

Mathematics

Quadratic equation:

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

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

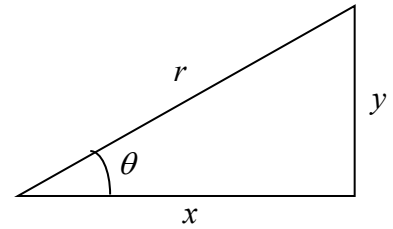
Trigonometry:

$$r^2 = x^2 + y^2$$

$$\sin \theta = y/r$$

$$\cos \theta = x/r$$

$$\tan \theta = y/x$$



Kinematics (for constant acceleration):

$$v = v_0 + at$$

$$x = v_0t + \frac{1}{2}at^2$$

$$x = \frac{1}{2}(v_0 + v)t$$

$$v^2 = v_0^2 + 2ax$$

$$x = vt - \frac{1}{2}at^2$$

Forces:

Newton's second law: $\sum \vec{F} = m\vec{a}$

First condition for equilibrium: $\sum \vec{F} = 0$

Gravity:

Gravitational force near the earth: $F = mg$

Newton's law of universal gravitation: $F = G \frac{m_1 m_2}{r^2}$

$$g = 9.80 \text{ m/s}^2$$

$$G = 6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$$

Friction:

Static: $0 \leq f_s \leq \mu_s F_N$ direction is always opposite to motion (or tendency to motion)

Kinetic: $f_k = \mu_k F_N$

Uniform Circular Motion

Period: $T = \frac{2\pi r}{v}$, where v is the speed of the object and r is the radius of the circle

Frequency: $f = \frac{1}{T}$ θ (in radians) = $\frac{\text{Arc length}}{\text{radius}}$

Centripetal Acceleration: $a_c = \frac{v^2}{r}$

Centripetal Force: $F_c = \frac{mv^2}{r}$ (directed towards the centre)

Work, Energy, and Power:

Work: $W = (F \cos \theta) s$

Kinetic energy: $\text{KE} = \frac{1}{2} mv^2$

Potential energy:

Gravitational (near Earth): $\text{PE} = mgh$

Work-energy theorem: $W_{\text{nc}} = \Delta\text{KE} + \Delta\text{PE} = E_f - E_i$

Total mechanical energy: $E = \text{KE} + \text{PE}$

Conservation of mechanical energy: $E = \text{KE} + \text{PE} = \text{constant}; E_f = E_i$

Power (rate of doing work): $\bar{P} = \frac{W}{t}$

Linear Momentum

Impulse: $\vec{J} = \vec{F}\Delta t = \Delta\vec{p} = m\vec{v}_f - m\vec{v}_i$

Conservation of Momentum: $\vec{p}_i = \vec{p}_f$, if no external forces

Elastic collisions, $v_{2i} = 0$: $v_{1f} = \frac{m_1 - m_2}{m_1 + m_2} v_{1i}$

$$v_{2f} = \frac{2m_1}{m_1 + m_2} v_{1i}$$

Torque and Angular Momentum

Torque: $\tau = Fl = Fr \sin\theta$; $l = (\text{lever arm}) = r \sin\theta$

Second condition of equilibrium: $\sum \vec{\tau} = 0$

Angular momentum: $L = I\omega$ is conserved, in the absence of external torques

Moment of inertia: $I = \sum mr^2$

Simple Harmonic Motion

Hooke's law: Restoring force = $F = -kx$

Elastic potential energy: $PE = \frac{1}{2}kx^2$

Displacement: $x = A \cos(\omega t)$ (when $x = A$ at $t = 0$)

Velocity: $v = -A\omega \sin(\omega t)$ Acceleration: $a = -A\omega^2 \cos(\omega t)$

Frequency, Period $\omega^2 = \frac{k}{m}$; $f = \frac{\omega}{2\pi} = \frac{1}{2\pi} \sqrt{\frac{k}{m}}$; $T = \frac{2\pi}{\omega} = 2\pi \sqrt{\frac{m}{k}}$

Simple pendulum $T = 2\pi \sqrt{\frac{L}{g}}$

Energy $E = KE + PE = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$

Fluids

Pressure: $P = \text{Force/Area}$

Pressure and Depth: $P_2 = P_1 + \rho gh$

Continuity Equation: $\rho_1 v_1 A_1 = \rho_2 v_2 A_2$

Bernoulli's Equation: $P + \rho gh + \frac{1}{2}\rho v^2 = \text{constant}$

Heat, Temperature and Kinetic Theory

Linear thermal expansion: $\Delta L = \alpha L_0 \Delta T$

Volume thermal expansion: $\Delta V = \beta V_0 \Delta T$

Heat and temperature change: $Q = c m \Delta T$

Heat required for change of phase: $Q = mL$

Conduction of heat through a material: $\frac{Q}{t} = \frac{k A \Delta T}{L}$

$n = \frac{N}{N_A} = \frac{m}{\text{mass per mole}}$ $N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$

$PV = nRT = \frac{2}{3} N \overline{KE}$ $R = 8.314 \text{ J/(mol}\cdot\text{K)}$

$\overline{KE} = \frac{1}{2} m v_{rms}^2 = \frac{3}{2} kT$ $0^\circ\text{C} = 273.15 \text{ K}$

Table of Constants

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Fundamental Constants

Constant	Symbol	SI value	Value in non-SI units
Gravitational Constant	G	$6.674 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$	
Avogadro's Number	N_A	$6.022 \times 10^{23} \text{ mol}^{-1}$	
Boltzmann's constant	k	$1.381 \times 10^{-23} \text{ J/K}$	$8.61 \times 10^{-5} \text{ eV/K}$
Gas Constant	R	8.314 J/(mol K)	

Other useful physical data

Constant	Symbol	SI value	Value in non-SI units
Acceleration due to earth's gravity	g	9.80 m/s^2	980 cm/s^2
Standard atmospheric pressure		101.3 kPa	$1.013 \text{ bar}, 760 \text{ Torr}$
Density of air (0 °C, 1 atm)		1.29 kg/m^3	1.29 g/L
Speed of sound in air (20 °C)		343 m/s	
Water:			
Density (liquid)		1000 kg/m^3	$1 \text{ g/cm}^3, 1 \text{ g/mL}$
Spec. heat capacity (liquid at 20 °C)		4184 J/(kg K)	1 cal/(g K)
Spec. heat capacity (ice at -10 °C)		2030 J/(kg K)	0.49 cal/(g K)
Spec. heat capacity (steam at 100 °C)		2080 J/(kg K)	0.50 cal/(g K)
Latent heat of fusion		$3.35 \times 10^5 \text{ J/kg}$	80 cal/g
Latent heat of vaporization		$2.26 \times 10^6 \text{ J/kg}$	540 cal/g
Earth			
Mass		$5.98 \times 10^{24} \text{ kg}$	
Radius (equatorial)		$6.38 \times 10^6 \text{ m}$	
Moon			
Mass		$7.35 \times 10^{22} \text{ kg}$	
Radius (mean)		$1.74 \times 10^6 \text{ m}$	
Orbital radius (mean)		$3.85 \times 10^8 \text{ m}$	

Conversion factors

$$1 \text{ kcal} = 4184 \text{ J}$$

$$1 \text{ kWh} = 3.6 \text{ MJ}$$

$$1 \text{ u} = 1 \text{ Da} = 1.6605 \times 10^{-27} \text{ kg}$$

$$1 \text{ bar} = 100 \text{ kPa} = 760 \text{ Torr}$$

$$1 \text{ L} = 1000 \text{ cm}^3 = 10^{-3} \text{ m}^3$$

$$\pi \text{ rad} = 180^\circ$$