

ANSWERS

Chapter 9

- 9.1** 1.8
- 9.2** (a) From the given graph for a stress of $150 \times 10^6 \text{ N m}^{-2}$ the strain is 0.002
(b) Approximate yield strength of the material is $3 \times 10^8 \text{ N m}^{-2}$
- 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** $1.5 \times 10^{-4} \text{ m}$ (steel); $1.3 \times 10^{-4} \text{ m}$ (brass)
- 9.6** Deflection = $4 \times 10^{-6} \text{ m}$
- 9.7** 2.8×10^{-6}
- 9.8** 0.127
- 9.9** $7.07 \times 10^4 \text{ N}$
- 9.10** $D_{\text{copper}}/D_{\text{iron}} = 1.25$
- 9.11** $1.539 \times 10^{-4} \text{ m}$
- 9.12** $2.026 \times 10^9 \text{ Pa}$
- 9.13** $1.034 \times 10^3 \text{ kg/m}^3$
- 9.14** 0.0027
- 9.15** 0.058 cm^3
- 9.16** $2.2 \times 10^6 \text{ N/m}^2$

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 $2.51 \times 10^{-4} \text{ m}^3$

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 $2.5 \times 10^{-2} \text{ N m}^{-1}$

10.18 $4.5 \times 10^{-2} \text{ N}$ 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 becomes 19 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) $1.24 \times 10^{-5} \text{ m}^3 \text{ s}^{-1}$
- 10.27** 4393 kg
- 10.28** 5.8 cm s^{-1} , $3.9 \times 10^{-10} \text{ N}$
- 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 $[48.7 / (10^3 \times 9.8)] \text{ m} = 5.0 \text{ mm}$.
- 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: $-248.58^\circ\text{C} = -415.44^\circ\text{F}$;
 CO_2 : $-56.60^\circ\text{C} = -69.88^\circ\text{F}$
- (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) $T_A = 392.69 \text{ K}$, $T_B = 391.98 \text{ K}$; (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 $45.0^\circ\text{C} = (63.0 + 0.0136) \text{ cm} = 63.0136 \text{ cm}$. (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 $27.0^\circ\text{C} = 63.0 \text{ cm}$.
- 11.7** When the shaft is cooled to temperature -69°C the wheel can slip on the shaft.
- 11.8** The diameter increases by an amount $= 1.44 \times 10^{-2} \text{ cm}$.
- 11.9** $3.8 \times 10^2 \text{ N}$
- 11.10** Since the ends of the combined rod are not clamped, each rod expands freely.
 $\Delta l_{\text{brass}} = 0.21 \text{ cm}$, $\Delta l_{\text{steel}} = 0.126 \text{ cm} = 0.13 \text{ cm}$
 Total change in length $= 0.34 \text{ cm}$. No 'thermal stress' is developed at the junction since the rods freely expand.
- 11.11** $0.0147 = 1.5 \times 10^{-2}$
- 11.12** 103°C
- 11.13** 1.5 kg
- 11.14** $0.43 \text{ J g}^{-1} \text{ K}^{-1}$; 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 $= -56.6^\circ\text{C}$ and pressure $= 5.11 \text{ atm}$.
 (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, $6.3 \times 10^{-5} \text{ kg}$ of H_2 would yield the same value

13.4 0.14 kg

13.5 $5.3 \times 10^{-6} \text{ m}^3$

13.6 6.10×10^{26}

13.7 (a) $6.2 \times 10^{-21} \text{ J}$ (b) $1.24 \times 10^{-19} \text{ J}$ (c) $2.1 \times 10^{-16} \text{ J}$

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

13.9 $2.52 \times 10^3 \text{ K}$

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 $N/V = 5.10 \times 10^{25} \text{ m}^{-3}$ and $\lambda = 1.0 \times 10^{-7} \text{ m}$. $v_{\text{rms}} = 5.1 \times 10^2 \text{ m s}^{-1}$.

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

Time taken between successive collisions $= 1 / \nu_{\text{rms}} = 2 \times 10^{-10} \text{ s}$. 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 $\rightarrow \infty$ as $t \rightarrow \infty$).

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

14.6 (c) represents a simple harmonic motion.

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

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, $\alpha = 2.0 \text{ N m rad}^{-1}$.

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

14.25 $\sqrt{x_0^2 + \frac{v_0^2}{\omega^2}}$

Chapter 15

15.1 0.5 s

15.2 8.7 s

15.3 $2.06 \times 10^4 \text{ N}$

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) $3.4 \times 10^{-4} \text{ m}$ (b) $1.49 \times 10^{-3} \text{ m}$
- 15.7** $4.1 \times 10^{-4} \text{ m}$
- 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) $6.4 \pi \text{ rad}$
(b) $0.8 \pi \text{ rad}$
(c) $\pi \text{ rad}$
(d) $(\pi/2) \text{ rad}$
- 15.11** (a) Stationary wave
(b) $l = 3 \text{ m}$, $n = 60 \text{ Hz}$, and $v = 180 \text{ m s}^{-1}$ 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 : $v_n = \frac{(2n-1)v}{4l}$; $n = 1, 2, 3, \dots$ 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 $n\lambda$ ($n = \pm 1, \pm 2, \pm 3, \dots$) where $\lambda = 12.6 \text{ m}$ from the point $x = 1 \text{ cm}$.

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 $\omega = 1.61 \times 10^3 \text{ s}^{-1}$, $k = 4.84 \text{ m}^{-1}$; 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

A

Absolute scale temperature	280
Absolute zero	280
Acceleration (linear)	45
Acceleration due to gravity	49, 189
Accuracy	22
Action-reaction	97
Addition of vectors	67
Adiabatic process	311, 312
Aerofoil	262
Air resistance	79
Amplitude	344, 372
Angle of contact	267, 268
Angstrom	21
Angular Acceleration	154
Angular displacement	342
Angular frequency	344, 373
Angular momentum	155
Angular velocity	152
Angular wave number	372
Antinodes	381, 382
Archimedes Principle	255
Area expansion	281
Atmospheric pressure	253
Average acceleration	45, 74
Average speed	42
Average velocity	42
Avogadro's law	325

B

Banked road	104
Barometer	254
Beat frequency	383
Beats	382, 383
Bending of beam	244
Bernoulli's Principle	258
Blood pressure	276
Boiling point	287
Boyle's law	326
Buckling	244

Bulk modulus	242
Buoyant force	255

C

Calorimeter	285
Capillary rise	268
Capillary waves	370
Carnot engine	316
Central forces	186
Centre of Gravity	161
Centre of mass	144
Centripetal acceleration	81
Centripetal force	104
Change of state	287
Charles's law	326
Chemical Energy	126
Circular motion	104
Clausius statement	315
Coefficient of area expansion	283
Coefficient of linear expansion	281
Coefficient of performance	314
Coefficient of static friction	101
Coefficient of viscosity	262
Coefficient of volume expansion	281
Cold reservoir	313
Collision	129
Collision in two dimensions	131
Compressibility	242, 243
Compressions	368, 369, 374
Compressive stress	236, 243
Conduction	290
Conservation laws	12
Conservation of angular momentum	157, 173
Conservation of Mechanical Energy	121
Conservation of momentum	98
Conservative force	121
Constant acceleration	46, 75
Contact force	100
Convection	293
Couple	159
Crest	371
Cyclic process	312

D

Dalton's law of partial pressure	325
Damped oscillations	355
Damped simple Harmonic motion	355
Damping constant	355
Damping force	355
Derived units	16
Detergent action	269
Diastolic pressure	277
Differential calculus	61
Dimensional analysis	32
Dimensions	31
Displacement vector	66
Displacement	40
Doppler effect	385, 386
Doppler shift	387
Driving frequency	358
Dynamics of rotational motion	169

E

Efficiency of heat engine	313
Elastic Collision	129
Elastic deformation	236, 238
Elastic limit	238
Elastic moduli	239
Elasticity	235
Elastomers	239
Electromagnetic force	8
Energy	117
Equality of vectors	66
Equation of continuity	257
Equilibrium of a particle	99
Equilibrium of Rigid body	158
Equilibrium position	341, 342, 353
Errors in measurement	22
Escape speed	193

F

First law of Thermodynamics	307
Fluid pressure	251
Force	94
Forced frequency	357
Forced oscillations	357, 358
Fracture point	238
Free Fall	49
Free-body diagram	100
Frequency of periodic motion	342, 372
Friction	101
Fundamental Forces	6
Fundamental mode	381
Fusion	287

G

Gauge pressure	253
Geocentric model	183

Geostationary satellite	196
Gravitational constant	189
Gravitational Force	8, 192
Gravitational potential energy	191
Gravity waves	370

H

Harmonic frequency	380, 381
Harmonics	380, 381
Heat capacity	284
Heat engines	313
Heat pumps	313
Heat	279
Heliocentric model	183
Hertz	343
Hooke's law	238
Horizontal range	78
Hot reservoir	313
Hydraulic brakes	255, 256
Hydraulic lift	255, 256
Hydraulic machines	255
Hydraulic pressure	238
Hydraulic stress	238, 243
Hydrostatic paradox	253

I

Ideal gas equation	280
Ideal gas	280, 325
Impulse	96
Inelastic collision	129
Initial phase angle	372
Instantaneous acceleration	74
Instantaneous speed	45
Instantaneous velocity	43
Interference	377
Internal energy	306, 330
Irreversible engine	315, 317
Irreversible processes	315
Isobaric process	311, 312
Isochoric process	311, 312
Isotherm	310
Isothermal process	311

K

Kelvin-Planck statement	315
Kepler's laws of planetary motion	184
Kinematics of Rotational Motion	167
Kinematics	39
Kinetic energy of rolling motion	174
Kinetic Energy	117
Kinetic interpretation of temperature	329
Kinetic theory of gases	328

L

Laminar flow	258, 264
Laplace correction	376

Latent heat of fusion	290
Latent heat of vapourisation	290
Latent heat	289
Law of cosine	72
Law of equipartition of energy	332
Law of Inertia	90
Law of sine	72
Linear expansion	281
Linear harmonic oscillator	349, 351
Linear momentum	155
Longitudinal strain	236
Longitudinal strain	236, 239
Longitudinal stress	236
Longitudinal Wave	369, 376

M

Magnus effect	261
Manometer	254
Mass Energy Equivalence	126
Maximum height of projectile	78
Maxwell Distribution	331
Mean free path	324, 335
Measurement of length	18
Measurement of mass	21
Measurement of temperature	279
Measurement of time	22
Melting point	286
Modes	380
Modulus of elasticity	238
Modulus of rigidity	242
Molar specific heat capacity at constant pressure	284, 308
Molar specific heat capacity at constant volume	284, 308
Molar specific heat capacity	284
Molecular nature of matter	323
Moment of Inertia	163
Momentum	93
Motion in a plane	72
Multiplication of vectors	67
Musical instruments	384

N

Natural frequency	358
Newton's first law of motion	91
Newton's Law of cooling	295
Newton's law of gravitation	185
Newton's second law of motion	93
Newton's third law of motion	96
Newtons' formula for speed of sound	377
Nodes	381
Normal Modes	381, 382, 384
Note	384, 385
Nuclear Energy	126
Null vector	68

O

Odd harmonics	382
Orbital velocity/speed	194
Order of magnitude	28
Oscillations	342
Oscillatory motion	342

P

Parallax method	18
Parallelogram law of addition of vectors	66
Pascal's law	252
Path length	40
Path of projectile	78
Periodic force	358
Periodic motion	342
Periodic time	342
Permanent set	238
Phase angle	344
Phase constant	344
Pipe open at both ends	382
Pipe open at one end	381
Pitch	384
Plastic deformation	238
Plasticity	235
Polar satellite	196
Position vector and displacement	73
Potential energy of a spring	123
Potential energy	120
Power	128
Precession	143
Pressure gauge	253
Pressure of an ideal gas	328
Pressure	250
Principle of Conservation of Energy	128
Principle of moments	160
Progressive wave	373
Projectile motion	77
Projectile	77
Propagation constant	371
Pulse	369

Q

Quasi-static process	310, 311
----------------------	----------

R

Radiation	294
Radius of Gyration	164
Raman effect	11
Rarefactions	369
Ratio of specific heat capacities	334
Reaction time	51
Real gases	326
Rectilinear motion	39
Reductionism	2
Reflected wave	379
Reflection of waves	378

Refracted wave	379	Surface tension	265
Refrigerator	313	Symmetry	146
Regelation	287	System of units	16
Relative velocity in two dimensions	76	Systolic pressure	277
Relative velocity	51		
Resolution of vectors	69	T	
Resonance	358	Temperature	279
Restoring force	236, 350, 369	Tensile strength	238
Reversible engine	316, 317	Tensile stress	236
Reversible processes	315	Terminal velocity	264
Reynolds number	264	Theorem of parallel axes	167
Rigid body	141	Theorem of perpendicular axes	165
Rolling motion	173	Thermal conductivity	291
Root mean square speed	329	Thermal equilibrium	304
Rotation	142	Thermal expansion	281
		Thermal stress	284
S		Thermodynamic processes	310
S.H.M. (Simple Harmonic Motion)	343	Thermodynamic state variables	309
Scalar-product	114	Thermodynamics	3, 303
Scalars	65	Time of flight	78
Scientific Method	1	Torque	154
Second law of Thermodynamics	314	Torricelli's Law	259, 260
Shear modulus	242	Trade wind	294
Shearing strain	237	Transmitted wave	379
Shearing stress	237, 243	Travelling wave	380
SI units	16	Triangle law of addition of vectors	66
Significant figures	27	Triple point	288
Simple pendulum	343, 353	Trough	371
Soap bubbles	268	Tune	384
Sonography	387	Turbulent flow	258, 259
Sound	375		
Specific heat capacity of Solids	308, 335	U	
Specific heat capacity of Gases	333, 334	Ultimate strength	238
Specific heat capacity of Water	335	Ultrasonic waves	387
Specific heat capacity	285, 308	Unification of Forces	10
Speed of efflux	259	Unified Atomic Mass Unit	21
Speed of Sound	375, 376	Uniform circular motion	79
Speed of Transverse wave	375, 376	Uniform Motion	41
on a stretched string		Uniformly accelerated motion	47
Sphygmomanometer	277	Unit vectors	70
Spring constant	352, 355		
Standing waves	380	V	
Stationary waves	382	Vane	356
Steady flow	257	Vaporisation	288
Stethoscope	281	Vector-product	151
Stokes' law	263	Vectors	66
Stopping distance	50	Velocity amplitude	349
Strain	236	Venturi meter	260
Streamline flow	257, 258	Vibration	341
Streamline	257, 258	Viscosity	262
Stress	236	Volume expansion	281
Stress-strain curve	238	Volume Strain	238
Stretched string	374		
Sublimation	294	W	
Subtraction of vectors	67	Wave equation	374
Superposition principle	378	Wavelength	372
Surface energy	265	Wave speed	374

Waves	368	Y	
Waxing and waning of sound	385	Yield Point	238
Weak nuclear force	9	Yield strength	238
Weightlessness	197	Young's modulus	239
Work done by variable force	118		
Work	116	Z	
Work-Energy Theorem	116	Zeroth law of Thermodynamics	305
Working substance	313		

NOTES