

APPENDICES

APPENDIX A 1 THE GREEK ALPHABET

| | | | | | | | | |
|---------|----------|---------------|---------|-----------|-----------|---------|----------|-----------------|
| Alpha | A | α | Iota | I | ι | Rho | P | ρ |
| Beta | B | β | Kappa | K | κ | Sigma | Σ | σ |
| Gamma | Γ | γ | Lambda | Λ | λ | Tau | T | τ |
| Delta | Δ | δ | Mu | M | μ | Upsilon | Y | υ |
| Epsilon | E | ε | Nu | N | ν | Phi | Φ | ϕ, φ |
| Zeta | Z | ζ | Xi | Ξ | ξ | Chi | X | χ |
| Eta | H | η | Omicron | O | \circ | Psi | Ψ | ψ |
| Theta | Θ | θ | Pi | Π | π | Omega | Ω | ω |

APPENDIX A 2 COMMON SI PREFIXES AND SYMBOLS FOR MULTIPLES AND SUB-MULTIPLES

| Multiple | | | Sub-Multiple | | |
|-----------|--------|--------|--------------|--------|--------|
| Factor | Prefix | Symbol | Factor | Prefix | symbol |
| 10^{18} | Exa | E | 10^{-18} | atto | a |
| 10^{15} | Peta | P | 10^{-15} | femto | f |
| 10^{12} | Tera | T | 10^{-12} | pico | p |
| 10^9 | Giga | G | 10^{-9} | nano | n |
| 10^6 | Mega | M | 10^{-6} | micro | μ |
| 10^3 | kilo | k | 10^{-3} | milli | m |
| 10^2 | Hecto | h | 10^{-2} | centi | c |
| 10^1 | Deca | da | 10^{-1} | deci | d |

APPENDIX A 3
SOME IMPORTANT CONSTANTS

| Name | Symbol | Value |
|-------------------------------|------------------------------------|---|
| Speed of light in vacuum | c | $2.9979 \times 10^8 \text{ m s}^{-1}$ |
| Charge of electron | e | $1.602 \times 10^{-19} \text{ C}$ |
| Gravitational constant | G | $6.673 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$ |
| Planck constant | h | $6.626 \times 10^{-34} \text{ J s}$ |
| Boltzmann constant | k | $1.381 \times 10^{-23} \text{ J K}^{-1}$ |
| Avogadro number | N_A | $6.022 \times 10^{23} \text{ mol}^{-1}$ |
| Universal gas constant | R | $8.314 \text{ J mol}^{-1} \text{ K}^{-1}$ |
| Mass of electron | m_e | $9.110 \times 10^{-31} \text{ kg}$ |
| Mass of neutron | m_n | $1.675 \times 10^{-27} \text{ kg}$ |
| Mass of proton | m_p | $1.673 \times 10^{-27} \text{ kg}$ |
| Electron-charge to mass ratio | e/m_e | $1.759 \times 10^{11} \text{ C/kg}$ |
| Faraday constant | F | $9.648 \times 10^4 \text{ C/mol}$ |
| Rydberg constant | R | $1.097 \times 10^7 \text{ m}^{-1}$ |
| Bohr radius | a_0 | $5.292 \times 10^{-11} \text{ m}$ |
| Stefan-Boltzmann constant | σ | $5.670 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$ |
| Wien's Constant | b | $2.898 \times 10^{-3} \text{ m K}$ |
| Permittivity of free space | ϵ_0 $1/4\pi\epsilon_0$ | $8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$ $8.987 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$ |
| Permeability of free space | μ_0 | $4\pi \times 10^{-7} \text{ T m A}^{-1}$ $\cong 1.257 \times 10^{-6} \text{ Wb A}^{-1} \text{ m}^{-1}$ |

Other useful constants

| Name | Symbol | Value |
|--|-------------------|------------------------------------|
| Mechanical equivalent of heat | J | 4.186 J cal^{-1} |
| Standard atmospheric pressure | 1 atm | $1.013 \times 10^5 \text{ Pa}$ |
| Absolute zero | 0 K | $-273.15 \text{ }^\circ\text{C}$ |
| Electron volt | 1 eV | $1.602 \times 10^{-19} \text{ J}$ |
| Unified Atomic mass unit | 1 u | $1.661 \times 10^{-27} \text{ kg}$ |
| Electron rest energy | mc^2 | 0.511 MeV |
| Energy equivalent of 1 u | 1 u c^2 | 931.5 MeV |
| Volume of ideal gas(0 °C and 1atm) | V | 22.4 L mol^{-1} |
| Acceleration due to gravity (sea level, at equator) | g | 9.78049 m s^{-2} |

APPENDIX A 4 CONVERSION FACTORS

Conversion factors are written as equations for simplicity.

Length

$$\begin{aligned}1 \text{ km} &= 0.6215 \text{ mi} \\1 \text{ mi} &= 1.609 \text{ km} \\1 \text{ m} &= 1.0936 \text{ yd} = 3.281 \text{ ft} = 39.37 \text{ in} \\1 \text{ in} &= 2.54 \text{ cm} \\1 \text{ ft} &= 12 \text{ in} = 30.48 \text{ cm} \\1 \text{ yd} &= 3 \text{ ft} = 91.44 \text{ cm} \\1 \text{ lightyear} &= 1 \text{ ly} = 9.461 \times 10^{15} \text{ m} \\1 \text{ Å} &= 0.1 \text{ nm}\end{aligned}$$

Area

$$\begin{aligned}1 \text{ m}^2 &= 10^4 \text{ cm}^2 \\1 \text{ km}^2 &= 0.3861 \text{ mi}^2 = 247.1 \text{ acres} \\1 \text{ in}^2 &= 6.4516 \text{ cm}^2 \\1 \text{ ft}^2 &= 9.29 \times 10^{-2} \text{ m}^2 \\1 \text{ m}^2 &= 10.76 \text{ ft}^2 \\1 \text{ acre} &= 43,560 \text{ ft}^2 \\1 \text{ mi}^2 &= 460 \text{ acres} = 2.590 \text{ km}^2\end{aligned}$$

Volume

$$\begin{aligned}1 \text{ m}^3 &= 10^6 \text{ cm}^3 \\1 \text{ L} &= 1000 \text{ cm}^3 = 10^{-3} \text{ m}^3 \\1 \text{ gal} &= 3.786 \text{ L} \\1 \text{ gal} &= 4 \text{ qt} = 8 \text{ pt} = 128 \text{ oz} = 231 \text{ in}^3 \\1 \text{ in}^3 &= 16.39 \text{ cm}^3 \\1 \text{ ft}^3 &= 1728 \text{ in}^3 = 28.32 \text{ L} = 2.832 \times 10^4 \text{ cm}^3\end{aligned}$$

Speed

$$\begin{aligned}1 \text{ km h}^{-1} &= 0.2778 \text{ m s}^{-1} = 0.6215 \text{ mi h}^{-1} \\1 \text{ mi h}^{-1} &= 0.4470 \text{ m s}^{-1} = 1.609 \text{ km h}^{-1} \\1 \text{ mi h}^{-1} &= 1.467 \text{ ft s}^{-1}\end{aligned}$$

Magnetic Field

$$\begin{aligned}1 \text{ G} &= 10^{-4} \text{ T} \\1 \text{ T} &= 1 \text{ Wb m}^{-2} = 10^4 \text{ G}\end{aligned}$$

Angle and Angular Speed

$$\begin{aligned}\pi \text{ rad} &= 180^\circ \\1 \text{ rad} &= 57.30^\circ \\1^\circ &= 1.745 \times 10^{-2} \text{ rad} \\1 \text{ rev min}^{-1} &= 0.1047 \text{ rad s}^{-1} \\1 \text{ rad s}^{-1} &= 9.549 \text{ rev min}^{-1}\end{aligned}$$

Mass

$$\begin{aligned}1 \text{ kg} &= 1000 \text{ g} \\1 \text{ tonne} &= 1000 \text{ kg} = 1 \text{ Mg} \\1 \text{ u} &= 1.6606 \times 10^{-27} \text{ kg} \\1 \text{ kg} &= 6.022 \times 10^{26} \text{ u} \\1 \text{ slug} &= 14.59 \text{ kg} \\1 \text{ kg} &= 6.852 \times 10^{-2} \text{ slug} \\1 \text{ u} &= 931.50 \text{ MeV/c}^2\end{aligned}$$

Density

$$1 \text{ g cm}^{-3} = 1000 \text{ kg m}^{-3} = 1 \text{ kg L}^{-1}$$

Force

$$\begin{aligned}1 \text{ N} &= 0.2248 \text{ lbf} = 10^5 \text{ dyn} \\1 \text{ lbf} &= 4.4482 \text{ N} \\1 \text{ kgf} &= 2.2046 \text{ lbf}\end{aligned}$$

Time

$$\begin{aligned}1 \text{ h} &= 60 \text{ min} = 3.6 \text{ ks} \\1 \text{ d} &= 24 \text{ h} = 1440 \text{ min} = 86.4 \text{ ks} \\1 \text{ y} &= 365.24 \text{ d} = 31.56 \text{ Ms}\end{aligned}$$

Pressure

$$\begin{aligned}1 \text{ Pa} &= 1 \text{ N m}^{-2} \\1 \text{ bar} &= 100 \text{ kPa} \\1 \text{ atm} &= 101.325 \text{ kPa} = 1.01325 \text{ bar} \\1 \text{ atm} &= 14.7 \text{ lbf/in}^2 = 760 \text{ mm Hg} \\&= 29.9 \text{ in Hg} = 33.8 \text{ ft H}_2\text{O} \\1 \text{ lbf in}^{-2} &= 6.895 \text{ kPa} \\1 \text{ torr} &= 1 \text{ mm Hg} = 133.32 \text{ Pa}\end{aligned}$$

Energy

$$1 \text{ kW h} = 3.6 \text{ MJ}$$

$$1 \text{ cal} = 4.186 \text{ J}$$

$$1 \text{ ft lbf} = 1.356 \text{ J} = 1.286 \times 10^{-3} \text{ Btu}$$

$$1 \text{ L atm} = 101.325 \text{ J}$$

$$1 \text{ L atm} = 24.217 \text{ cal}$$

$$1 \text{ Btu} = 778 \text{ ft lb} = 252 \text{ cal} = 1054.35 \text{ J}$$

$$1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$$

$$1 \text{ u } c^2 = 931.50 \text{ MeV}$$

$$1 \text{ erg} = 10^{-7} \text{ J}$$

Power

$$\begin{aligned}1 \text{ horsepower (hp)} &= 550 \text{ ft lbf/s} \\&= 745.7 \text{ W}\end{aligned}$$

$$1 \text{ Btu min}^{-1} = 17.58 \text{ W}$$

$$\begin{aligned}1 \text{ W} &= 1.341 \times 10^{-3} \text{ hp} \\&= 0.7376 \text{ ft lbf/s}\end{aligned}$$

Thermal Conductivity

$$1 \text{ W m}^{-1} \text{ K}^{-1} = 6.938 \text{ Btu in/hft}^2 \text{ }^{\circ}\text{F}$$

$$1 \text{ Btu in/hft}^2 \text{ }^{\circ}\text{F} = 0.1441 \text{ W/m K}$$

APPENDIX A 5
MATHEMATICAL FORMULAE

Geometry

Circle of radius r : circumference = $2\pi r$;
area = πr^2

Sphere of radius r : area = $4\pi r^2$;

$$\text{volume} = \frac{4}{3}\pi r^3$$

Right circular cylinder of radius r and height h : area = $2\pi r^2 + 2\pi r h$;

$$\text{volume} = \pi r^2 h;$$

Triangle of base a and altitude h .

$$\text{area} = \frac{1}{2} a h$$

Quadratic Formula

If $ax^2 + bx + c = 0$,

$$\text{then } x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

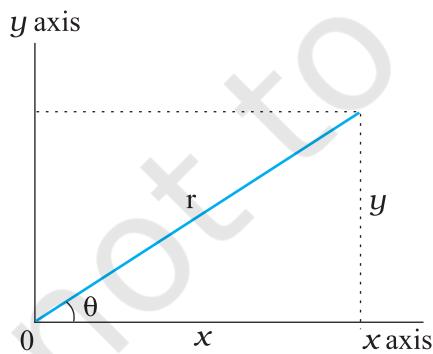
Trigonometric Functions of Angle θ 

Fig. A 5.1

$$\begin{array}{ll}\sin \theta = \frac{y}{r} & \cos \theta = \frac{x}{r} \\ \tan \theta = \frac{y}{x} & \cot \theta = \frac{x}{y} \\ \sec \theta = \frac{r}{x} & \csc \theta = \frac{r}{y}\end{array}$$

Pythagorean Theorem

In this right triangle, $a^2 + b^2 = c^2$

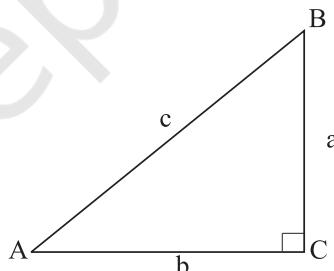


Fig. A 5.2

Triangles

Angles are A, B, C

Opposite sides are a, b, c

Angles $A + B + C = 180^{\circ}$

$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$

$$c^2 = a^2 + b^2 - 2ab \cos C$$

Exterior angle $D = A + C$

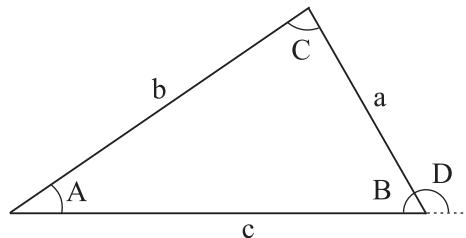


Fig. A 5.3

Mathematical Signs and Symbols

- = equals
- \approx equals approximately
- \sim is the order of magnitude of
- \neq is not equal to
- \equiv is identical to, is defined as
- $>$ is greater than ($>>$ is much greater than)
- $<$ is less than ($<<$ is much less than)
- \geq is greater than or equal to (or, is no less than)
- \leq is less than or equal to (or, is no more than)
- \pm plus or minus
- \propto is proportional to
- Σ the sum of
- \bar{x} or $\langle x \rangle$ or x_{av} the average value of x

Trigonometric Identities

$$\sin(90^\circ - \theta) = \cos \theta$$

$$\cos(90^\circ - \theta) = \sin \theta$$

$$\sin \theta / \cos \theta = \tan \theta$$

$$\sin^2 \theta + \cos^2 \theta = 1$$

$$\sec^2 \theta - \tan^2 \theta = 1$$

$$\csc^2 \theta - \cot^2 \theta = 1$$

$$\sin 2\theta = 2 \sin \theta \cos \theta$$

$$\begin{aligned} \cos 2\theta &= \cos^2 \theta - \sin^2 \theta = 2\cos^2 \theta - 1 \\ &= 1 - 2 \sin^2 \theta \end{aligned}$$

$$\sin(\alpha \pm \beta) = \sin \alpha \cos \beta \pm \cos \alpha \sin \beta$$

$$\cos(\alpha \pm \beta) = \cos \alpha \cos \beta \mp \sin \alpha \sin \beta$$

$$\tan(\alpha \pm \beta) = \frac{\tan \alpha \pm \tan \beta}{1 \mp \tan \alpha \tan \beta}$$

$$\sin \alpha \pm \sin \beta = 2 \sin \frac{1}{2}(\alpha \pm \beta) \cos \frac{1}{2}(\alpha \mp \beta)$$

$$\cos \alpha + \cos \beta$$

$$= 2 \cos \frac{1}{2}(\alpha + \beta) \cos \frac{1}{2}(\alpha - \beta)$$

$$\cos \alpha - \cos \beta$$

$$= -2 \sin \frac{1}{2}(\alpha + \beta) \sin \frac{1}{2}(\alpha - \beta)$$

Binomial Theorem

$$(1-x)^n = 1 - \frac{nx}{1!} + \frac{n(n-1)x^2}{2!} + \dots \quad (x^2 < 1)$$

$$(1-x)^{-n} = 1 + \frac{nx}{1!} + \frac{n(n+1)x^2}{2!} + \dots \quad (x^2 < 1)$$

Exponential Expansion

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \dots$$

Logarithmic Expansion

$$\ln(1+x) = x - \frac{1}{2}x^2 + \frac{1}{3}x^3 - \dots \quad (|x| < 1)$$

Trigonometric Expansion

(θ in radians)

$$\sin \theta = \theta - \frac{\theta^3}{3!} + \frac{\theta^5}{5!} - \dots$$

$$\cos \theta = 1 - \frac{\theta^2}{2!} + \frac{\theta^4}{4!} - \dots$$

$$\tan \theta = \theta + \frac{\theta^3}{3} + \frac{2\theta^5}{15} - \dots$$

Products of Vectors

Let \hat{i}, \hat{j} and \hat{k} be unit vectors in the x, y and z directions. Then

$$\hat{i} \cdot \hat{i} = \hat{j} \cdot \hat{j} = \hat{k} \cdot \hat{k} = 1, \quad \hat{i} \cdot \hat{j} = \hat{j} \cdot \hat{k} = \hat{k} \cdot \hat{i} = 0$$

$$\hat{i} \times \hat{i} = \hat{j} \times \hat{j} = \hat{k} \times \hat{k} = 0, \quad \hat{i} \times \hat{j} = \hat{k}, \quad \hat{j} \times \hat{k} = \hat{i}, \quad \hat{k} \times \hat{i} = \hat{j}$$

Any vector \mathbf{a} with components a_x, a_y , and a_z along the x, y , and z axes can be written,

$$\mathbf{a} = a_x \hat{i} + a_y \hat{j} + a_z \hat{k}$$

Let \mathbf{a} , \mathbf{b} and \mathbf{c} be arbitrary vectors with magnitudes a , b and c . Then

$$\mathbf{a} \times (\mathbf{b} + \mathbf{c}) = (\mathbf{a} \times \mathbf{b}) + (\mathbf{a} \times \mathbf{c})$$

$$(\mathbf{s}\mathbf{a}) \times \mathbf{b} = \mathbf{a} \times (\mathbf{s}\mathbf{b}) = \mathbf{s}(\mathbf{a} \times \mathbf{b}) \quad (\mathbf{s} \text{ is a scalar})$$

Let θ be the smaller of the two angles between \mathbf{a} and \mathbf{b} . Then

$$\mathbf{a} \cdot \mathbf{b} = \mathbf{b} \cdot \mathbf{a} = a_x b_x + a_y b_y + a_z b_z = ab \cos \theta$$

$$|\mathbf{a} \times \mathbf{b}| = ab \sin \theta$$

$$\mathbf{a} \times \mathbf{b} = -\mathbf{b} \times \mathbf{a} = \begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ a_x & a_y & a_z \\ b_x & b_y & b_z \end{vmatrix}$$

$$= (a_y b_z - b_y a_z) \hat{\mathbf{i}} + (a_z b_x - b_z a_x) \hat{\mathbf{j}} + (a_x b_y - b_x a_y) \hat{\mathbf{k}}$$

$$\mathbf{a} \cdot (\mathbf{b} \times \mathbf{c}) = \mathbf{b} \cdot (\mathbf{c} \times \mathbf{a}) = \mathbf{c} \cdot (\mathbf{a} \times \mathbf{b})$$

$$\mathbf{a} \times (\mathbf{b} \times \mathbf{c}) = (\mathbf{a} \cdot \mathbf{c}) \mathbf{b} - (\mathbf{a} \cdot \mathbf{b}) \mathbf{c}$$

APPENDIX A 6

SI DERIVED UNITS

A 6.1 Some SI Derived Units expressed in SI Base Units

| Physical quantity | SI Unit | |
|--|---------------------------|--|
| | Name | Symbol |
| Area | square metre | m^2 |
| Volume | cubic metre | m^3 |
| Speed, velocity | metre per second | m/s or m s^{-1} |
| Angular velocity | radian per second | rad/s or rad s^{-1} |
| Acceleration | metre per second square | m/s^2 or m s^{-2} |
| Angular acceleration | radian per second square | rad/s^2 or rad s^{-2} |
| Wave number | per metre | m^{-1} |
| Density, mass density | kilogram per cubic metre | kg/m^3 or kg m^{-3} |
| Current density | ampere per square metre | A/m^2 or A m^{-2} |
| Magnetic field strength, magnetic intensity, magnetic moment density | ampere per metre | A/m or A m^{-1} |
| Concentration (of amount of substance) | mole per cubic metre | mol/m^3 or mol m^{-3} |
| Specific volume | cubic metre per kilogram | m^3/kg or $\text{m}^3 \text{ kg}^{-1}$ |
| Luminance, intensity of illumination | candela per square metre | cd/m^2 or cd m^{-2} |
| Kinematic viscosity | square metre per second | m^2/s or $\text{m}^2 \text{ s}^{-1}$ |
| Momentum | kilogram metre per second | kg m s^{-1} |
| Moment of inertia | kilogram square metre | kg m^2 |
| Radius of gyration | metre | m |
| Linear/superficial/volume expansivities | per kelvin | K^{-1} |
| Flow rate | cubic metre per second | $\text{m}^3 \text{ s}^{-1}$ |

A 6.2 SI Derived Units with special names

| Physical quantity | SI Unit | | | |
|---|-----------|----------|-------------------------------------|---|
| | Name | Symbol | Expression in terms of other units | Expression in terms of SI base Units |
| Frequency | hertz | Hz | - | s^{-1} |
| Force | newton | N | - | kg m s^{-2} or kg m/s^2 |
| Pressure, stress | pascal | Pa | N/m^2 or N m^{-2} | $\text{kg m}^{-1} \text{s}^{-2}$ or $\text{kg/s}^2 \text{m}$ |
| Energy, work, quantity of heat | joule | J | N m | $\text{kg m}^2 \text{s}^{-2}$ or $\text{kg m}^2/\text{s}^2$ |
| Power, radiant flux | watt | W | J/s or J s^{-1} | $\text{kg m}^2 \text{s}^{-3}$ or $\text{kg m}^2/\text{s}^3$ |
| Quantity of electricity, electric charge | coulomb | C | - | A s |
| Electric potential, potential difference, electromotive force | volt | V | W/A or W A^{-1} | $\text{kg m}^2 \text{s}^{-3} \text{A}^{-1}$ or $\text{kg m}^2/\text{s}^3 \text{A}$ |
| Capacitance | farad | F | C/V | $\text{A}^2 \text{s}^4 \text{kg}^{-1} \text{m}^{-2}$ |
| Electric resistance | ohm | Ω | V/A | $\text{kg m}^2 \text{s}^{-3} \text{A}^{-2}$ |
| Conductance | siemens | S | A/V | $\text{m}^{-2} \text{kg}^{-1} \text{s}^3 \text{A}^2$ |
| Magnetic flux | weber | Wb | V s or J/A | $\text{kg m}^2 \text{s}^{-2} \text{A}^{-1}$ |
| Magnetic field, magnetic flux density, magnetic induction | tesla | T | Wb/m ² | $\text{kg s}^{-2} \text{A}^{-1}$ |
| Inductance | henry | H | Wb/A | $\text{kg m}^2 \text{s}^{-2} \text{A}^{-2}$ |
| Luminous flux, luminous power | lumen | lm | - | cd /sr |
| Illuminance | lux | lx | lm/m ² | $\text{m}^{-2} \text{cd sr}^{-1}$ |
| Activity (of a radio nuclide/radioactive source) | becquerel | Bq | - | s ⁻¹ |
| Absorbed dose, absorbed dose index | gray | Gy | J/kg | m^2/s^2 or $\text{m}^2 \text{s}^{-2}$ |

A 6.3 Some SI Derived Units expressed by means of SI Units with special names

| Physical quantity | SI Unit | | |
|--|---|-----------------------------|--------------------------------------|
| | Name | Symbol | Expression in terms of SI base units |
| Magnetic moment | joule per tesla | J T ⁻¹ | $\text{m}^2 \text{A}$ |
| Dipole moment | coulomb metre | C m | s A m |
| Dynamic viscosity | poiseilles or pascal second or newton second per square metre | Pa s or N s m ⁻² | $\text{m}^{-1} \text{kg s}^{-1}$ |
| Torque, couple, moment of force | newton metre | N m | $\text{m}^2 \text{kg s}^{-2}$ |
| Surface tension | newton per metre | N/m | kg s^{-2} |
| Power density, irradiance, heat flux density | watt per square metre | W/m ² | kg s^{-3} |

| | | | |
|---|---------------------------|---------------------------------------|---|
| Heat capacity, entropy | joule per kelvin | J/K | $m^2 \text{ kg s}^2 \text{ K}^{-1}$ |
| Specific heat capacity, specific entropy | joule per kilogram kelvin | J/kg K | $m^2 \text{ s}^2 \text{ K}^{-1}$ |
| Specific energy, latent heat | joule per kilogram | J/kg | $m^2 \text{ s}^{-2}$ |
| Radiant intensity | watt per steradian | W sr ⁻¹ | $\text{kg m}^2 \text{ s}^{-3} \text{ sr}^{-1}$ |
| Thermal conductivity | watt per metre kelvin | W m ⁻¹ K ⁻¹ | $\text{m kg s}^{-3} \text{ K}^{-1}$ |
| Energy density | joule per cubic metre | J/m ³ | $\text{kg m}^{-1} \text{ s}^{-2}$ |
| Electric field strength | volt per metre | V/m | $\text{m kg s}^3 \text{ A}^{-1}$ |
| Electric charge density | coulomb per cubic metre | C/m ³ | $\text{m}^{-3} \text{ A s}$ |
| Electric flux density | coulomb per square metre | C/m ² | $\text{m}^{-2} \text{ A s}$ |
| Permittivity | farad per metre | F/m | $\text{m}^{-3} \text{ kg}^{-1} \text{ s}^4 \text{ A}^2$ |
| Permeability | henry per metre | H/m | $\text{m kg s}^{-2} \text{ A}^2$ |
| Molar energy | joule per mole | J/mol | $\text{m}^2 \text{ kg s}^2 \text{ mol}^{-1}$ |
| Angular momentum, Planck's constant | joule second | J s | $\text{kg m}^2 \text{ s}^{-1}$ |
| Molar entropy, molar heat capacity | joule per mole kelvin | J/mol K | $\text{m}^2 \text{ kg s}^2 \text{ K}^{-1} \text{ mol}^{-1}$ |
| Exposure (α -rays and γ -rays) | coulomb per kilogram | C/kg | $\text{kg}^{-1} \text{ s A}$ |
| Absorbed dose rate | gray per second | Gy/s | $\text{m}^2 \text{ s}^{-3}$ |
| Compressibility | per pascal | Pa ⁻¹ | $\text{m kg}^{-1} \text{ s}^2$ |
| Elastic moduli | newton per square metre | N/m ² or N m ⁻² | $\text{kg m}^{-1} \text{ s}^2$ |
| Pressure gradient | pascal per metre | Pa/m or N m ⁻³ | $\text{kg m}^{-2} \text{ s}^{-2}$ |
| Surface potential | joule per kilogram | J/kg or N m/kg | $\text{m}^2 \text{ s}^{-2}$ |
| Pressure energy | pascal cubic metre | Pa m ³ or N m | $\text{kg m}^2 \text{ s}^{-2}$ |
| Impulse | newton second | N s | kg m s^{-1} |
| Angular impulse | newton metre second | N m s | $\text{kg m}^2 \text{ s}^{-1}$ |
| Specific resistance | ohm metre | Ωm | $\text{kg m}^3 \text{ s}^{-3} \text{ A}^{-2}$ |
| Surface energy | joule per square metre | J/m ² or N/m | kg s^2 |

APPENDIX A 7 GENERAL GUIDELINES FOR USING SYMBOLS FOR PHYSICAL QUANTITIES, CHEMICAL ELEMENTS AND NUCLIDES

- Symbols for physical quantities are normally single letters and printed in italic (or sloping) type. However, in case of the two letter symbols, appearing as a factor in a product, some spacing is necessary to separate this symbol from other symbols.
- Abbreviations, i.e., shortened forms of names or expressions, such as p.e. for potential energy, are not used in physical equations. These abbreviations in the text are written in ordinary normal/roman (upright) type.
- Vectors are printed in bold and normal/roman (upright) type. However, in class room situations, vectors may be indicated by an arrow on the top of the symbol.
- Multiplication or product of two physical quantities is written with some spacing between them. Division of one physical quantity by another may be indicated with a horizontal bar or with

solidus, a slash or a short oblique stroke mark (/) or by writing it as a product of the numerator and the inverse first power of the denominator, using brackets at appropriate places to clearly distinguish between the numerator and the denominator.

- Symbols for chemical elements are written in normal/roman (upright) type. The symbol is not followed by a full stop.

For example, Ca, C, H, He, U, etc.

- The attached numerals specifying a nuclide are placed as a left subscript (atomic number) and superscript (mass number).

For example, a U-235 nuclide is expressed as $^{235}_{92}\text{U}$ (with 235 expressing the mass number and 92 as the atomic number of uranium with chemical symbol U).

- The right superscript position is used, if required, for indicating a state of ionisation (in case of ions).

For example, Ca^{2+} , PO_4^{3-}

APPENDIX A 8

GENERAL GUIDELINES FOR USING SYMBOLS FOR SI UNITS, SOME OTHER UNITS, AND SI PREFIXES

- Symbols for units of physical quantities are printed/written in Normal/Roman (upright) type.
- Standard and recommended symbols for units are written in lower case roman (upright) type, starting with small letters. The shorter designations for units such as kg, m, s, cd, etc., are symbols and not the abbreviations. The unit names are never capitalised. However, the unit symbols are capitalised only if the symbol for a unit is derived from a proper name of scientist, beginning with a capital, normal/roman letter.

For example, m for the unit 'metre', d for the unit 'day', atm for the unit 'atmospheric pressure', Hz for the unit 'hertz', Wb for the unit 'weber', J for the unit 'joule', A for the unit 'ampere', V for the unit 'volt', etc. The single exception is L, which is the symbol for the unit 'litre'. This exception is made to avoid confusion of the lower case letter l with the Arabic numeral 1.

- Symbols for units do not contain any final full stop at the end of recommended letter and remain unaltered in the plural, using only singular form of the unit.

For example, for a length of 25 centimetres the unit symbol is written as 25 cm and not 25 cms or 25 cm. or 25 cms., etc.

- Use of solidus (/) is recommended only for indicating a division of one letter unit symbol by another unit symbol. Not more than one solidus is used.

For example :

m/s^2 or m s^{-2} (with a spacing between m and s^{-2}) but not m/s/s ;

$1 \text{ Pl} = 1 \text{ N s m}^{-2} = 1 \text{ N s/m}^2 = 1 \text{ kg/s m} = 1 \text{ kg m}^{-1} \text{ s}^{-1}$, but not 1 kg/m/s ;

J/K mol or $\text{J K}^{-1} \text{ mol}^{-1}$, but not J/K/mol ; etc.

- Prefix symbols are printed in normal/roman (upright) type without spacing between the prefix symbol and the unit symbol. Thus certain approved prefixes written very close to the unit symbol are used to indicate decimal fractions or multiples of a SI unit, when it is inconveniently small or large.

For example :

megawatt ($1\text{MW} = 10^6 \text{W}$);

nanosecond ($1 \text{ ns} = 10^{-9} \text{s}$);

centimetre ($1 \text{ cm} = 10^{-2} \text{ m}$);

picofarad ($1 \text{ pF} = 10^{-12} \text{ F}$);

kilometre ($1 \text{ km} = 10^3 \text{ m}$);

microsecond ($1 \mu\text{s} = 10^{-6} \text{s}$);

millivolt ($1 \text{ mV} = 10^{-3} \text{ V}$);

gigahertz ($1\text{GHz} = 10^9 \text{Hz}$);

kilowatt-hour ($1 \text{ kW h} = 10^3 \text{ W h} = 3.6 \text{ MJ} = 3.6 \times 10^6 \text{ J}$);
 microampere ($1\mu\text{A} = 10^{-6} \text{ A}$); micron ($1\mu\text{m} = 10^{-6} \text{ m}$);
 angstrom ($1 \text{ \AA} = 0.1 \text{ nm} = 10^{-10} \text{ m}$); etc.

The unit ‘micron’ which equals 10^{-6} m , i.e. a micrometre, is simply the name given to convenient sub-multiple of the metre. In the same spirit, the unit ‘fermi’, equal to a femtometre or 10^{-15} m has been used as the convenient length unit in nuclear studies. Similarly, the unit ‘barn’, equal to 10^{-28} m^2 , is a convenient measure of cross-sectional areas in sub-atomic particle collisions. However, the unit ‘micron’ is preferred over the unit ‘micrometre’ to avoid confusion of the ‘micrometre’ with the length measuring instrument called ‘micrometer’. These newly formed multiples or sub-multiples (cm, km, μm , μs , ns) of SI units, metre and second, constitute a new composite inseparable symbol for units.

- When a prefix is placed before the symbol of a unit, the combination of prefix and symbol is considered as a new symbol, for the unit, which can be raised to a positive or negative power without using brackets. These can be combined with other unit symbols to form compound unit. Rules for binding-in indices are not those of ordinary algebra.

For example :

cm^3 means always $(\text{cm})^3 = (0.01 \text{ m})^3 = (10^{-2} \text{ m})^3 = 10^{-6} \text{ m}^3$, but never 0.01 m^3 or 10^{-2} m^3 or 1cm^3 (prefix c with a spacing with m^3 is meaningless as prefix c is to be attached to a unit symbol and it has no physical significance or independent existence without attachment with a unit symbol).

Similarly, mA^2 means always $(\text{mA})^2 = (0.001\text{A})^2 = (10^{-3} \text{ A})^2 = 10^{-6} \text{ A}^2$, but never 0.001 A^2 or 10^{-3} A^2 or m A^2 ;

$1 \text{ cm}^{-1} = (10^{-2} \text{ m})^{-1} = 10^2 \text{ m}^{-1}$, but not 1c m^{-1} or 10^{-2} m^{-1} ;

$1\mu\text{s}^{-1}$ means always $(10^{-6} \text{ s})^{-1} = 10^6 \text{ s}^{-1}$, but not $1 \times 10^{-6} \text{ s}^{-1}$,

1 km^2 means always $(\text{km})^2 = (10^3 \text{ m})^2 = 10^6 \text{ m}^2$, but not 10^3 m^2 ;

1mm^2 means always $(\text{mm})^2 = (10^{-3} \text{ m})^2 = 10^{-6} \text{ m}^2$, but not 10^{-3} m^2 .

- A prefix is never used alone. It is always attached to a unit symbol and written or fixed before (pre-fix) the unit symbol.

For example :

$10^3/\text{m}^3$ means $1000/\text{m}^3$ or 1000 m^{-3} , but not k/m^3 or k m^{-3} .

$10^6/\text{m}^3$ means $10,00,000/\text{m}^3$ or $10,00,000 \text{ m}^{-3}$, but not M/m^3 or M m^{-3}

- Prefix symbol is written very close to the unit symbol without spacing between them, while unit symbols are written separately with spacing when units are multiplied together.

For example :

m s^{-1} (symbols m and s^{-1} , in lower case, small letter m and s, are separate and independent unit symbols for metre and second respectively, with spacing between them) means ‘metre per second’, but not ‘milli per second’.

Similarly, ms^{-1} [symbol m and s are written very close to each other, with prefix symbol m (for prefix milli) and unit symbol s, in lower case, small letter (for unit ‘second’) without any spacing between them and making ms as a new composite unit] means ‘per millisecond’, but never ‘metre per second’.

mS^{-1} [symbol m and S are written very close to each other, with prefix symbol m (for prefix milli) and unit symbol S, in capital roman letter S (for unit ‘siemens’) without any spacing between them, and making mS as a new composite unit] means ‘per millisiemens’, but never ‘per millisecond’.

C m [symbol C and m are written separately, representing unit symbols C (for unit ‘coulomb’) and m (for unit ‘metre’), with spacing between them] means ‘coulomb metre’, but never ‘centimetre’, etc.

- The use of double prefixes is avoided when single prefixes are available.

For example :

$10^{-9} \text{ m} = 1 \text{ nm}$ (nanometre), but not $1 \text{ m}\mu\text{m}$ (millimicrometre),
 $10^{-6} \text{ m} = 1 \mu\text{m}$ (micron), but not 1 mmm (millimillimetre),
 $10^{-12} \text{ F} = 1 \text{ pF}$ (picofarad), but not $1 \mu\mu\text{F}$ (micromicrofarad),
 $10^9 \text{ W} = 1 \text{ GW}$ (giga watt), but not 1 kMW (kilomegawatt), etc.

- The use of a combination of unit and the symbols for units is avoided when the physical quantity is expressed by combining two or more units.

For example :

joule per mole kelvin is written as J/mol K or $\text{J mol}^{-1} \text{ K}^{-1}$, but not joule/mole K or $\text{J}/\text{mol kelvin}$ or J/mole K , etc.

joule per tesla is written as J/T or J T^{-1} , but not joule /T or J per tesla or J/tesla, etc.
newton metre second is written as N m s , but not Newton m second or N m second or N metre s or newton metre s, etc.

joule per kilogram kelvin is written as J/kg K or $\text{J kg}^{-1} \text{ K}^{-1}$, but not J/kilog K or joule/kg K or J/kg kelvin or J/kilogram K , etc.

- To simplify calculations, the prefix symbol is attached to the unit symbol in the numerator and not to the denominator.

For example :

10^6 N/m^2 is written more conveniently as MN/m^2 , in preference to N/mm^2 .

A preference has been expressed for multiples or sub-multiples involving the factor 1000, 10^{+3n} where n is the integer.

- Proper care is needed when same symbols are used for physical quantities and units of physical quantities.

For example :

The physical quantity weight (W) expressed as a product of mass (m) and acceleration due to gravity (g) may be written in terms of symbols W, m and g printed in italic (or sloping) type as $W = m g$, preferably with a spacing between m and g. It should not be confused with the unit symbols for the units watt (W), metre (m) and gram (g). However, in the equation $W=m g$, the symbol W expresses the weight with a unit symbol J, m as the mass with a unit symbol kg and g as the acceleration due to gravity with a unit symbol m/s^2 . Similarly, in equation $F=m a$, the symbol F expresses the force with a unit symbol N, m as the mass with a unit symbol kg, and a as the acceleration with a unit symbol m/s^2 . These symbols for physical quantities should not be confused with the unit symbols for the units 'farad' (F), 'metre'(m) and 'are' (a).

Proper distinction must be made while using the symbols h (prefix hecto, and unit hour), c (prefix centi, and unit carat), d (prefix deci and unit day), T (prefix tera, and unit tesla), a (prefix atto, and unit are), da (prefix deca, and unit deciare), etc.

- SI base unit 'kilogram' for mass is formed by attaching SI prefix (a multiple equal to 10^3) 'kilo' to a cgs (centimetre, gram, second) unit 'gram' and this may seem to result in an anomaly. Thus, while a thousandth part of unit of length (metre) is called a millimetre (mm), a thousandth part of the unit of mass (kg) is not called a millikilogram, but just a gram. This appears to give the impression that the unit of mass is a gram (g) which is not true. Such a situation has arisen because we are unable to replace the name 'kilogram' by any other suitable unit. Therefore, as an exception, name of the multiples and sub-multiples of the unit of mass are formed by attaching prefixes to the word 'gram' and not to the word 'kilogram'.

For example :

$10^3 \text{ kg} = 1 \text{ megagram}$ (1 Mg), but not 1 kilo kilogram (1 kkg);

$10^{-6} \text{ kg} = 1 \text{ milligram}$ (1 mg), but not 1 microkilogram (1 μkkg);

$10^{-3} \text{ kg} = 1 \text{ gram}$ (1g), but not 1 millikilogram (1 mkg), etc.

It may be emphasised again that you should use the internationally approved and recommended symbols only. Continual practice of following general rules and guidelines in unit symbol writing would make you learn mastering the correct use of SI units, prefixes and related symbols for physical quantities in a proper perspective.

APPENDIX A 9
DIMENSIONAL FORMULAE OF PHYSICAL QUANTITIES

| S.No | Physical quantity | Relationship with other physical quantities | Dimensions | Dimensional formula |
|------|--|--|--|--|
| 1. | Area | Length × breadth | [L ²] | [M ⁰ L ² T ⁰] |
| 2. | Volume | Length × breadth × height | [L ³] | [M ⁰ L ³ T ⁰] |
| 3. | Mass density | Mass/volume | [M]/[L ³] or [M L ⁻³] | [ML ⁻³ T ⁰] |
| 4. | Frequency | 1/time period | 1/[T] | [M ⁰ L ⁰ T ⁻¹] |
| 5. | Velocity, speed | Displacement/time | [L]/[T] | [M ⁰ LT ⁻¹] |
| 6. | Acceleration | Velocity /time | [LT ⁻¹]/[T] | [M ⁰ LT ⁻²] |
| 7. | Force | Mass × acceleration | [M][LT ⁻²] | [M LT ⁻²] |
| 8. | Impulse | Force × time | [M LT ⁻²][T] | [M LT ⁻¹] |
| 9. | Work, Energy | Force × distance | [MLT ⁻²][L] | [M L ² T ⁻²] |
| 10. | Power | Work/time | [ML ² T ⁻²]/[T] | [M L ² T ⁻³] |
| 11. | Momentum | Mass × velocity | [M][LT ⁻¹] | [M LT ⁻¹] |
| 12. | Pressure, stress | Force/area | [M LT ⁻²]/[L ²] | [ML ⁻¹ T ⁻²] |
| 13. | Strain | <u>Change in dimension</u> Original dimension | [L] / [L] or [L ³] / [L ³] | [M ⁰ L ⁰ T ⁰] |
| 14. | Modulus of elasticity | Stress/strain | $\frac{[M L^{-1} T^{-2}]}{[M^0 L^0 T^0]}$ | [M L ⁻¹ T ⁻²] |
| 15. | Surface tension | Force/length | [MLT ⁻²]/[L] | [ML ⁰ T ⁻²] |
| 16. | Surface energy | Energy/area | [ML ² T ⁻²]/[L ²] | [ML ⁰ T ⁻²] |
| 17. | Velocity gradient | Velocity/distance | [LT ⁻¹]/[L] | [M ⁰ L ⁰ T ⁻¹] |
| 18. | Pressure gradient | Pressure/distance | [ML ⁻¹ T ⁻²]/[L] | [ML ⁻² T ⁻²] |
| 19. | Pressure energy | Pressure × volume | [ML ⁻¹ T ⁻²][L ³] | [ML ² T ⁻²] |
| 20. | Coefficient of viscosity | Force/area × velocity gradient | $\frac{[MLT^{-2}]}{[L^2][LT^{-1}/L]}$ | [ML ⁻¹ T ⁻¹] |
| 21. | Angle, Angular displacement | Arc/radius | [L]/[L] | [M ⁰ L ⁰ T ⁰] |
| 22. | Trigonometric ratio (sinθ, cosθ, tanθ, etc.) | Length/length | [L]/[L] | [M ⁰ L ⁰ T ⁰] |
| 23. | Angular velocity | Angle/time | [L ⁰]/[T] | [M ⁰ L ⁰ T ⁻¹] |

| | | | | |
|-----|--------------------------------------|---|--|-----------------------|
| 24. | Angular acceleration | Angular velocity/time | $[T^{-1}]/[T]$ | $[M^0 L^0 T^{-2}]$ |
| 25. | Radius of gyration | Distance | $[L]$ | $[M^0 L T^0]$ |
| 26. | Moment of inertia | Mass \times (radius of gyration) 2 | $[M] [L^2]$ | $[ML^2 T^0]$ |
| 27. | Angular momentum | Moment of inertia \times angular velocity | $[ML^2] [T^{-1}]$ | $[ML^2 T^{-1}]$ |
| 28. | Moment of force, moment of couple | Force \times distance | $[MLT^{-2}] [L]$ | $[ML^2 T^{-2}]$ |
| 29. | Torque | Angular momentum/time, Or Force \times distance | $[ML^2 T^{-1}] / [T]$ or $[MLT^{-2}] [L]$ | $[ML^2 T^{-2}]$ |
| 30. | Angular frequency | $2\pi \times$ Frequency | $[T^{-1}]$ | $[M^0 L^0 T^{-1}]$ |
| 31. | Wavelength | Distance | $[L]$ | $[M^0 L T^0]$ |
| 32. | Hubble constant | Recession speed/distance | $[LT^{-1}] / [L]$ | $[M^0 L^0 T^{-1}]$ |
| 33. | Intensity of wave | (Energy/time)/area | $[ML^2 T^{-2}/T] / [L^2]$ | $[ML^0 T^{-3}]$ |
| 34. | Radiation pressure | $\frac{\text{Intensity of wave}}{\text{Speed of light}}$ | $[MT^{-3}] / [LT^{-1}]$ | $[ML^{-1} T^{-2}]$ |
| 35. | Energy density | Energy/volume | $[ML^2 T^{-2}] / [L^3]$ | $[ML^{-1} T^{-2}]$ |
| 36. | Critical velocity | $\frac{\text{Reynold's number} \times \text{coefficient of viscosity}}{\text{Mass density} \times \text{radius}}$ | $\frac{[M^0 L^0 T^0] [ML^{-1} T^{-1}]}{[ML^{-3}] [L]}$ | $[M^0 L T^{-1}]$ |
| 37. | Escape velocity | $(2 \times \text{acceleration due to gravity} \times \text{earth's radius})^{1/2}$ | $[LT^{-2}]^{1/2} \times [L]^{1/2}$ | $[M^0 L T^{-1}]$ |
| 38. | Heat energy, internal energy | Work (= Force \times distance) | $[MLT^{-2}] [L]$ | $[ML^2 T^{-2}]$ |
| 39. | Kinetic energy | $(1/2) \text{mass} \times (\text{velocity})^2$ | $[M] [LT^{-1}]^2$ | $[ML^2 T^{-2}]$ |
| 40. | Potential energy | Mass \times acceleration due to gravity \times height | $[M] [LT^{-2}] [L]$ | $[ML^2 T^{-2}]$ |
| 41. | Rotational kinetic energy | $\frac{1}{2} \times \text{moment of inertia} \times (\text{angular velocity})^2$ | $[M^0 L^0 T^0] [ML^2] \times [T^{-1}]^2$ | $[M L^2 T^{-2}]$ |
| 42. | Efficiency | $\frac{\text{Output work or energy}}{\text{Input work or energy}}$ | $\frac{[ML^2 T^{-2}]}{[ML^2 T^{-2}]}$ | $[M^0 L^0 T^0]$ |
| 43. | Angular impulse | Torque \times time | $[ML^2 T^{-2}] [T]$ | $[M L^2 T^{-1}]$ |
| 44. | Gravitational constant | $\frac{\text{Force} \times (\text{distance})^2}{\text{mass} \times \text{mass}}$ | $\frac{[MLT^{-2}] [L^2]}{[M] [M]}$ | $[M^{-1} L^3 T^{-2}]$ |
| 45. | Planck constant | Energy/frequency | $[ML^2 T^{-2}] / [T^{-1}]$ | $[ML^2 T^{-1}]$ |

| | | | | |
|-----|--|---|---|---------------------------------|
| 46. | Heat capacity, entropy | Heat energy / temperature | $[ML^2 T^{-2}]/[K]$ | $[ML^2 T^{-2} K^{-1}]$ |
| 47. | Specific heat capacity | $\frac{\text{Heat Energy}}{\text{Mass} \times \text{temperature}}$ | $[ML^2 T^{-2}]/[M] [K]$ | $[M^0 L^2 T^{-2} K^{-1}]$ |
| 48. | Latent heat | Heat energy/mass | $[ML^2 T^{-2}]/[M]$ | $[M^0 L^2 T^{-2}]$ |
| 49. | Thermal expansion coefficient or Thermal expansivity | $\frac{\text{Change in dimension}}{\text{Original dimension} \times \text{temperature}}$ | $[L]/[L][K]$ | $[M^0 L^0 K^{-1}]$ |
| 50. | Thermal conductivity | $\frac{\text{Heat energy} \times \text{thickness}}{\text{Area} \times \text{temperature} \times \text{time}}$ | $\frac{[ML^2 T^{-2}][L]}{[L^2][K][T]}$ | $[MLT^{-3} K^{-1}]$ |
| 51. | Bulk modulus or (compressibility) $^{-1}$ | $\frac{\text{Volume} \times (\text{change in pressure})}{(\text{change in volume})}$ | $\frac{[L^3][ML^{-1} T^{-2}]}{[L^3]}$ | $[ML^{-1} T^{-2}]$ |
| 52. | Centripetal acceleration | $(\text{Velocity})^2 / \text{radius}$ | $[LT^{-1}]^2/[L]$ | $[M^0 LT^{-2}]$ |
| 53. | Stefan constant | $\frac{(\text{Energy} / \text{area} \times \text{time})}{(\text{Temperature})^4}$ | $\frac{[ML^2 T^{-2}]}{[L^2][T][K]^4}$ | $[ML^0 T^{-3} K^{-4}]$ |
| 54. | Wien constant | Wavelength \times temperature | $[L][K]$ | $[M^0 LT^0 K]$ |
| 55. | Boltzmann constant | Energy/temperature | $[ML^2 T^{-2}]/[K]$ | $[ML^2 T^{-2} K^{-1}]$ |
| 56. | Universal gas constant | $\frac{\text{Pressure} \times \text{volume}}{\text{mole} \times \text{temperature}}$ | $\frac{[ML^{-1} T^{-2}][L^3]}{[\text{mol}][K]}$ | $[ML^2 T^{-2} K^{-1} mol^{-1}]$ |
| 57. | Charge | Current \times time | $[A][T]$ | $[M^0 L^0 TA]$ |
| 58. | Current density | Current /area | $[A]/[L^2]$ | $[M^0 L^{-2} T^0 A]$ |
| 59. | Voltage, electric potential, electromotive force | Work/charge | $[ML^2 T^{-2}]/[AT]$ | $[ML^2 T^{-3} A^{-1}]$ |
| 60. | Resistance | $\frac{\text{Potential difference}}{\text{Current}}$ | $\frac{[ML^2 T^{-3} A^{-1}]}{[A]}$ | $[ML^2 T^{-3} A^{-2}]$ |
| 61. | Capacitance | Charge/potential difference | $\frac{[AT]}{[ML^2 T^{-3} A^{-1}]}$ | $[M^{-1} L^{-2} T^4 A^2]$ |
| 62. | Electrical resistivity or (electrical conductivity) $^{-1}$ | $\frac{\text{Resistance} \times \text{area}}{\text{length}}$ | $\frac{[ML^2 T^{-3} A^{-2}]}{[L^2]/[L]}$ | $[ML^3 T^{-3} A^{-2}]$ |
| 63. | Electric field | Electrical force/charge | $[MLT^{-2}]/[AT]$ | $[MLT^{-3} A^{-1}]$ |
| 64. | Electric flux | Electric field \times area | $[MLT^{-3} A^{-1}][L^2]$ | $[ML^3 T^{-3} A^{-1}]$ |

| | | | | |
|-----|--|--|---|---------------------------|
| 65. | Electric dipole moment | Torque/electric field | $\frac{[ML^2 T^{-2}]}{[MLT^{-3} A^{-1}]}$ | $[M^0 LTA]$ |
| 66. | Electric field strength or electric intensity | $\frac{\text{Potential difference}}{\text{distance}}$ | $\frac{[ML^2 T^{-3} A^{-1}]}{[L]}$ | $[MLT^{-3} A^{-1}]$ |
| 67. | Magnetic field, magnetic flux density, magnetic induction | $\frac{\text{Force}}{\text{Current} \times \text{length}}$ | $[MLT^{-2}]/[A] [L]$ | $[ML^0 T^{-2} A^{-1}]$ |
| 68. | Magnetic flux | Magnetic field \times area | $[MT^{-2} A^{-2}] [L^2]$ | $[ML^2 T^{-2} A^{-1}]$ |
| 69. | Inductance | $\frac{\text{Magnetic flux}}{\text{Current}}$ | $\frac{[ML^2 T^{-2} A^{-1}]}{[A]}$ | $[ML^2 T^{-2} A^{-2}]$ |
| 70. | Magnetic dipole moment | Torque/magnetic field or current \times area | $[ML^2 T^{-2}] / [MT^{-2} A^{-1}]$ or $[A] [L^2]$ | $[M^0 L^2 T^0 A]$ |
| 71. | Magnetic field strength, magnetic intensity or magnetic moment density | $\frac{\text{Magnetic moment}}{\text{Volume}}$ | $\frac{[L^2 A]}{[L^3]}$ | $[M^0 L^{-1} T^0 A]$ |
| 72 | Permittivity constant (of free space) | $\frac{\text{Charge} \times \text{charge}}{4 \pi \times \text{electric force} \times (\text{distance})^2}$ | $\frac{[AT][AT]}{[MLT^{-2}][L]^2}$ | $[M^{-1} L^{-3} T^4 A^2]$ |
| 73. | Permeability constant (of free space) | $\frac{2 \pi \times \text{force} \times \text{distance}}{\text{current} \times \text{current} \times \text{length}}$ | $\frac{[M^0 L^0 T^0][MLT^{-2}][L]}{[A][A][L]}$ | $[MLT^{-2} A^{-2}]$ |
| 74. | Refractive index | $\frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}}$ | $[LT^{-1}]/[LT^{-1}]$ | $[M^0 L^0 T^0]$ |
| 75. | Faraday constant | Avogadro constant \times elementary charge | $[AT]/[\text{mol}]$ | $[M^0 L^0 TA mol^{-1}]$ |
| 76. | Wave number | $2\pi/\text{wavelength}$ | $[M^0 L^0 T^0] / [L]$ | $[M^0 L^{-1} T^0]$ |
| 77. | Radiant flux, Radiant power | Energy emitted/time | $[ML^2 T^{-2}]/[T]$ | $[ML^2 T^{-3}]$ |
| 78. | Luminosity of radiant flux or radiant intensity | $\frac{\text{Radiant power or radiant flux of source}}{\text{Solid angle}}$ | $[ML^2 T^{-3}] / [M^0 L^0 T^0]$ | $[ML^2 T^{-3}]$ |
| 79. | Luminous power or luminous flux of source | $\frac{\text{Luminous energy emitted}}{\text{time}}$ | $[ML^2 T^{-2}]/[T]$ | $[ML^2 T^{-3}]$ |

| | | | | |
|-----|--|--|---|--|
| 80. | Luminous intensity or illuminating power of source | $\frac{\text{Luminous flux}}{\text{Solid angle}}$ | $\frac{[\text{ML}^2 \text{T}^{-3}]}{[\text{M}^0 \text{L}^0 \text{T}^0]}$ | $[\text{ML}^2 \text{T}^{-3}]$ |
| 81. | Intensity of illumination or luminance | $\frac{\text{Luminous intensity}}{(\text{distance})^2}$ | $[\text{ML}^2 \text{T}^{-3}] / [\text{L}^2]$ | $[\text{ML}^0 \text{T}^{-3}]$ |
| 82. | Relative luminosity | $\frac{\text{Luminous flux of a source of given wavelength}}{\text{luminous flux of peak sensitivity wavelength (555 nm) source of same power}}$ | $\frac{[\text{ML}^2 \text{T}^{-1}]}{[\text{ML}^2 \text{T}^{-3}]}$ | $[\text{M}^0 \text{L}^0 \text{T}^0]$ |
| 83. | Luminous efficiency | $\frac{\text{Total luminous flux}}{\text{Total radiant flux}}$ | $[\text{ML}^2 \text{T}^{-3}] / [\text{ML}^2 \text{T}^{-3}]$ | $[\text{M}^0 \text{L}^0 \text{T}^0]$ |
| 84. | Illuminance or illumination | $\frac{\text{Luminous flux incident}}{\text{area}}$ | $[\text{ML}^2 \text{T}^{-3}] / [\text{L}^2]$ | $[\text{ML}^0 \text{T}^{-3}]$ |
| 85. | Mass defect | (sum of masses of nucleons)-(mass of the nucleus) | $[\text{M}]$ | $[\text{ML}^0 \text{T}^0]$ |
| 86. | Binding energy of nucleus | Mass defect \times (speed of light in vacuum) 2 | $[\text{M}] [\text{L T}^{-1}]^2$ | $[\text{ML}^2 \text{T}^{-2}]$ |
| 87. | Decay constant | 0.693/half life | $[\text{T}^{-1}]$ | $[\text{M}^0 \text{L}^0 \text{T}^{-1}]$ |
| 88. | Resonant frequency | $(\text{Inductance} \times \text{capacitance})^{-\frac{1}{2}}$ | $[\text{ML}^2 \text{T}^{-2} \text{A}^{-2}]^{-\frac{1}{2}} \times \\ [\text{M}^{-1} \text{L}^{-2} \text{T}^4 \text{A}^2]^{-\frac{1}{2}}$ | $[\text{M}^0 \text{L}^0 \text{A}^0 \text{T}^{-1}]$ |
| 89. | Quality factor or Q-factor of coil | $\frac{\text{Resonant frequency} \times \text{inductance}}{\text{Resistance}}$ | $\frac{[\text{T}^{-1}] [\text{ML}^2 \text{T}^{-2} \text{A}^{-2}]}{[\text{ML}^2 \text{T}^{-3} \text{A}^{-2}]}$ | $[\text{M}^0 \text{L}^0 \text{T}^0]$ |
| 90. | Power of lens | $(\text{Focal length})^{-1}$ | $[\text{L}^{-1}]$ | $[\text{M}^0 \text{L}^{-1} \text{T}^0]$ |
| 91. | Magnification | $\frac{\text{Image distance}}{\text{Object distance}}$ | $[\text{L}] / [\text{L}]$ | $[\text{M}^0 \text{L}^0 \text{T}^0]$ |
| 92. | Fluid flow rate | $\frac{(\pi/8)(\text{pressure}) \times (\text{radius})^4}{(\text{viscosity coefficient}) \times (\text{length})}$ | $\frac{[\text{ML}^{-1} \text{T}^{-2}] [\text{L}^4]}{[\text{ML}^{-1} \text{T}^{-1}] [\text{L}]}$ | $[\text{M}^0 \text{L}^3 \text{T}^{-1}]$ |
| 93. | Capacitive reactance | $(\text{Angular frequency} \times \text{capacitance})^{-1}$ | $[\text{T}^{-1}]^{-1} [\text{M}^{-1} \text{L}^{-2} \text{T}^4 \text{A}^2 \text{T}^{-1}]$ | $[\text{ML}^2 \text{T}^{-3} \text{A}^{-2}]$ |
| 94. | Inductive reactance | $(\text{Angular frequency} \times \text{inductance})^{-1}$ | $[\text{T}^{-1}] [\text{ML}^2 \text{T}^{-2} \text{A}^{-2}]$ | $[\text{ML}^2 \text{T}^{-3} \text{A}^{-2}]$ |

ANSWERS

Chapter 1

- 1.1** (a) 10^{-6} ; (b) 1.5×10^4 ; (c) 5 ; (d) 11.3, 1.13×10^4 .
- 1.2** (a) 10^7 ; (b) 10^{-16} ; (c) 3.9×10^4 ; (d) 6.67×10^{-8} .
- 1.5** 500
- 1.6** (c)
- 1.7** 0.035 mm
- 1.9** 94.1
- 1.10** (a) 1 ; (b) 3 ; (c) 4 ; (d) 4 ; (e) 4 ; (f) 4.
- 1.11** 8.72 m^2 ; 0.0855 m^3
- 1.12** (a) 2.3 kg ; (b) 0.02 g
- 1.13** The correct formula is $m = m_0(1 - v^2/c^2)^{-1/2}$
- 1.14** $\cong 3 \times 10^{-7} \text{ m}^3$
- 1.15** $\cong 10^4$; intermolecular separation in a gas is much larger than the size of a molecule.
- 1.16** Near objects make greater angle than distant (far off) objects at the eye of the observer. When you are moving, the angular change is less for distant objects than nearer objects. So, these distant objects seem to move along with you, but the nearer objects in opposite direction.
- 1.17** $1.4 \times 10^3 \text{ kg m}^{-3}$; the mass density of the Sun is in the range of densities of liquids / solids and *not* gases. This high density arises due to inward gravitational attraction on outer layers due to inner layers of the Sun.

Chapter 2

- 2.1** (a), (b)
- 2.2** (a) A....B, (b) A....B, (c) B....A, (d) Same, (e) B....A....once.
- 2.4** 37 s
- 2.5** 3.06 m s^{-2} ; 11.4 s

- 2.6** (a) Vertically downwards; (b) zero velocity, acceleration of 9.8 m s^{-2} downwards; (c) $x > 0$ (upward and downward motion); $v < 0$ (upward), $v > 0$ (downward), $a > 0$ throughout; (d) 44.1 m, 6 s.
- 2.7** (a) True; (b) False; (c) True (if the particle rebounds instantly with the same speed, it implies infinite acceleration which is unphysical); (d) False (true only when the chosen positive direction is along the direction of motion)
- 2.10** (a) 5 km h^{-1} , 5 km h^{-1} ; (b) 0, 6 km h^{-1} ; (c) $\frac{15}{8} \text{ km h}^{-1}$, $\frac{45}{8} \text{ km h}^{-1}$
- 2.11** Because, for an arbitrarily small interval of time, the magnitude of displacement is equal to the length of the path.
- 2.12** All the four graphs are impossible. (a) a particle cannot have two different positions at the same time; (b) a particle cannot have velocity in opposite directions at the same time; (c) speed is always non-negative; (d) total path length of a particle can never decrease with time. (Note, the arrows on the graphs are meaningless).
- 2.13** No, wrong. x - t plot does not show the trajectory of a particle. Context: A body is dropped from a tower ($x = 0$) at $t = 0$.
- 2.14** 105 m s^{-1}
- 2.15** (a) A ball at rest on a smooth floor is kicked, it rebounds from a wall with reduced speed and moves to the opposite wall which stops it; (b) A ball thrown up with some initial velocity rebounding from the floor with reduced speed after each hit; (c) A uniformly moving cricket ball turned back by hitting it with a bat for a very short time-interval.
- 2.16** $x < 0, v < 0, a > 0$; $x > 0, v > 0, a < 0$; $x < 0, v > 0, a > 0$.
- 2.17** Greatest in 3, least in 2; $v > 0$ in 1 and 2, $v < 0$ in 3.
- 2.18** Acceleration magnitude greatest in 2; speed greatest in 3; $v > 0$ in 1, 2 and 3; $a > 0$ in 1 and 3, $a < 0$ in 2; $a = 0$ at A, B, C, D.

Chapter 3

- 3.1** Volume, mass, speed, density, number of moles, angular frequency are scalars; the rest are vectors.
- 3.2** Work, current
- 3.3** Impulse
- 3.4** Only (c) and (d) are permissible
- 3.5** (a) T, (b) F, (c) F, (d) T, (e) T
- 3.6** Hint: The sum (difference) of any two sides of a triangle is never less (greater) than the third side. Equality holds for collinear vectors.
- 3.7** All statements except (a) are correct
- 3.8** 400 m for each; B
- 3.9** (a) O; (b) O; (c) 21.4 km h^{-1}
- 3.10** Displacement of magnitude 1 km and direction 60° with the initial direction; total path length = 1.5 km (third turn); null displacement vector; path length = 3 km (sixth turn); 866 m, 30° , 4 km (eighth turn)

- 3.11** (a) 49.3 km h^{-1} ; (b) 21.4 km h^{-1} . No, the average speed equals average velocity magnitude only for a straight path.

3.12 150.5 m

3.13 50 m

3.14 9.9 m s^{-2} , along the radius at every point towards the centre.

3.15 6.4 g

3.16 (a) False (true only for uniform circular motion)
(b) True, (c) True.

3.17 (a) $\mathbf{v}(t) = (3.0 \hat{\mathbf{i}} - 4.0t \hat{\mathbf{j}}) \text{ m s}^{-1}$ $\hat{\mathbf{a}}(t) = -4.0 \hat{\mathbf{j}}$
(b) 8.54 m s^{-1} , 70° with x -axis.

3.18 (a) 2 s, 24 m, 21.26 m s^{-1}

3.19 $\sqrt{2}$, 45° with the x -axis; $\sqrt{2}$, -45° with the x -axis, $(5/\sqrt{2}, -1/\sqrt{2})$.

3.20 (b) and (e)

3.21 Only (e) is true

3.22 182 m s^{-1}

Chapter 4

$$t = 25 \text{ s} : \quad x = u t + (\frac{1}{2}) a t^2 = (10 \times 25 - 10 \times 625) \text{ m} = -6 \text{ km}$$

$t = 100 \text{ s} :$ First consider motion up to 30 s

$$x_1 = 10 \times 30 - 10 \times 900 = -8700 \text{ m}$$

$$\text{At } t = 30 \text{ s}, \quad v = 10 - 20 \times 30 = -590 \text{ m s}^{-1}$$

For motion from 30 s to 100 s : $x_2 = -590 \times 70 = -41300 \text{ m}$

$$x = x_1 + x_2 = -50 \text{ km}$$

- 4.11** (a) Velocity of car (at $t = 10 \text{ s}$) = $0 + 2 \times 10 = 20 \text{ m s}^{-1}$

By the First Law, the horizontal component of velocity is 20 m s^{-1} throughout.

$$\text{Vertical component of velocity (at } t = 11 \text{ s}) = 0 + 10 \times 1 = 10 \text{ m s}^{-1}$$

Velocity of stone (at $t = 11 \text{ s}$) = $\sqrt{20^2 + 10^2} = \sqrt{500} = 22.4 \text{ m s}^{-1}$ at an angle of $\tan^{-1}(\frac{1}{2})$ with the horizontal.

(b) 10 m s^{-2} vertically downwards.

- 4.12** (a) At the extreme position, the speed of the bob is zero. If the string is cut, it will fall vertically downwards.

(b) At the mean position, the bob has a horizontal velocity. If the string is cut, it will fall along a parabolic path.

- 4.13** The reading on the scale is a measure of the force on the floor by the man. By the Third Law, this is equal and opposite to the normal force N on the man by the floor.

$$(a) N = 70 \times 10 = 700 \text{ N}; \quad \text{Reading is } 70 \text{ kg}$$

$$(b) 70 \times 10 - N = 70 \times 5; \quad \text{Reading is } 35 \text{ kg}$$

$$(c) N - 70 \times 10 = 70 \times 5; \quad \text{Reading is } 105 \text{ kg}$$

$$(d) 70 \times 10 - N = 70 \times 10; \quad \text{Reading would be zero; the scale would read zero.}$$

- 4.14** (a) In all the three intervals, acceleration and, therefore, force are zero.

$$(b) 3 \text{ kg m s}^{-1} \text{ at } t = 0; (c) -3 \text{ kg m s}^{-1} \text{ at } t = 4 \text{ s.}$$

- 4.15** If the 20 kg mass is pulled,

$$600 - T = 20 a, \quad T = 10 a$$

$$a = 20 \text{ m s}^{-2}, \quad T = 200 \text{ N}$$

If the 10 kg mass is pulled, $a = 20 \text{ m s}^{-2}, \quad T = 400 \text{ N}$

- 4.16** $T - 8 \times 10 = 8 a, \quad 12 \times 10 - T = 12 a$

$$\text{i.e. } a = 2 \text{ m s}^{-2}, \quad T = 96 \text{ N}$$

- 4.17** By momentum conservation principle, total final momentum is zero. Two momentum vectors cannot sum to a null momentum unless they are equal and opposite.

- 4.18** Impulse on each ball = $0.05 \times 12 = 0.6 \text{ kg m s}^{-1}$ in magnitude. The two impulses are opposite in direction.

- 4.19** Use momentum conservation : $100 v = 0.02 \times 80$

$$v = 0.016 \text{ m s}^{-1} = 1.6 \text{ cm s}^{-1}$$

- 4.20** Impulse is directed along the bisector of the initial and final directions. Its magnitude is $0.15 \times 2 \times 15 \times \cos 22.5^\circ = 4.2 \text{ kg m s}^{-1}$

$$\mathbf{4.21} \quad v = 2\pi \times 1.5 \times \frac{40}{60} = 2\pi \text{ m s}^{-1}$$

$$T = \frac{mw^2}{R} = \frac{0.25 \times 4\pi^2}{1.5} = 6.6 \text{ N}$$

$$200 = \frac{mw_{max}^2}{R}, \text{ which gives } v_{max} = 35 \text{ m s}^{-1}$$

- 4.22** Alternative (b) is correct, according to the First Law
- 4.23** (a) The horse-cart system has no external force in empty space. The mutual forces between the horse and the cart cancel (Third Law). On the ground, the contact force between the system and the ground (friction) causes their motion from rest.
 (b) Due to inertia of the body not directly in contact with the seat.
 (c) A lawn mower is pulled or pushed by applying force at an angle. When you push, the normal force (N) must be more than its weight, for equilibrium in the vertical direction. This results in greater friction f ($f \propto N$) and, therefore, a greater applied force to move. Just the opposite happens while pulling.
 (d) To reduce the rate of change of momentum and hence to reduce the force necessary to stop the ball.

Chapter 5

- 5.1** (a) +ve (b) -ve (c) -ve (d) + ve (e) - ve
- 5.2** (a) 882 J ; (b) -247 J; (c) 635 J ; (d) 635 J;
 Work done by the net force on a body equals change in its kinetic energy.
- 5.3** (a) $x > a ; 0$ (c) $x < a, x > b ; -V_1$
 (b) $-\infty < x < \infty; V_1$ (d) $-b/2 < x < -a/2, a/2 < x < b/2; -V_1$
- 5.5** (a) rocket; (b) For a conservative force work done over a path is minus of change in potential energy. Over a complete orbit, there is no change in potential energy; (c) K.E. increases, but P.E. decreases, and the sum decreases due to dissipation against friction; (d) in the second case.
- 5.6** (a) decrease; (b) kinetic energy; (c) external force; (d) total linear momentum, and also total energy (if the system of two bodies is isolated).
- 5.7** (a) F ; (b) F ; (c) F ; (d) F (true usually but not always, why?)
- 5.8** (a) No
 (b) Yes
 (c) Linear momentum is conserved during an inelastic collision, kinetic energy is, of course, not conserved even after the collision is over.
 (d) elastic.
- 5.9** (b) t
- 5.10** (c) $t^{3/2}$
- 5.11** 12 J
- 5.12** The electron is faster, $v_e / v_p = 13.5$
- 5.13** 0.082 J in each half ; - 0.163 J
- 5.14** Yes, momentum of the molecule + wall system is conserved. The wall has a recoil momentum such that the momentum of the wall + momentum of the outgoing molecule equals momentum of the incoming molecule, assuming the wall to be stationary initially. However, the recoil momentum produces negligible velocity because of the large mass of the wall. Since kinetic energy is also conserved, the collision is elastic.
- 5.15** 43.6 kW
- 5.16** (b)
- 5.17** It transfers its entire momentum to the ball on the table, and does not rise at all.
- 5.18** 5.3 m s⁻¹

- 5.19** 27 km h^{-1} (no change in speed)
- 5.20** 50 J
- 5.21** (a) $m = \rho A v t$ (b) $K = \rho A v^3 t / 2$ (c) $P = 4.5 \text{ kW}$
- 5.22** (a) $49,000 \text{ J}$ (b) $6.45 \times 10^{-3} \text{ kg}$
- 5.23** (a) 200 m^2 (b) comparable to the roof of a large house of dimension $14\text{m} \times 14\text{m}$.

Chapter 6

- 6.1** The geometrical centre of each. No, the CM may lie outside the body, as in case of a ring, a hollow sphere, a hollow cylinder, a hollow cube etc.
- 6.2** Located on the line joining H and C1 nuclei at a distance of 1.24 \AA from the H end.
- 6.3** The speed of the CM of the (trolley + child) system remains unchanged (equal to v) because no external force acts on the system. The forces involved in running on the trolley are internal to this system.
- 6.6** $I_z = xp_y - yp_x$, $I_x = yp_z - zp_y$, $I_y = zp_x - xp_z$
- 6.8** 72 cm
- 6.9** 3675 N on each front wheel, 5145 N on each back wheel.
- 6.10** Sphere
- 6.11** Kinetic Energy = 3125 J ; Angular Momentum = 62.5 J s
- 6.12** (a) 100 rev/min (use angular momentum conservation).
 (b) The new kinetic energy is 2.5 times the initial kinetic energy of rotation. The child uses his internal energy to increase his rotational kinetic energy.
- 6.13** 25 s^{-2} ; 10 m s^{-2}
- 6.14** 36 kW
- 6.15** at $R/6$ from the center of original disc opposite to the center of cut portion.
- 6.16** 66.0 g
- 6.17** $6.75 \times 10^{12} \text{ rad s}^{-1}$

Chapter 7

- 7.1** (a) No.
 (b) Yes, if the size of the space ship is large enough for him to detect the variation in g .
 (c) Tidal effect depends inversely on the cube of the distance unlike force, which depends inversely on the square of the distance.
- 7.2** (a) decreases; (b) decreases; (c) mass of the body; (d) more.
- 7.3** Smaller by a factor of 0.63.
- 7.5** $3.54 \times 10^8 \text{ years}$.
- 7.6** (a) Kinetic energy, (b) less,
- 7.7** (a) No, (b) No, (c) No, (d) Yes

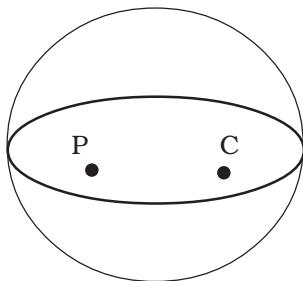
[The escape velocity is independent of mass of the body and the direction of projection. It depends upon the gravitational potential at the point from where the body is launched. Since this potential depends (slightly) on the latitude and height of the point, the escape

velocity (speed) depends (slightly) on these factors.]

7.8 All quantities vary over an orbit except angular momentum and total energy.

7.9 (b), (c) and (d)

7.10 and **7.11** For these two problems, complete the hemisphere to sphere. At both P, and C, potential is constant and hence intensity = 0. Therefore, for the hemisphere, (c) and (e) are correct.



7.12 2.6×10^8 m

7.13 2.0×10^{30} kg

7.14 1.43×10^{12} m

7.15 28 N

7.16 125 N

7.17 8.0×10^6 m from the earth's centre

7.18 31.7 km/s

7.19 5.9×10^9 J

7.20 2.6×10^6 m/s

7.21 0, 2.7×10^{-8} J/kg; an object placed at the mid point is in an unstable equilibrium

Notes

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