions cannot possibly represent a travelling wave.

15.6 (a) 3.4×10^{-4} m (b) 1.49×10^{-3} m

15.7 4.1×10^{-4} m

15.8 (a) A travelling wave. It travels from right to left with a speed of 20 ms^{-1}.

(b) 3.0 cm, 5.7 Hz

(c) $\pi/4$

(d) 3.5 m

15.9 All the graphs are sinusoidal. They have same amplitude and frequency, but different initial phases.

15.10 (a) 6.4 π rad

(b) 0.8 π rad

(c) π rad

(d) $(\pi/2)$ rad

15.11 (a) Stationary wave

(b) $l = 3$ m, n = 60 Hz, and $v = 180$ m s^{-1} for each wave

(c) 648 N

15.12 (a) All the points except the nodes on the string have the same frequency and phase, but not the same amplitude.

(b) 0.042 m

15.13 (a) Stationary wave.

(b) Unacceptable function for any wave.

(c) Travelling harmonic wave.

(d) Superposition of two stationary waves.

15.14 (a) 79 m s^{-1}

(b) 248 N

15.15 347 m s^{-1}

Hint : $v_n = \frac{(2n-1)v}{4l}$; n = 1,2,3,....for a pipe with one end closed

15.16 5.06 km s^{-1}

15.17 First harmonic (fundamental); No.

15.18 318 Hz

15.20 (i) (a) 412 Hz, (b) 389 Hz, (ii) 340 m s^{-1} in each case.

15.21 400 Hz, 0.875 m, 350 m s^{-1}. No, because in this case, with respect to the medium, both the observer and the source are in motion.

15.22 (a) 1.666 cm, 87.75 cm s^{-1}; No, the velocity of wave propagation is – 24 m s^{-1}

(b) All points at distances of $n\lambda$ ($n = \pm1, \pm2, \pm3, ...$) where λ = 12.6 m from the point x = 1 cm.

15.23 (a) The pulse does not have a definite wavelength or frequency, but has a definite speed of propagation (in a non-dispersive medium).

(b) No

15.24 $y = 0.05 \sin(\omega t - kx)$; here $\omega = 1.61 \times 10^3$ s^{-1}, k = 4.84 m^{-1}; x and y are in m.

15.25 45.9 kHz

15.26 1920 km

15.27 42.47 kHz

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INDEX

Notes