 Physics Equation List : Form 4
 Introduction to Physics

Relative Deviation

\[
\text{Relative Deviation} = \frac{\text{Mean Deviation}}{\text{Mean Value}} \times 100\%
\]

Prefixes

<table>
<thead>
<tr>
<th>Prefixes</th>
<th>Value</th>
<th>Standard form</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tera</td>
<td>1 000 000 000 000</td>
<td>$10^{12}$</td>
<td>T</td>
</tr>
<tr>
<td>Giga</td>
<td>1 000 000 000</td>
<td>$10^9$</td>
<td>G</td>
</tr>
<tr>
<td>Mega</td>
<td>1 000 000</td>
<td>$10^6$</td>
<td>M</td>
</tr>
<tr>
<td>Kilo</td>
<td>1 000</td>
<td>$10^3$</td>
<td>k</td>
</tr>
<tr>
<td>deci</td>
<td>0.1</td>
<td>$10^{-1}$</td>
<td>d</td>
</tr>
<tr>
<td>centi</td>
<td>0.01</td>
<td>$10^{-2}$</td>
<td>c</td>
</tr>
<tr>
<td>milli</td>
<td>0.001</td>
<td>$10^{-3}$</td>
<td>m</td>
</tr>
<tr>
<td>micro</td>
<td>0.000 001</td>
<td>$10^{-6}$</td>
<td>μ</td>
</tr>
<tr>
<td>nano</td>
<td>0.000 000 001</td>
<td>$10^{-9}$</td>
<td>n</td>
</tr>
<tr>
<td>pico</td>
<td>0.000 000 000 001</td>
<td>$10^{-12}$</td>
<td>p</td>
</tr>
</tbody>
</table>

Units for Area and Volume

\[
\begin{align*}
1 \text{ m} & = 10^2 \text{ cm} \\
1 \text{ m}^2 & = 10^4 \text{ cm}^2 \\
1 \text{ m}^3 & = 10^6 \text{ cm}^3 \\
1 \text{ cm} & = 10^{-2} \text{ m} \\
1 \text{ cm}^2 & = 10^{-4} \text{ m}^2 \\
1 \text{ cm}^3 & = 10^{-6} \text{ m}^3
\end{align*}
\]

\[
\begin{align*}
\text{(100 cm)} & \quad \text{(10,000 cm)}^2 \quad \text{cm} \quad \text{m} \quad \text{m}^2 \quad \text{m}^3
\end{align*}
\]

http://www.one-school.net/notes.html
**Force and Motion**

**Average Speed**

Average Speed = \( \frac{\text{Total Distance}}{\text{Total Time}} \)

**Velocity**

\[ v = \frac{s}{t} \]

- \( v \) = velocity \( (\text{ms}^{-1}) \)
- \( s \) = displacement \( (\text{m}) \)
- \( t \) = time \( (\text{s}) \)

**Acceleration**

\[ a = \frac{v - u}{t} \]

- \( a \) = acceleration \( (\text{ms}^{-2}) \)
- \( v \) = final velocity \( (\text{ms}^{-1}) \)
- \( u \) = initial velocity \( (\text{ms}^{-1}) \)
- \( t \) = time for the velocity change \( (\text{s}) \)

**Equation of Linear Motion**

- **Motion with constant velocity**
  \[ v = \frac{s}{t} \]

- **Motion with constant acceleration**
  \[ v = u + at \]
  \[ s = \frac{1}{2} (u + v)t \]
  \[ s = ut + \frac{1}{2} at^2 \]
  \[ v^2 = u^2 + 2as \]

- **Motion with changing acceleration**
  Using Calculus (In Additional Mathematics Syllabus)

- \( u \) = initial velocity \( (\text{ms}^{-1}) \)
- \( v \) = final velocity \( (\text{ms}^{-1}) \)
- \( a \) = acceleration \( (\text{ms}^{-2}) \)
- \( s \) = displacement \( (\text{m}) \)
- \( t \) = time \( (\text{s}) \)
Ticker Tape

Finding Velocity:

\[ \text{velocity} = \frac{s}{\text{number of ticks} \times 0.02s} \]

1 tick = 0.02s

Finding Acceleration:

\[ a = \frac{v - u}{t} \]

\[ a = \text{acceleration} \quad (ms^{-2}) \]
\[ v = \text{final velocity} \quad (ms^{-1}) \]
\[ u = \text{initial velocity} \quad (ms^{-1}) \]
\[ t = \text{time for the velocity change} \quad (s) \]

Graph of Motion

Gradient of a Graph

The gradient 'm' of a line segment between two points and is defined as follows:

Gradient, \( m = \frac{\Delta y}{\Delta x} \)

or

\[ m = \frac{\Delta y}{\Delta x} \]
### Displacement-Time Graph

Gradient = Velocity (ms\(^{-1}\))

### Velocity-Time Graph

Gradient = Acceleration (ms\(^{-2}\))

Area in between the graph and x-axis = Displacement

### Momentum

\[ p = m \times v \]

- \( p \) = momentum (kg ms\(^{-1}\))
- \( m \) = mass (kg)
- \( v \) = velocity (ms\(^{-1}\))

### Principle of Conservation of Momentum

\[ m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2 \]

- \( m_1 \) = mass of object 1 (kg)
- \( m_2 \) = mass of object 2 (kg)
- \( u_1 \) = initial velocity of object 1 (ms\(^{-1}\))
- \( u_2 \) = initial velocity of object 2 (ms\(^{-1}\))
- \( v_1 \) = final velocity of object 1 (ms\(^{-1}\))
- \( v_2 \) = final velocity of object 2 (ms\(^{-1}\))

### Newton’s Law of Motion

#### Newton’s First Law

In the absence of external forces, an object at rest remains at rest and an object in motion continues in motion with a constant velocity (that is, with a constant speed in a straight line).
Newton’s Second Law

\[ F = ma \]

\[ \frac{mv - mu}{t} \]

The rate of change of momentum of a body is directly proportional to the resultant force acting on the body and is in the same direction.

- \( F \) = Net Force \((N \text{ or } kgm^2)\)
- \( m \) = mass \((kg)\)
- \( a \) = acceleration \((ms^{-2})\)

**Implication**
When there is resultant force acting on an object, the object will **accelerate** (moving faster, moving slower or change direction).

Newton’s Third Law

Newton’s third law of motion states that for every force, there is a reaction force with the same magnitude but in the opposite direction.

**Impulse**

\[ \text{Impulse} = Ft \]

\[ mv - mu \]

- \( F \) = force \((N)\)
- \( t \) = time \((s)\)
- \( m \) = mass \((kg)\)
- \( v \) = final velocity \((ms^{-1})\)
- \( u \) = initial velocity \((ms^{-1})\)

**Impulsive Force**

\[ F = \frac{mv - mu}{t} \]

- \( F \) = Force \((N \text{ or } kgm^2)\)
- \( t \) = time \((s)\)
- \( m \) = mass \((kg)\)
- \( v \) = final velocity \((ms^{-1})\)
- \( u \) = initial velocity \((ms^{-1})\)

**Gravitational Field Strength**

\[ g = \frac{F}{m} \]

- \( g \) = gravitational field strength \((N \text{ kg}^{-1})\)
- \( F \) = gravitational force \((N \text{ or } kgm^2)\)
- \( m \) = mass \((kg)\)

**Weight**

\[ W = mg \]

- \( W \) = Weight \((N \text{ or } kgm^2)\)
- \( m \) = mass \((kg)\)
- \( g \) = gravitational field strength/gravitational acceleration \((ms^{-2})\)
**Vertical Motion**

- If an object is released from a high position:
  - The initial velocity, \( u = 0 \).
  - The acceleration of the object = gravitational acceleration = \( 10 \text{ms}^{-2} \) (or \( 9.81 \text{ms}^{-2} \)).
  - The displacement of the object when it reaches the ground = the height of the original position, \( h \).

- If an object is launched vertically upward:
  - The velocity at the maximum height, \( v = 0 \).
  - The deceleration of the object = -gravitational acceleration = \(-10\text{ms}^{-2}\) (or \(-9.81\text{ms}^{-2}\)).
  - The displacement of the object when it reaches the ground = the height of the original position, \( h \).

---

**Lift**

**In Stationary**

- When a man standing inside an elevator, there are two forces acting on him.
  - (a) His weight, which acting downward.
  - (b) Normal reaction \((R)\), acting in the opposite direction of weight.

- The reading of the balance is equal to the normal reaction.

\[ R = mg \]
<table>
<thead>
<tr>
<th>Moving Upward with positive acceleration</th>
<th>Moving downward with positive acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Diagram" /></td>
<td><img src="image2" alt="Diagram" /></td>
</tr>
<tr>
<td>[ R = mg + ma ]</td>
<td>[ R = mg - ma ]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Moving Upward with constant velocity</th>
<th>Moving downward with constant velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3" alt="Diagram" /></td>
<td><img src="image4" alt="Diagram" /></td>
</tr>
<tr>
<td>[ R = mg ]</td>
<td>[ R = mg ]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Moving Upward with negative acceleration</th>
<th>Moving downward with negative acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image5" alt="Diagram" /></td>
<td><img src="image6" alt="Diagram" /></td>
</tr>
<tr>
<td>[ R = mg - ma ]</td>
<td>[ R = mg + ma ]</td>
</tr>
</tbody>
</table>
Smooth Pulley

With 1 Load

<table>
<thead>
<tr>
<th>Moving with uniform speed:</th>
<th>Stationary:</th>
<th>Accelerating:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_1 = T_2$</td>
<td>$T_1 = mg$</td>
<td>$T_1 - mg = ma$</td>
</tr>
</tbody>
</table>

With 2 Loads

Finding Acceleration:
(If $m_2 > m_1$)

$m_2g - m_1g = (m_1 + m_2)a$

Finding Tension:
(If $m_2 > m_1$)

$T_1 = T_2$
$T_1 - m_1g = ma$
$m_2g - T_2 = ma$

Vector

Vector Addition (Perpendicular Vector)

Magnitude = $\sqrt{x^2 + y^2}$

Direction = $\tan^{-1}\left|\frac{y}{x}\right|$

Vector Resolution

$|x| = p |\sin \theta|$

$|y| = p |\cos \theta|$
Inclined Plane

Component parallel to the plane \( = mgsin\theta \)
Component perpendicular to the plane \( = mgcos\theta \)

Forces In Equilibrium

\[ T_3 = mg \]
\[ T_2 \sin \theta = mg \]
\[ T_2 \cos \theta = T_1 \]
\[ T_1 \tan \theta = mg \]
\[ T_3 = mg \]
\[ T_2 \cos \theta = T_1 \cos \alpha \]
\[ T_2 \sin \theta + T_1 \sin \alpha = mg \]

Work Done

\[ W = Fx \cos \theta \]
\( W = \) Work Done \((J\ or\ Nm)\)
\( F = \) Force \((N\ or\ kgm^{-2})\)
\( x = \) displacement \((m)\)
\( \theta = \) angle between the force and the direction of motion \((^\circ)\)

When the force and motion are in the same direction.

\[ W = Fs \]
\( W = \) Work Done \((J\ or\ Nm)\)
\( F = \) Force \((N\ or\ kgm^{-2})\)
\( s = \) displacement \((m)\)
Energy

Kinetic Energy

\[ E_K = \frac{1}{2}mv^2 \]

- \( E_K \) = Kinetic Energy \((J)\)
- \( m \) = mass \((kg)\)
- \( v \) = velocity \((ms^{-1})\)

Gravitational Potential Energy

\[ E_P = mgh \]

- \( E_P \) = Potential Energy \((J)\)
- \( m \) = mass \((kg)\)
- \( g \) = gravitational acceleration \((ms^{-2})\)
- \( h \) = height \((m)\)

Elastic Potential Energy

\[ E_P = \frac{1}{2}kx^2 \]

- \( E_P \) = Potential Energy \((J)\)
- \( k \) = spring constant \((N m^{-1})\)
- \( x \) = extension of spring \((m)\)

\[ E_P = \frac{1}{2}Fx \]

- \( F \) = Force \((N)\)

Power and Efficiency

Power

\[ P = \frac{W}{t} \]

- \( P \) = power \((W or Js^{-1})\)
- \( W \) = work done \((J or Nm)\)
- \( E \) = energy change \((J or Nm)\)
- \( t \) = time \((s)\)

Efficiency

\[ \text{Efficiency} = \frac{\text{Useful Energy}}{\text{Energy}} \times 100\% \]

Or

\[ \text{Efficiency} = \frac{\text{Power Output}}{\text{Power Input}} \times 100\% \]

Hooke’s Law

\[ F = kx \]

- \( F \) = Force \((N or kgms^{-2})\)
- \( k \) = spring constant \((N m^{-1})\)
- \( x \) = extension or compression of spring \((m)\)
Force and Pressure

Density

\[ \rho = \frac{m}{V} \]

\( \rho \) = density \hspace{2cm} (kg m\(^{-3}\))
\( m \) = mass \hspace{2cm} (kg)
\( V \) = volume \hspace{2cm} (m\(^3\))

Pressure

\[ P = \frac{F}{A} \]

\( P \) = Pressure \hspace{2cm} (Pa or N m\(^{-2}\))
\( A \) = Area of the surface \hspace{2cm} (m\(^2\))
\( F \) = Force acting normally to the surface \hspace{2cm} (N or kgms\(^{-2}\))

Liquid Pressure

\[ P = h \rho g \]

\( h \) = depth \hspace{2cm} (m)
\( \rho \) = density \hspace{2cm} (kg m\(^{-3}\))
\( g \) = gravitational Field Strength \hspace{2cm} (N kg\(^{-1}\))

Pressure in Liquid

\[ P = P_{atm} + h \rho g \]

\( h \) = depth \hspace{2cm} (m)
\( \rho \) = density \hspace{2cm} (kg m\(^{-3}\))
\( g \) = gravitational Field Strength \hspace{2cm} (N kg\(^{-1}\))
\( P_{atm} \) = atmospheric Pressure \hspace{2cm} (Pa or N m\(^{-2}\))

Gas Pressure

\[ P = P_{atm} + h \rho g \]

\( P_{gas} \) = Pressure \hspace{2cm} (Pa or N m\(^{-2}\))
\( P_{atm} \) = Atmospheric Pressure \hspace{2cm} (Pa or N m\(^{-2}\))
\( g \) = gravitational field strength \hspace{2cm} (N kg\(^{-1}\))
Pressure in a Capillary Tube

\[ h_1 \rho_1 = h_2 \rho_2 \]

\[ P_{\text{gas}} = P_{\text{atm}} + h \rho g \]

\[ P_{\text{gas}} = P_{\text{atm}} \]

\[ P_{\text{gas}} = P_{\text{atm}} - h \rho g \]

**U-tube**

- \( P_{\text{gas}} \): gas pressure in the capillary tube (Pa or N m\(^{-2}\))
- \( P_{\text{atm}} \): atmospheric pressure (Pa or N m\(^{-2}\))
- \( h \): length of the captured mercury (m)
- \( \rho \): density of mercury (kg m\(^{-3}\))
- \( g \): gravitational field strength (N kg\(^{-1}\))

**Barometer**

<table>
<thead>
<tr>
<th>Pressure in unit cmHg</th>
<th>Pressure in unit Pa</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P_a = 0 )</td>
<td>( P_a = 0 )</td>
</tr>
<tr>
<td>( P_b = 26 )</td>
<td>( P_b = 0.26 \times 13600 \times 10 )</td>
</tr>
<tr>
<td>( P_c = 76 )</td>
<td>( P_c = 0.76 \times 13600 \times 10 )</td>
</tr>
<tr>
<td>( P_d = 76 )</td>
<td>( P_d = 0.76 \times 13600 \times 10 )</td>
</tr>
<tr>
<td>( P_e = 76 )</td>
<td>( P_e = 0.76 \times 13600 \times 10 )</td>
</tr>
<tr>
<td>( P_f = 84 )</td>
<td>( P_f = 0.84 \times 13600 \times 10 )</td>
</tr>
</tbody>
</table>

(Density of mercury = 13600 kg m\(^{-3}\))
Pascal’s Principle

\[
\frac{F_1}{A_1} = \frac{F_2}{A_2}
\]

- \(F_1\) = Force exerted on the small piston
- \(A_1\) = area of the small piston
- \(F_2\) = Force exerted on the big piston
- \(A_2\) = area of the big piston

Archimedes Principle

- Weight of the object, \(W = \rho_1V_1g\)
- Upthrust, \(F = \rho_2V_2g\)

\(\rho_1\) = density of wooden block
\(V_1\) = volume of the wooden block
\(\rho_2\) = density of water
\(V_2\) = volume of the displaced water
\(g\) = gravitational field strength

Density of water > Density of wood

\[
F = T + W
\]

\[
\rho Vg = T + mg
\]

Density of Iron > Density of water

\[
T + F = W
\]

\[
\rho Vg + T = mg
\]
Heat

Heat Change

\[ Q = mc\theta \]

- \( m \) = mass (kg)
- \( c \) = specific heat capacity \( (J \text{ kg}^{-1} \text{°C}^{-1}) \)
- \( \theta \) = temperature change (°)

<table>
<thead>
<tr>
<th>Electric Heater</th>
<th>Mixing 2 Liquid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Supply, ( E = Pt )</td>
<td>Heat Gain by Liquid 1 = Heat Loss by Liquid 2</td>
</tr>
<tr>
<td>Energy Receive, ( Q = mc\theta )</td>
<td>( m_1c_1\theta_1 = m_2c_2\theta_2 )</td>
</tr>
<tr>
<td>Energy Supply, ( E = ) Energy Receive, ( Q )</td>
<td>( m_1 = ) mass of liquid 1</td>
</tr>
<tr>
<td>( Pt = mc\theta )</td>
<td>( c_1 = ) specific heat capacity of liquid 1</td>
</tr>
<tr>
<td>( E = ) electrical Energy ( (J \text{ or } Nm) )</td>
<td>( \theta_1 = ) temperature change of liquid 1</td>
</tr>
<tr>
<td>( P = ) Power of the electric heater ( (W) )</td>
<td>( m_2 = ) mass of liquid 2</td>
</tr>
<tr>
<td>( t = ) time (in second) ( (s) )</td>
<td>( c_2 = ) specific heat capacity of liquid 2</td>
</tr>
<tr>
<td>( Q = ) Heat Change ( (J \text{ or } Nm) )</td>
<td>( \theta_2 = ) temperature change of liquid 2</td>
</tr>
<tr>
<td>( m = ) mass ( (kg) )</td>
<td></td>
</tr>
<tr>
<td>( c = ) specific heat capacity ( (J \text{ kg}^{-1} \text{°C}^{-1}) )</td>
<td></td>
</tr>
<tr>
<td>( \theta = ) temperature change (°)</td>
<td></td>
</tr>
</tbody>
</table>

Specific Latent Heat

\[ Q = mL \]

- \( Q = \) Heat Change \( (J \text{ or } Nm) \)
- \( m = \) mass \( (kg) \)
- \( L = \) specific latent heat \( (J \text{ kg}^{-1}) \)

Boyle’s Law

\[ P_1V_1 = P_2V_2 \]

(Requirement: Temperature in constant)

**Pressure Law**

\[ \frac{P_1}{T_1} = \frac{P_2}{T_2} \]

(Requirement: Volume is constant)
Charles’s Law

\[ \frac{V_1}{T_1} = \frac{V_2}{T_2} \]

(Requirement: Pressure is constant)

Universal Gas Law

\[ \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \]

\( P = \text{Pressure} \quad \text{(Pa or cmHg .......)} \)

\( V = \text{Volume} \quad \text{(m}^3 \text{ or cm}^3 \text{)} \)

\( T = \text{Temperature} \quad \text{(MUST be in K(Kelvin))} \)

Light

Refractive Index

Snell’s Law

Real depth/Apparent Depth

\[ n = \frac{\sin i}{\sin r} \]

\( n = \text{refractive index} \quad \text{(No unit)} \)

\( i = \text{angle of incident} \quad \text{(^o)} \)

\( r = \text{angle of reflection} \quad \text{(^o)} \)

\[ n = \frac{D}{d} \]

\( n = \text{refractive index} \quad \text{(No unit)} \)

\( D = \text{real depth} \quad \text{(m or cm...)} \)

\( d = \text{apparent depth} \quad \text{(m or cm...)} \)

Speed of light

\[ n = \frac{c}{v} \]

\( n = \text{refractive index} \quad \text{(No unit)} \)

\( c = \text{speed of light in vacuum} \quad \text{(ms}^{-1}) \)

\( v = \text{speed of light in a medium (like water, glass ...)} \quad \text{(ms}^{-1}) \)

Total Internal Reflection

\[ n = \frac{1}{\sin c} \]

\( n = \text{refractive index} \quad \text{(No unit)} \)

\( c = \text{critical angle} \quad \text{(^o)} \)
Lens

Power

\[ P = \frac{1}{f} \]

\( P = \text{Power} \) \hspace{1cm} \( (\text{D(Diopter)}) \)
\( f = \text{focal length} \) \hspace{1cm} \( (\text{m}) \)

Linear Magnification

\[ m = \frac{h_i}{h_o} \]
\[ m = \frac{v}{u} \]
\[ \frac{h_i}{h_o} = \frac{v}{u} \]

\( m = \text{linear magnification} \) \hspace{1cm} \( (\text{No unit}) \)
\( u = \text{distance of object} \) \hspace{1cm} \( (\text{m or cm}...) \)
\( v = \text{distance of image} \) \hspace{1cm} \( (\text{m or cm}...) \)
\( h_i = \text{height of image} \) \hspace{1cm} \( (\text{m or cm}...) \)
\( h_o = \text{height of object} \) \hspace{1cm} \( (\text{m or cm}...) \)

Lens Equation

\[ \frac{1}{u} + \frac{1}{v} = \frac{1}{f} \]

Conventional symbol

<table>
<thead>
<tr>
<th>( u )</th>
<th>( v )</th>
<th>( f )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real object</td>
<td>Real image</td>
<td>Convex lens</td>
</tr>
<tr>
<td>Virtual object</td>
<td>Virtual image</td>
<td>Concave lens</td>
</tr>
</tbody>
</table>
Astronomical Telescope

Magnification,

$$m = \frac{P_e}{P_o} \quad m = \frac{f_o}{f_e}$$

$m =$ linear magnification  
$P_e =$ Power of the eyepiece  
$P_o =$ Power of the objective lens  
$f_e =$ focal length of the eyepiece  
$f_o =$ focal length of the objective lens

Distance between eye lens and objective lens

$$d = f_o + f_e$$

$d =$ Distance between eye lens and objective lens  
$f_e =$ focal length of the eyepiece  
$f_o =$ focal length of the objective lens

Compound Microscope

Magnification

$$m = m_1 \times m_2$$

$$= \frac{\text{Height of first image}, I_1 \times \text{Height of second image}, I_2}{\text{Height of object}} \times \frac{\text{Height of first image}, I_1}{\text{Height of second image}, I_2}$$

\[
= \frac{\text{Height of second image}, I_2}{\text{Height of object}, I_1}
\]

$m =$ Magnification of the microscope  
$m_1 =$ Linear magnification of the object lens  
$m_2 =$ Linear magnification of the eyepiece

Distance in between the two lens

$$d > f_o + f_e$$

$d =$ Distance between eye lens and objective lens  
$f_e =$ focal length of the eyepiece  
$f_o =$ focal length of the objective lens