Physics Formulas

Wei Meng Soh *

February 2021

Abstract

This is a list of formulas for physics...

1 Thermometry

Type of thermometers

Liquid thermometer

Thermometric Property: $\Delta V \propto \Delta\theta$
Formulae:

$$\theta = \frac{\ell_\theta - \ell_0}{\ell_{100} - \ell_0} \times 100°\text{C} \quad , \quad T = \frac{\ell_T - \ell_{00}}{\ell_{tr} - \ell_{00}} \times 273.16 \text{ K}$$

Gas thermometer

Thermometric Property: $\Delta P \Delta V \propto \Delta\theta \quad$ (where $P = \rho g h$)
Formulae:

$$\theta = \frac{P_\theta V_\theta - P_0 V_0}{P_{100} V_{100} - P_0 V_0} \times 100°\text{C} \quad , \quad T = \frac{P_T V_T}{P_{tr} V_{tr}} \times 273.16 \text{ K}$$

Resistance thermometer

Thermometric Property: $\Delta R \propto \Delta\theta \quad$ (where (i)$R = \frac{P}{Q} \times S$ (ii) $R_t = R_0(1 + at + bt^2)$)
Formulae:

$$\theta = \frac{R_\theta - R_0}{R_{100} - R_0} \times 100°\text{C} \quad , \quad T = \frac{R_T}{R_{tr}} \times 273.16 \text{ K}$$

Thermoelectric thermometer

Thermometric Property: $\Delta\varepsilon \propto \Delta\theta$
Formulae:

$$\theta = \frac{\varepsilon_\theta - \varepsilon_0}{\varepsilon_{100} - \varepsilon_0} \times 100°\text{C} \quad , \quad T = \frac{\varepsilon_T - \varepsilon_{00}}{\varepsilon_{tr} - \varepsilon_{00}} \times 273.16 \text{ K}$$

2 Calorimetry

Heat Capacity and specific heat capacity

Heat Capacity

$$C = \frac{Q}{\Delta T} \quad (\text{JK}^{-1})$$

Specific Heat Capacity

$$c = \frac{Q}{m\Delta T} \quad (\text{Jkg}^{-1}\text{K}^{-1})$$

Molar Heat Capacity

$$C_v = \frac{Q}{n\Delta T} \ (\text{Jmol}^{-1}\text{K}^{-1}) \quad , \quad C_p = \frac{Q}{n\Delta T} \ (\text{Jmol}^{-1}\text{K}^{-1})$$

*Chong Hwa Independent High School Kuala Lumpur

Measurement of specific heat capacity

Method of Mixture

$$mc(\theta_3 - \theta_2) = m_w c_w(\theta_2 - \theta_1) + m_c c_c(\theta_2 - \theta_1)$$

Electrical Heating Method

$$VIt = (mc_\ell + C)\Delta\theta$$

Continuous Flow Method (Callendar & Barnes' method)

$$\begin{cases} V_1 I_1 t = m_1 c(\theta_2 - \theta_1) + ht & (1) \\ V_2 I_2 t = m_2 c(\theta_2 - \theta_1) + ht & (2) \end{cases}$$

Specific Latent Heat

$$L_f = \frac{Q}{m} \quad (Jkg^{-1}) \quad , \quad L_v = \frac{Q}{m} \quad (Jkg^{-1})$$

Finding specific latent heat of fusion of ice

$$m_1 c_w(\theta_1 - \theta_2) + C(\theta_1 - \theta_2) = mL_f + mc_w(\theta_2 - 0)$$

Finding specific latent heat of vaporisation of water

$$mL_v + mc_w(100 - \theta_2) = (m_1 c_w + C)(\theta_2 - \theta_1)$$

Thermal Expansion of solid

Linear Expansion

$$\alpha = \frac{l_2 - l_1}{(\theta_2 - \theta_1)l_1} \quad \Rightarrow \quad l_2 = l_1[1 + \alpha(\theta_2 - \theta_1)]$$

Area Expansion

$$\beta = \frac{A_2 - A_1}{(\theta_2 - \theta_1)A_1} \quad \Rightarrow \quad A_2 = A_1[1 + \beta(\theta_2 - \theta_1)]$$

$$\beta = 2\alpha$$

Volume Expansion

$$\gamma = \frac{V_2 - V_1}{(\theta_2 - \theta_1)V_1} \quad \Rightarrow \quad V_2 = V_1[1 + \gamma(\theta_2 - \theta_1)]$$

$$\gamma = 3\alpha$$

Thermal Expansion of Liquid

$$\gamma_\ell = \frac{V_1 - V_0}{V_0 \Delta\theta} \quad \Rightarrow \quad V_1 = V_0(1 + \gamma_\ell \Delta\theta)$$

$$3\alpha_c = \gamma_c = \frac{V_1' - V_0}{V_0 \Delta\theta} \quad \Rightarrow \quad V_1' = V_0(1 + \gamma_c \Delta\theta)$$

$$\gamma_a = \frac{V_1 - V_1'}{V_0 \Delta\theta} \quad \Rightarrow \quad \gamma_\ell = \gamma_a + \gamma_c$$

3 Transmission of Heat

Conduction

Temperature Gradient

$$\frac{d\theta}{dx} = \frac{\theta_2 - \theta_1}{\ell} \quad (\theta_2 > \theta_1)$$

$$\frac{Q}{t} \propto \frac{\theta_2 - \theta_1}{\ell} \quad (\theta_2 > \theta_1)$$

$$\frac{Q}{t} \propto A$$

$$\Rightarrow \quad \frac{Q}{t} = kA\,\frac{\theta_2 - \theta_1}{\ell} \quad (\theta_2 > \theta_1)$$

$$\frac{dQ}{dt} = kA\,\frac{d\theta}{dx}$$

Heat flow through compound bar

$$\left(\frac{Q}{t}\right)_1 = \left(\frac{Q}{t}\right)_2 = \left(\frac{Q}{t}\right)_3$$

$$k_1A\,\frac{\theta_1 - \theta_2}{\ell_1} = k_2A\,\frac{\theta_2 - \theta_3}{\ell_2} = k_3A\,\frac{\theta_3 - \theta_4}{\ell_3} \quad (\theta_1 > \theta_2 > \theta_3 > \theta_4)$$

Measuring thermal conductivity of good conductor

$$Rate\ of\ heat\ flow = mc_w(\theta_4 - \theta_3)$$

$$k = \frac{mc_w(\theta_4 - \theta_3)}{A(\theta_2 - \theta_1)} \times \ell$$

Thermal Resistance

$$\frac{Q}{t} = \frac{\Delta\theta}{R_\theta}$$

$$R_\theta = \frac{\ell}{kA}$$

When in series,

$$\text{Total thermal resistance} = R_{\theta_1} + R_{\theta_2}$$

$$\frac{Q}{t} = \frac{\text{temperature difference}}{\text{total thermal resistance}}$$

Wein's displacement law

$$\lambda \propto \frac{1}{T} \quad (\lambda \text{ is peak wavelength})$$

$$\lambda T = k \quad (k\text{is Wein's constant, } 2.93 \times 10^{-3} mK)$$

Stefan's law

$$E \propto T^4 \quad (E = \frac{Q}{At}, \text{ energy emitted per second per unit surface})$$

$$E = \sigma T^4 \quad (\sigma \text{ is Stefan's constant, } 5.67 \times 10^{-8} Wm^{-2}K^{-4})$$

4 Optics

Reflection

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \quad (\text{where } u = \text{object distance}, v = \text{image distance}, f = \text{focal length})$$

$$\text{Linear magnification}: \quad m = \frac{v}{u} = \frac{l}{h} = \frac{v}{f} - 1$$

$$\text{Angular magnification}: \quad m = \frac{\beta}{\alpha} = \frac{v}{f} - 1$$

No. of images:

$$n = \frac{360°}{\theta} - 1 \quad (\text{if n is even or n is odd when object lies on angle bisector})$$

$$n = \frac{360°}{\theta} \quad (\text{if n is odd when object does not lie on angle bisector})$$

Refraction

Snell's law: $n_1 \sin i_1 = n_2 \sin i_2$

$$if\ i = c\ and\ r = 90°,\ \frac{n}{n_a} = \frac{1}{\sin c}$$

$$\frac{n_2}{n_1} = \frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{t}{t'} \quad (\text{light passes from 1 to 2})$$

Difference between real and apparent depth:

$$d = t(1 - \frac{1}{n})$$

Refraction at prism:

$$\text{Angle of deviation}: d = i_1 + i_2 - A\ mathrmwhere\ A = r_1 + r_2$$

$$\text{Minimum Angle of deviation}: d = 2i - A,\ (i_1 = i_2 = i,\ r_1 = r_2 = r,\ A = 2r)\ or\ n = \frac{\sin\frac{A+D}{2}}{\sin\frac{A}{2}}$$

$$\text{Maximum Angle of deviation}: i_1 = 90°\ or\ i_2 = 90°$$

Power of a lens:

$$P = \frac{1}{f},\ f \text{ is in metres}$$

Lensmaker's equation:

$$\frac{1}{f} = (\frac{n_2}{n_1} - 1)(\frac{1}{r_1} + \frac{1}{r_2}),\ (r \text{ is } + \text{ when convex towards optically less dense medium})$$

Combination of thin lenses:

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

Conjugate points:

$$xx' = f^2$$

Convex lens with fixed object and image:

$$f = \frac{s^2 - l^2}{4d},\ (\text{where } d = u + v \text{ and } l = \text{distance between two convex lens})$$

$$u + v > 4f\ \Rightarrow 2 \text{ real images}$$

$$u + v = 4f\ \Rightarrow 1 \text{ real image}$$

$$u + v < 4f\ \Rightarrow \text{no real images}$$

Magnifying glass: convex lens, $u < f$, erect, magnified and virtual image

$$\text{Normal adjustment}: v = D,\ M = \frac{\beta}{\alpha} = \frac{D}{f} - 1$$

$$\text{Abnormal adjustment} : v = \infty,\ M = \frac{D}{f}\ (D = -25cm)$$

Compound microscope: convex lens, $f_o < f_e$, first image is magnified inverted real, second is magnified inverted virtual.

$$\text{Normal adjustment} : v_e = D,\ M = \frac{\beta}{\alpha} = m_o \times m_e = (\frac{v_o}{f_o} - 1)(\frac{-D}{f_e} - 1)$$

$$\text{Abnormal adjustment} : v_e = \infty,\ M = \frac{\beta}{\alpha} = m_o \times m_e = (\frac{v_o}{f_o} - 1)(\frac{D}{f_e})$$

Astromomical telescope (Keplerian telescope): convex lenses with

$$f_o < f_e,\ f_o + f_e = d,\ u_o = \infty,\ v_o = f_o,\ u_e = f_e$$

first image is diminished, inverted real, second is magnified inverted

$$\text{Normal adjustment} : v_e = \infty,\ M = \frac{\beta}{\alpha} = m_o \times m_e = \frac{f_o}{f_e}$$

$$\text{Abnormal adjustment} : v_e = D,\ M = \frac{\beta}{\alpha} = m_o \times m_e = (\frac{D+1}{D})(\frac{f_o}{f_e})$$