# Physics Equation List :Form 4

## Introduction to Physics

### Relative Deviation

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

### Prefixes

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



### Units for Area and Volume

1 m = $10^2$ cm (100 cm)

1 $m^2$ = $10^4$ $cm^2$ (10,000 $cm^2$)

1 $m^3$ = $10^6$ $cm^3$ (1,000,000 $cm^3$)

1 cm = $10^{-2}$ m $\left(\frac{1}{100} m\right)$

1 $cm^2$ = $10^{-4}$ $m^2$ $\left(\frac{1}{10{,}000} m^2\right)$

1 $cm^3$ = $10^{-6}$ $m^3$ $\left(\frac{1}{1{,}000{,}000} m^3\right)$

# Force and Motion

## Average Speed

$$\text{Average Speed} = \frac{\text{Total Distance}}{\text{Total Time}}$$

## Velocity

$$v = \frac{s}{t}$$

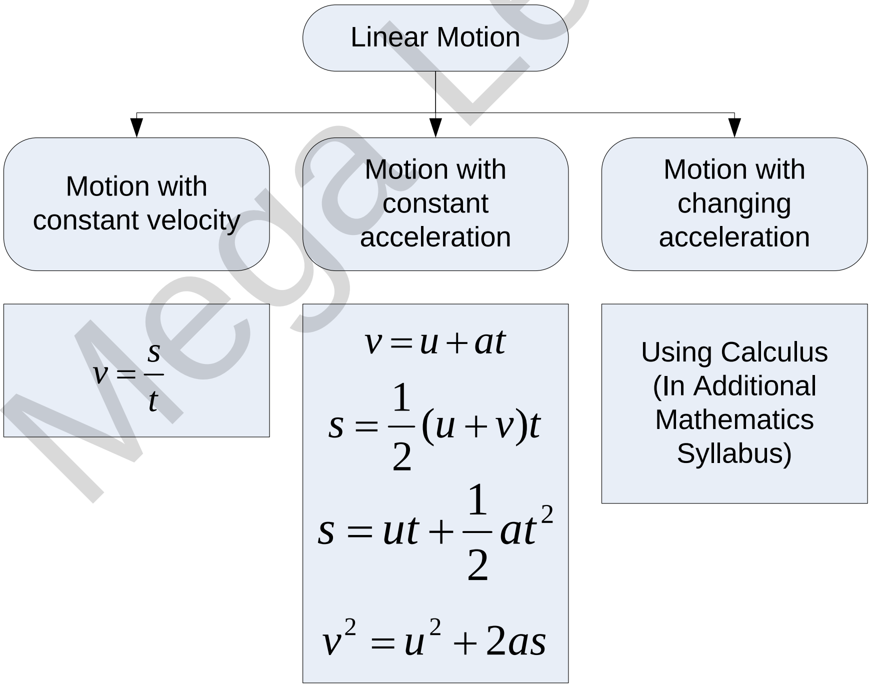
*v = velocity* *(ms$^{-1}$)*
*s = displacement* *(m)*
*t = time* *(s)*

## Acceleration

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

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

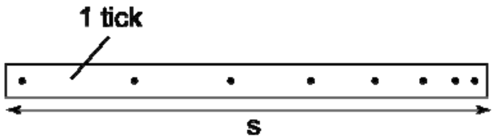
## Equation of Linear Motion




*u = initial velocity* *(ms$^{-1}$)*
*v = final velocity* *(ms$^{-1}$)*
*a = acceleration* *(ms$^{-2}$)*
*s = displacement* *(m)*
*t = time* *(s)*

## Ticker Tape

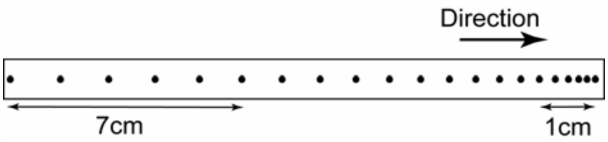
### Finding Velocity:

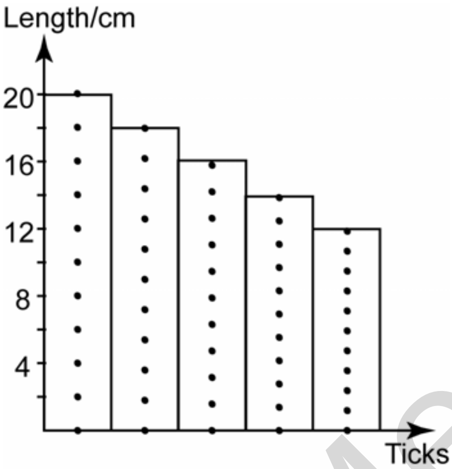



$$\text{velocity} = \frac{s}{\text{number of ticks} \times 0.02\text{s}}$$

1 tick = 0.02s

### Finding Acceleration:



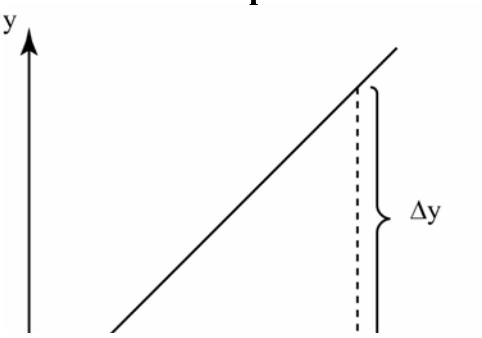

$$a = \frac{v - u}{t}$$

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



### Graph of Motion

**Gradient of a Graph**

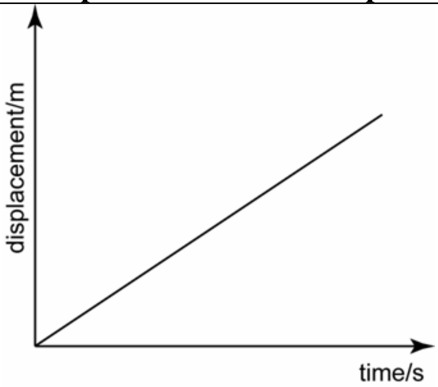
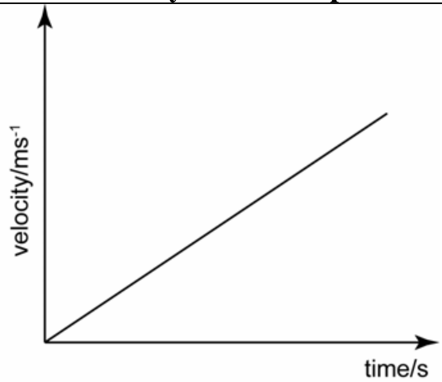



The gradient 'm' of a line segment between two points and is defined as follows:

$$\text{Gradient, } m = \frac{\text{Change in y coordinate, } \Delta y}{\text{Change in x coordinate, } \Delta x}$$

*or*

$$m = \frac{\Delta y}{\Delta x}$$

| Displacement-Time Graph | Velocity-Time Graph |
|---|---|
|  |  |
| Gradient = Velocity ($ms^{-1}$) | Gradient = Acceleration ($ms^{-2}$)<br>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

$$F \alpha \frac{mv - mu}{t}$$

$$F = ma$$

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 or $kgms^{-2}$) |
| $m$ = 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

$$\text{Impulse} = Ft$$

| | |
|---|---|
| $F$ = force | (N) |
| $t$ = time | (s) |

$$\text{Impulse} = mv - mu$$

| | |
|---|---|
| $m$ = mass | (kg) |
| $v$ = final velocity | ($ms^{-1}$) |
| $u$ = initial velocity | ($ms^{-1}$) |

## Impulsive Force

$$F = \frac{mv - mu}{t}$$

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



## Gravitational Field Strength

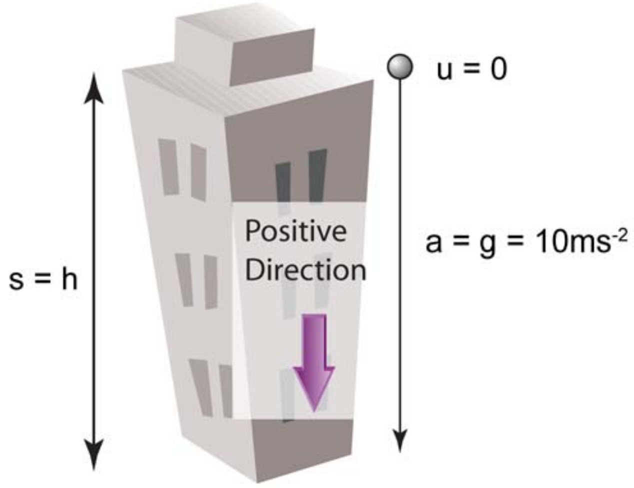
$$g = \frac{F}{m}$$

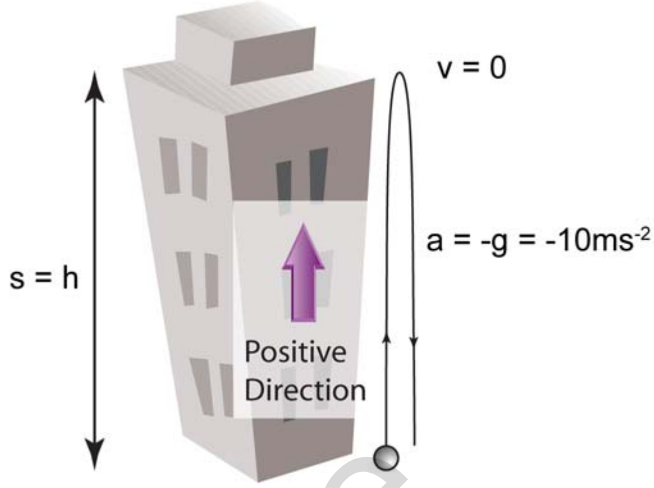
| | |
|---|---|
| $g$ = gravitational field strength | ($N\,kg^{-1}$) |
| $F$ = gravitational force | (N or $kgms^{-2}$) |
| $m$ = mass | (kg) |

## Weight

| | |
|---|---|
| $W$ = Weight | (N or $kgms^{-2}$) |
| $m$ = mass | (kg) |
| $g$ = gravitational field strength/gravitational acceleration | ($ms^{-2}$) |

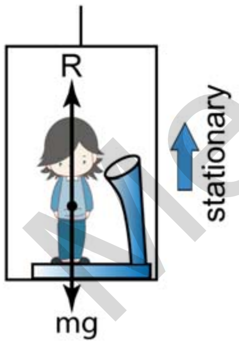
**Vertical Motion**

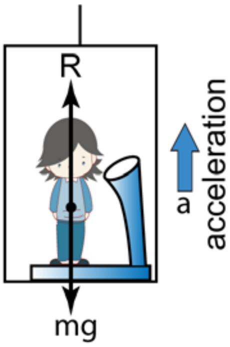
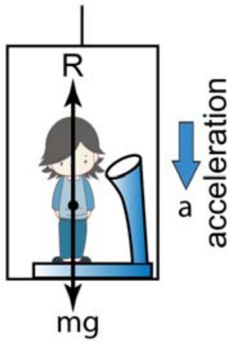
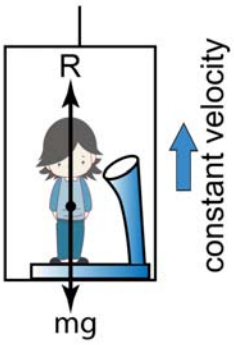
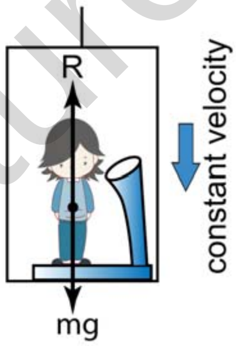
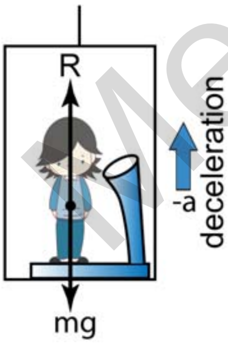
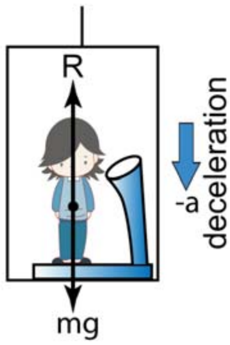



| | |
|---|---|
| • If an object is release from a high position:<br>• The initial velocity, u = 0.<br>• The acceleration of the object = gravitational acceleration = 10ms$^{-2}$(or 9.81 ms$^{-2}$).<br>• The displacement of the object when it reach the ground = the height of the original position, h. | • If an object is launched vertically upward:<br>• The velocity at the maximum height, v = 0.<br>• The deceleration of the object = -gravitational acceleration = -10ms$^{-2}$(or -9.81 ms$^{-2}$).<br>• The displacement of the object when it reach the ground = the height of the original position, h. |

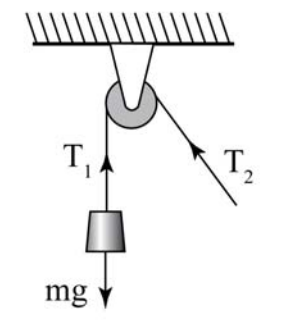
**Lift**

| **In Stationary** | |
|---|---|
| <br>$R = mg$ | • When a man standing inside an elevator, there are two forces acting on him.<br>(a) His weight, which acting downward.<br>(b) Normal reaction (R), acting in the opposite direction of weight.<br><br>• The reading of the balance is equal to the normal reaction. |

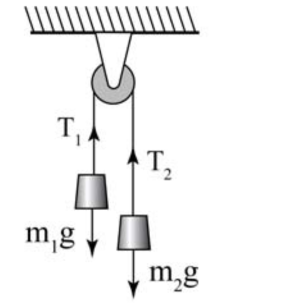
| **Moving Upward with positive acceleration** | **Moving downward with positive acceleration** |
|---|---|
|  $$R = mg + ma$$ |  $$R = mg - ma$$ |
| **Moving Upward with constant velocity** | **Moving downward with constant velocity.** |
|  $$R = mg$$ |  $$R = mg$$ |
| **Moving Upward with negative acceleration** | **Moving downward with negative acceleration** |
|  $$R = mg - ma$$ |  $$R = mg + ma$$ |

## Smooth Pulley

### With 1 Load

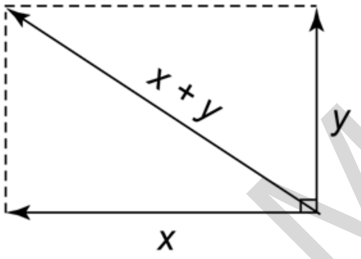
| | | |
|---|---|---|
|   | $T_1 = T_2$ | **Moving with uniform speed:** $T_1 = mg$ |
| | **Stationary:** $T_1 = mg$ | **Accelerating:** $T_1 - mg = ma$ |

### With 2 Loads

| | |
|---|---|
|   | **Finding Acceleration:**<br>(If $m_2 > m_1$)<br>$m_2g - m_1g = (m_1 + m_2)a$ |
| | **Finding Tension:**<br>(If $m_2 > m_1$)<br>$T_1 = T_2$<br>$T_1 - m_1g = ma$<br>$m_2g - T_2 = ma$ |

## Vector

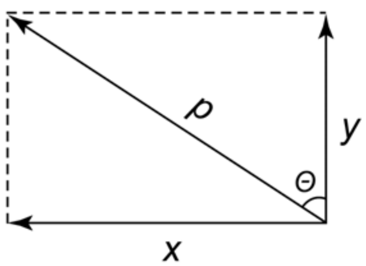
### Vector Addition (Perpendicular Vector)




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

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

### Vector Resolution




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



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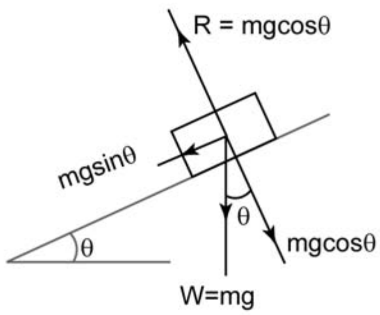
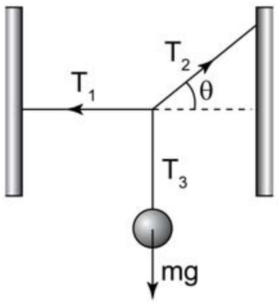
**Inclined Plane**

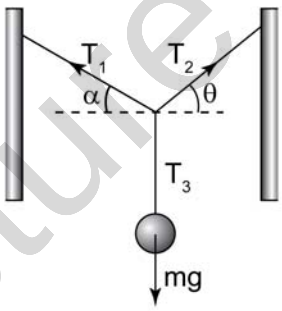



Component parallel to the plane = ***mgsin$\theta$***

Component perpendicular to the plane = ***mgcos$\theta$***

**Forces In Equilibrium**




$$T_3 = mg$$

$$T_2 \sin\theta = mg$$

$$T_2 \cos\theta = T_1$$

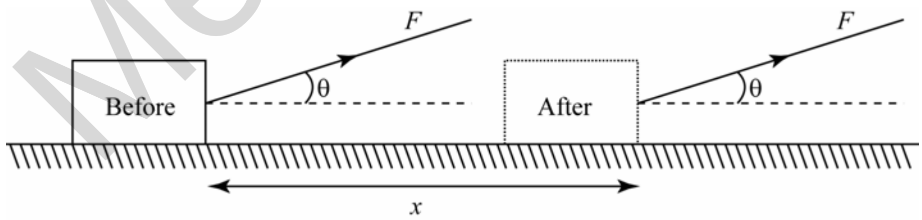
$$T_1 \tan\theta = mg$$

$$T_3 = mg$$

$$T_2 \cos\theta = T_1 \cos\alpha$$

$$T_2 \sin\theta + T_1 \sin\alpha = mg$$

**Work Done**




$$W = Fx\cos\theta$$

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

When the force and motion are in the same direction.

*Work Done* *(J or Nm)*
*Force* *(N or kgms$^{-2}$)*
*lisplacement* *(m)*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## 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

$$P = \frac{W}{t}$$

$$P = \frac{E}{t}$$

| | |
|---|---|
| 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 | ($N\ m^{-1}$) |
| extension or compression of spring | (m) |

# Force and Pressure

## Density

$$\rho = \frac{m}{V}$$

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

## Pressure

$$P = \frac{F}{A}$$

$P$ = Pressure (Pa or N $m^{-2}$)
$A$ = Area of the surface ($m^2$)
$F$ = Force acting normally to the surface (N or kg$ms^{-2}$)

## Liquid Pressure

$$P = h\rho g$$

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

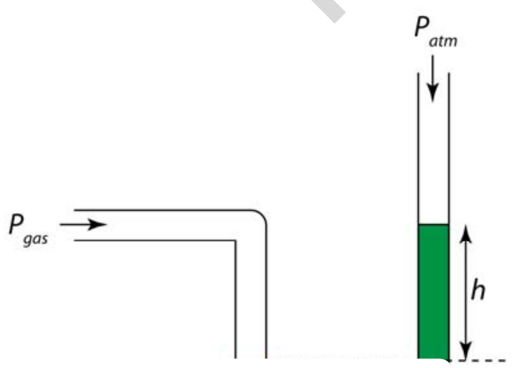
## Pressure in Liquid

$$P = P_{atm} + h\rho g$$

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

## Gas Pressure

### Manometer



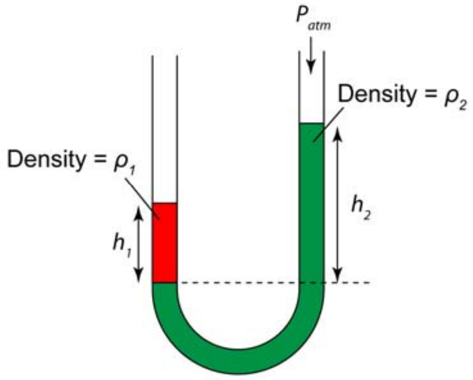

$$P = P_{atm} + h\rho g$$

$P_{gas}$ = Pressure (Pa or N $m^{-2}$)

$P_{atm}$ = Atmospheric Pressure (Pa or N $m^{-2}$)

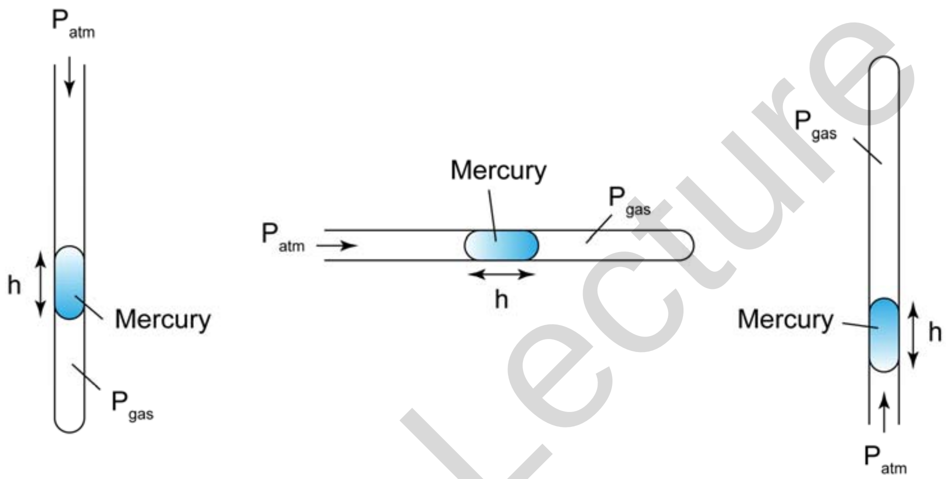
$g$ = gravitational field strength (N $kg^{-1}$)

**U=tube**




$$h_1\rho_1 = h_2\rho_2$$

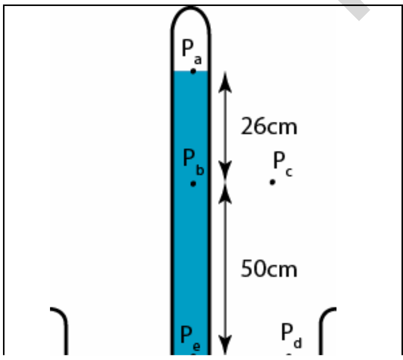
**Pressure in a Capillary Tube**




$P_{gas} = P_{atm} + h\rho g$ $\qquad$ $P_{gas} = P_{atm}$ $\qquad$ $P_{gas} = P_{atm} - h\rho g$

| | |
|---|---|
| *$P_{gas}$ = gas pressure in the capillary tube* | *(Pa or N $m^{-2}$)* |
| *$P_{atm}$ = 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 $kg^{-1}$)* |

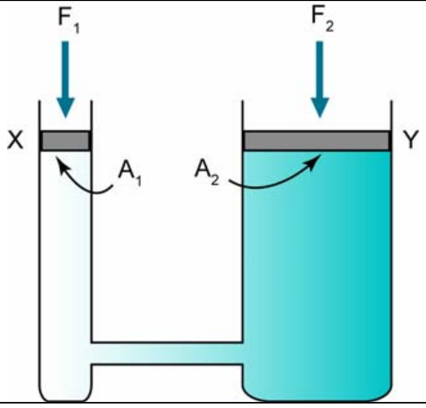
**Barometer**




| Pressure in unit cmHg | Pressure in unit Pa |
|---|---|
| $P_a$ = 0 | $P_a$ = 0 |
| $P_b$ = 26 | $P_b$ = 0.26×13600×10 |
| $P_c$ = 76 | $P_c$ = 0.76×13600×10 |
| $P_d$ = 76 | $P_d$ = 0.76×13600×10 |
| $P_e$ = 76 | $P_e$ = 0.76×13600×10 |
| 84 | $P_f$ = 0.84×13600×10 |

(Density of mercury = 13600kg$m^{-3}$)

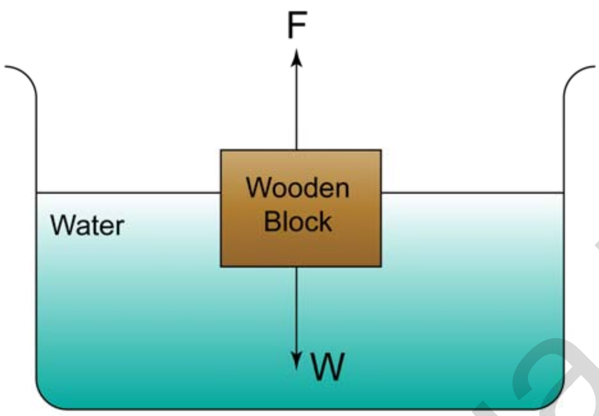
## Pascal's Principle




$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

*$F_1$ = 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*

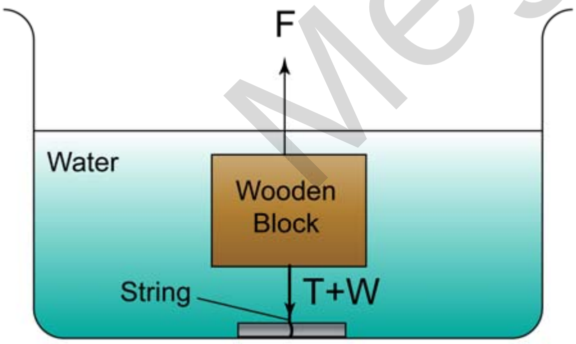
## Archimedes Principle




Weight of the object, $W = \rho_1 V_1 g$

Upthrust, $F = \rho_2 V_2 g$

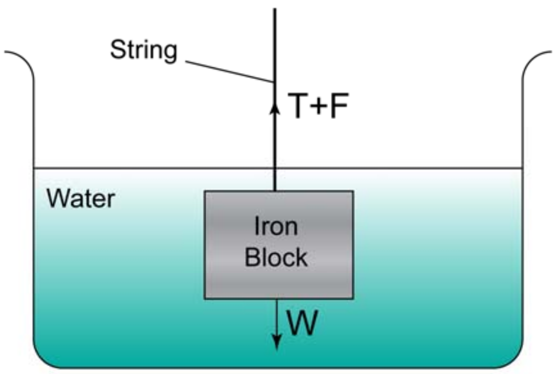
*$\rho_1$ = density of wooden block*
*$V_1$ = volume of the wooden block*
*$\rho_2$ = density of water*
*$V_2$ = volume of the displaced water*
*$g$ = gravitational field strength*




Density of water > Density of wood

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* ($J\ kg^{-1}\ {}^oC^{-1}$)
*θ = temperature change* ($^o$)

| Electric Heater | Mixing 2 Liquid |
|---|---|
| Energy Supply, $E = Pt$<br>Energy Receive, $Q = mc\theta$<br><br>Energy Supply, E = Energy Receive, Q<br><br>$$Pt = mc\theta$$<br><br>*E = electrical Energy (J or Nm)*<br>*P = Power of the electric heater (W)*<br>*t = time (in second) (s)*<br><br>*Q = Heat Change (J or Nm)*<br>*m = mass (kg)*<br>*c = specific heat capacity* ($J\ kg^{-1}\ {}^oC^{-1}$)<br>*θ = temperature change* ($^o$) | Heat Gain by Liquid 1 = Heat Loss by Liquid 2<br>$$m_1c_1\theta_1 = m_2c_2\theta_2$$<br><br>$m_1$ = *mass of liquid 1*<br>$c_1$ = *specific heat capacity of liquid 1*<br>$\theta_1$ = *temperature change of liquid 1*<br><br>$m_2$ = *mass of liquid 2*<br>$c_2$ = *specific heat capacity of liquid 2*<br>$\theta_2$ = *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**

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

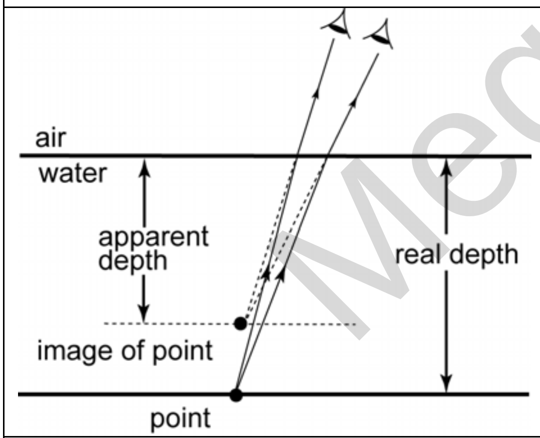
| | |
|---|---|
| *P = Pressure* | *(Pa or cmHg …….)* |
| *V = Volume* | *($m^3$ or $cm^3$)* |
| *T = Temperature* | *(MUST be in K(Kelvin))* |

# Light

**Refractive Index**

**Snell's Law**

**Real depth/Apparent Depth**

| | |
|---|---|
| | $n = \frac{\sin i}{\sin r}$<br>*n = refractive index* *(No unit)*<br>*i = angle of incident* *($^o$)*<br>*r = angle of reflection* *($^o$)* |
|  | $n = \frac{D}{d}$<br>*n = refractive index* *(No unit)*<br>*D = real depth* *(m or cm…)*<br>*d = apparent depth* *(m or cm…)* |
| **Speed of light**<br>$n = \frac{c}{v}$<br>*n = refractive index* *(No unit)*<br>*c = speed of light in vacuum* *($ms^{-1}$)*<br>*v = speed of light in a medium (like water,* | **Total Internal Reflection**<br>$n = \frac{1}{\sin c}$<br>*n = refractive index* *(No unit)*<br>*c = critical angle* *($^o$)* |

## Lens

### Power

$$P = \frac{1}{f}$$

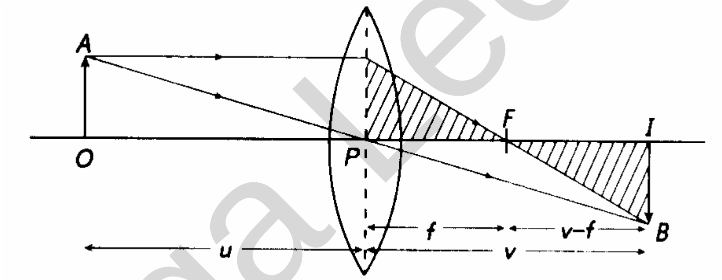
| | |
|---|---|
| *P = Power* | *(D(Diopter))* |
| *f = focal length* | *(m)* |

### Linear Magnification

$$m = \frac{h_i}{h_o} \qquad m = \frac{v}{u} \qquad \frac{h_i}{h_o} = \frac{v}{u}$$

| | |
|---|---|
| *m = linear magnification* | *(No unit)* |
| *u = distance of object* | *(m or cm…)* |
| *v = distance of image* | *(m or cm…)* |
| $h_i$ *= heigth of image* | *(m or cm…)* |
| $h_o$ *= heigth of object* | *(m or cm…)* |

### Lens Equation






$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

**Conventional symbol**

| | positive | negative |
|---|---|---|
| *u* | Real object | Virtual object |
| *v* | Real image | Virtual image |
| *f* | Convex lens | Concave lens |

## Astronomical Telescope

**Magnification,**

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

*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*