Relative Deviation

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

Units for Area and Volume

1 m = 10^2 cm  
1 m^2 = 10^4 cm^2  
1 m^3 = 10^6 cm^3

1 cm = 10^{-2} m  
1 cm^2 = 10^{-4} m^2  
1 cm^3 = 10^{-6} m^3

\[
1 \text{ m} = \frac{1}{100} m
\]

\[
1 \text{ cm}^2 = \frac{1}{10,000} m^2
\]

\[
1 \text{ cm}^3 = \frac{1}{1,000,000} m^3
\]
Average Speed

\[
\text{Average Speed} = \frac{\text{Total Distance}}{\text{Total Time}}
\]

Velocity

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

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

Acceleration

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

where:
- \(a\) = 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

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

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

3. **Using Calculus (In Additional Mathematics Syllabus)**

where:
- \(u\) = 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:

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

1 tick = 0.02s

Finding Acceleration:

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

a = \text{acceleration} \quad (\text{ms}^2)

v = \text{final velocity} \quad (\text{ms}^{-1})

u = \text{initial velocity} \quad (\text{ms}^{-1})

\text{t} = \text{time for the velocity change} \quad (\text{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

![Displacement-Time Graph]

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

### Velocity-Time Graph

![Velocity-Time Graph]

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

Area in between the graph and x-axis = Displacement

---

#### Momentum

\[ p = m \times v \]

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

---

#### Principle of Conservation of Momentum

\[ m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2 \]

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

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.

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

\[
F = ma
\]

**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

\[
\text{Impulse} = Ft
\]

**Impulse** \(mv - mu\)

### Impulsive Force

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

### Gravitational Field Strength

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

**Weight**

\[
W = Weight \quad (N \text{ or } kgm^2)
\]

\[
m = mass \quad (kg)
\]

\[
g = \text{gravitational field strength/gravitational acceleration} \quad (ms^{-2})
\]
Vertical Motion

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

Lift

<table>
<thead>
<tr>
<th>In Stationary</th>
<th>When a man standing inside an elevator, there are two forces acting on him.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(a) His weight, which acting downward.</td>
</tr>
<tr>
<td></td>
<td>(b) Normal reaction (R), acting in the opposite direction of weight.</td>
</tr>
<tr>
<td></td>
<td>The reading of the balance is equal to the normal reaction.</td>
</tr>
</tbody>
</table>

\[ R = mg \]
<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 \( = \text{mg} \sin \theta \)

Component perpendicular to the plane \( = \text{mg} \cos \theta \)

Forces In Equilibrium

\[
\begin{align*}
T_3 &= mg \\
T_2 \sin \theta &= mg \\
T_2 \cos \theta &= T_1 \\
T_1 \tan \theta &= mg \\
T_3 &= mg \\
T_2 \cos \theta &= T_1 \cos \alpha \\
T_2 \sin \theta + T_1 \sin \alpha &= mg
\end{align*}
\]

Work Done

\[
W = Fx \cos \theta
\]

Where:

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

When the force and motion are in the same direction.
Energy

Kinetic Energy

\[ E_K = \frac{1}{2} mv^2 \]
\[ E_K = \text{Kinetic Energy} \quad (J) \]
\[ m = \text{mass} \quad (kg) \]
\[ v = \text{velocity} \quad (ms^{-1}) \]

Gravitational Potential Energy

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

Elastic Potential Energy

\[ E_P = \frac{1}{2} kx^2 \]
\[ E_P = \text{Potential Energy} \quad (J) \]
\[ k = \text{spring constant} \quad (N \ m^{-1}) \]
\[ x = \text{extension of spring} \quad (m) \]

\[ E_P = \frac{1}{2} Fx \]
\[ F = \text{Force} \quad (N) \]

Power and Efficiency

Power

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

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

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

Density

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

\( \rho \) = density \hspace{1cm} (kg m^{-3})
\( m \) = mass \hspace{1cm} (kg)
\( V \) = volume \hspace{1cm} (m^3)

Pressure

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

\( P \) = Pressure \hspace{1cm} (Pa or N m^{-2})
\( A \) = Area of the surface \hspace{1cm} (m^2)
\( F \) = Force acting normally to the surface \hspace{1cm} (N or kgms^{-2})

Liquid Pressure

\[ P = h \rho g \]

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

Pressure in Liquid

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

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

Gas Pressure

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

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

\[ h_1 \rho_1 = h_2 \rho_2 \]

U-tube

Pressure in the capillary tube:

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

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

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

\[ P_{\text{gas}} = \text{gas pressure in the capillary tube} \]

\[ P_{\text{atm}} = \text{atmospheric pressure} \]

\[ h = \text{length of the captured mercury} \]

\[ \rho = \text{density of mercury} \]

\[ g = \text{gravitational field strength} \]

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, \( W = \rho \cdot V_1 \cdot g \)
- Upthrust, \( F = \rho \cdot V_2 \cdot g \)

- \( \rho_1 = \) 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

\[ \begin{align*}
F &= T + W \\
\rho V g &= T + mg
\end{align*} \]

Density of Iron > Density of water

\[ \begin{align*}
T + F &= W \\
\rho V g + T &= mg
\end{align*} \]
Heat Change

\[ Q = mc\theta \]

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

### Electric Heater

Energy Supply, \( E = Pt \)

Energy Supply, \( E = \) Energy Receive, \( Q \)

\[ Pt = mc\theta \]

- \( E \): electrical Energy (J or Nm)
- \( P \): Power of the electric heater (W)
- \( t \): time (in second) (s)

### Mixing 2 Liquid

Heat Gain by Liquid 1 = Heat Loss by Liquid 2

\[ m_1c_1\theta_1 = m_2c_2\theta_2 \]

- \( m_1 \): mass of liquid 1
- \( c_1 \): specific heat capacity of liquid 1
- \( \theta_1 \): temperature change of liquid 1
- \( m_2 \): mass of liquid 2
- \( c_2 \): specific heat capacity of liquid 2
- \( \theta_2 \): temperature change of liquid 2

### Specific Latent Heat

\[ Q = mL \]

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

### Boyle's Law

\[ P_1V_1 = P_2V_2 \]

(Requirement: Temperature in constant)

### Pressure Law

\[ \frac{P_1}{T_1} = \frac{P_2}{T_2} \]
Charles’s Law

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

(Requirement: Pressure is constant)

Universal Gas Law

\[ \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \]

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

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

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

**Light**

**Refractive Index**

Snell’s Law

**Real depth/Apparent Depth**

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

\[
\begin{align*}
&n = \text{refractive index} \quad \text{(No unit)} \\
i &= \text{angle of incident} \quad \text{(^o)} \\
r &= \text{angle of reflection} \quad \text{(^o)}
\end{align*}
\]

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

\[
\begin{align*}
&n = \text{refractive index} \quad \text{(No unit)} \\
&D = \text{real depth} \quad \text{(m or cm...)} \\
&d = \text{apparent depth} \quad \text{(m or cm...)}
\end{align*}
\]

**Speed of light**

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

\[
\begin{align*}
&n = \text{refractive index} \quad \text{(No unit)} \\
c &= \text{speed of light in vacuum} \quad \text{(ms^-1)} \\
v &= \text{speed of light in a medium} \quad \text{(like water,}
\]

**Total Internal Reflection**

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

\[
\begin{align*}
&n = \text{refractive index} \quad \text{(No unit)} \\
c &= \text{critical angle} \quad \text{(^o)}
\end{align*}
\]
Lens

Power

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

\( P = \text{Power} \quad (\text{D}(\text{Diopter})) \)

\( f = \text{focal length} \quad (m) \)

Linear Magnification

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

\( m = \text{linear magnification} \quad (\text{No unit}) \)

\( u = \text{distance of object} \quad (m \text{ or cm}...) \)

\( v = \text{distance of image} \quad (m \text{ or cm}...) \)

\( h_i = \text{height of image} \quad (m \text{ or cm}...) \)

\( h_o = \text{height of object} \quad (m \text{ or cm}...) \)

Lens Equation

![Lens Equation Diagram]

Conventional symbol

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

Magnification,

\[ m = \frac{P_e}{P_o} \]
\[ m = \frac{f_o}{f_e} \]

- \( m \) = 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

\[ m = m_1 \times m_2 \]
\[ = \frac{\text{Height of first image, } I_1}{\text{Height of object}} \times \frac{\text{Height of second image, } I_2}{\text{Height of first image, } I_1} \]
\[ = \frac{\text{Height of second image, } I_2}{\text{Height of object, } I_1} \]

- \( m \) = 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