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ENGINEERING
SCIENCE

Volume II

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ENGINEERING SCIENCE

Volume II

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Preface

Alhamdulillah! Welcome to **Engineering Science: Volume II**. It is with great enthusiasm and a profound sense of accomplishment that we present this comprehensive work to you. The journey to create this e-book has been a testament to the dedication, passion, and relentless pursuit of excellence by a diverse team of experts, and lecturers in the field of engineering science with experience more than 10 years. This e-book is finally published. It consists of three-chapter, Work, Energy and Power, Solid and Fluid lastly Temperature and Heat. Each of the content are carefully planned and organized according to reader expectation. A new feature we introduce in this e-book is interactive assessment. The objectives are to allow you to do interactive assessment in a fun way and to master a certain subtopic through interactive games. As you delve into the chapters that follow, we hope you will appreciate the level of effort and dedication that has gone into producing this e-book. Our goal is to empower you with knowledge that will inspire innovation, foster critical thinking, and contribute to the advancement of engineering science particularly in TVET Malaysia. Thank you for choosing to embark on this intellectual journey with us. Your curiosity and commitment to the field are the driving forces behind our work, and we are honoured to be part of your exploration of engineering science.

Acknowledgement

Work, Energy & Power

Jessie Grace Goh Poh Ling
Nur Maisarah Abdullah

Work

1. Work is done whenever force is applied through a distance.

2. The component of the force must be parallel to the direction of the motion.

3. Therefore, Work, W can be defined as the product of the Force, F and the displacement, s of an object in the direction of the force.

$$W = Fs$$

Where:

W is the work

F is the force acting

s is the displacement

4. Work is a scalar quantity, and its unit is the Joule (J) or N m. 1 joule = 1 N m.

5. There are **FIVE (5)** situations to be considered in defining the work done of an object.

Situation 1:

An object is positioned on a smooth, horizontal surface, with the force applied in the same direction as its displacement.
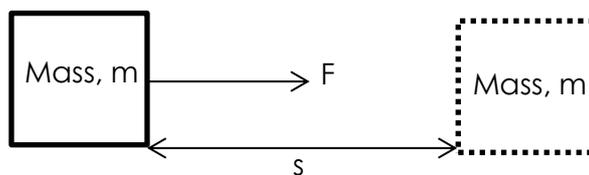
Example:

$$W = Fs$$
$$= 10\,(5)$$
$$= 50\,J$$
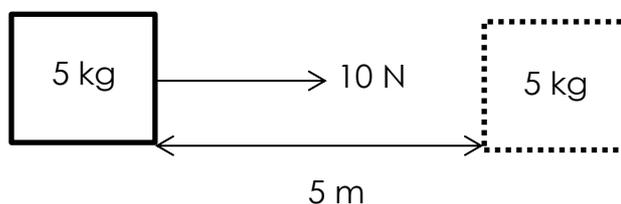
An object is positioned on a smooth horizontal plane, with a force applied at an angle, θ, to the horizontal direction of the displacement.

$$W = Fs$$
$$= F_x \, s \, (F \cos \theta)(s)$$
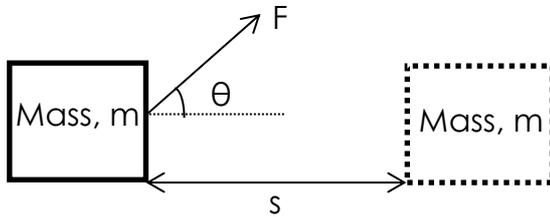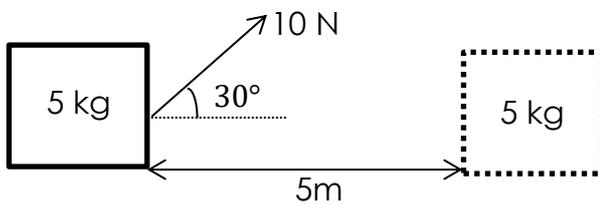
Example:

$$W = Fs$$
$$= F_x \, s$$
$$= (10 \cos 30°)(5)$$
$$= \mathbf{43.30 \, J}$$

An object is placed on an inclined plane, with the direction of force acting on it parallel with the displacement.
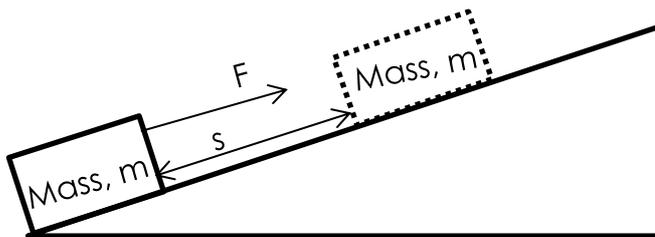
Example:

$$W = Fs$$
$$= 10 \, (5)$$
$$= \mathbf{50 \, J}$$
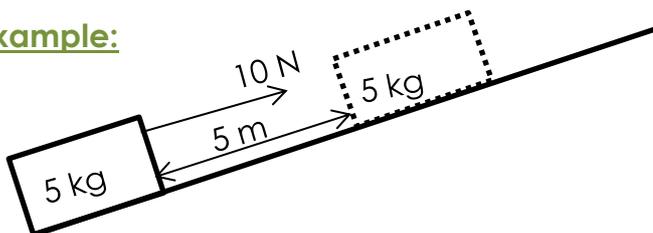
An object is placed on an inclined plane; with the force acting on it is inclined in a certain angle, θ to the horizontal with the displacement.

$$W = Fs$$
$$= F_x \, s$$
$$= (F \cos \theta)(s)$$

Example:

$$W = Fs$$
$$= F_x \, s$$
$$= (10 \cos 30°)(5)$$
$$= \mathbf{43.30 \, J}$$
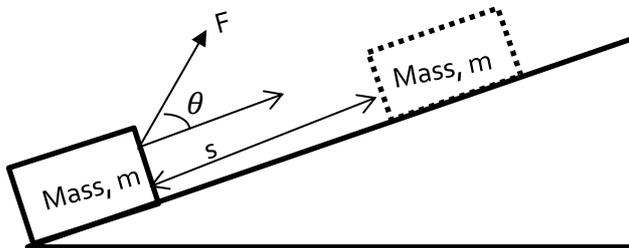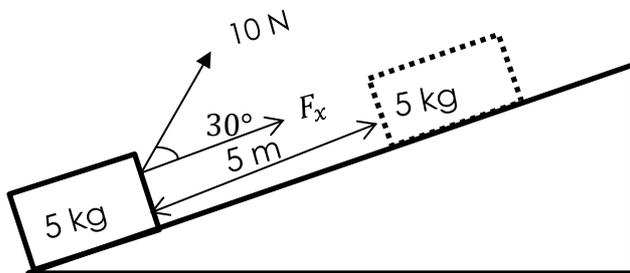
Situation 5:

An object is at a certain height and is influenced by gravity; which the force acting on the object is the gravity pulling down to the earth or ground.

Example:
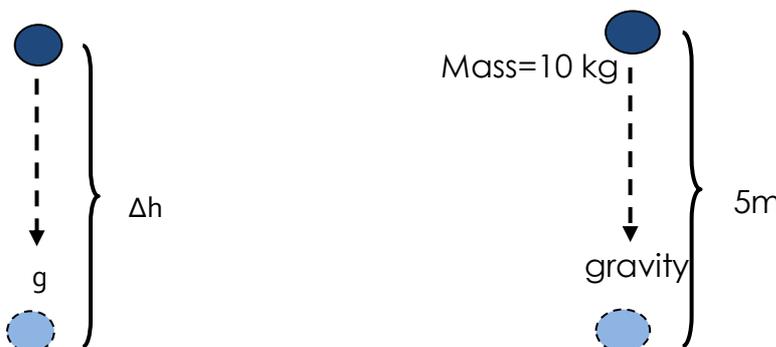
$$W = Fs$$
$$= mgh$$
$$= 10 \times 9.81 \times 5$$
$$= \mathbf{490.5 \, J}$$

Example 1

How much work is done by a force of 50 N acting 30° above the horizontal in pulling a box 7 m along the horizontal surface?

Solution:
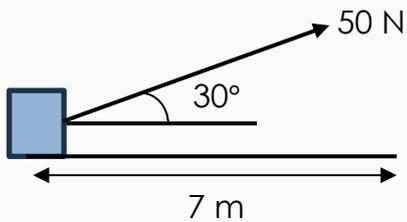
$$W = F_x d$$
$$= (50 \, \cos 30°)(7)$$
$$= 303.11 \, J$$

Example 2

During a circuit training exercise, Kevin Zahri ascends a staircase, lifting his 65 kg body vertically by 2500 millimeters in 0.05 minutes at a constant speed. Calculate the work done by Kevin Zahri in climbing the stairs.

Solution:

$W = mgh$

$W = 65 \times 9.81 \times 2.5$

$W = 1594.125 \, J$

$h = 2500 \, mm \; change \; to \; m$

$h = 2.5 \, m$

QUIZ

A cat pushes a toy mouse weighing 0.005 kg across the floor with a force of 3 N. If the cat performed 10 J of work, how far did the toy mouse move?

Answer: $3.333 \, m$

Exercise 1

A pole-vaulter with a mass of 50 kg clears a height of 5.0 m. Calculate the work done by the athlete.

Answer: 245.5 J

Exercise 2

A student pulls a 45 kg box up a smooth incline that is angled at 30° to the horizontal, as shown in the figure below. The length of the incline is 5 m. Calculate the work done in pulling the box to the top of the incline.
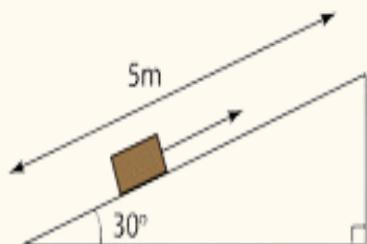
Answer: 2207.25 J

Exercise 3

A construction worker exerts a force of 200 N to push a wheelbarrow over 30 m at a constant speed. If the force is applied at an angle of 30° to the horizontal, calculate the work done by the worker.

Answer: 5196.15 J

Renewable Energy

Solar energy

Wind energy

Tidal energy

Geothermal energy

Hydroelectric energy

Biomass energy

1. Renewable energy is a sustainable energy that are endless source.

2. It is also known as alternative energy to substitute the non-renewable energy.

3. Example on electric car (EV) is now to be known as an alternative vehicle because the vehicle is running on electric charges.

QUIZ

SCAN ME   OR   CLICK HERE

Fuel energy

Coal energy

Nuclear energy

Natural gas energy

1. Non-renewable energy is a limited resources that will be depleted over time.

2. This form of energy usually man must dig out from the earth to gather the substance and to produce the product.

3. Over the years, non-renewable energy have been the backboned of modern industrialization.

QUIZ

SCAN ME

OR

CLICK HERE

Energy

1. Energy is defined as the ability to do work.

2. The S.I unit for energy is Joule (J).

3. Energy is a scalar quantity.

4. Example of an energy is potential energy, kinetic energy, chemical energy, elastic energy, light energy, sound energy and heat energy .

Potential Energy

Height, h

$$Potential\ Energy\ (Ep) = Work\ done\ (W)$$

$$E_p = mg \times h$$

$$E_p = mgh$$

1. Potential Energy is the energy of an object possessed due to its position.

2. The higher the object is placed from the ground the maximum the potential energy is produced.

3. A weightlifter athlete lift the barbell from the ground and rise above his head, The work done, **W = mg** by the athlete transferred the energy to potential energy because of changing of height, h .

4. The S.I unit for potential energy is Joule (J).

Example 1

A durian has a mass of 2.5 kg. The durian is lifted from the ground and placed on the back of a pickup truck. If the durian gains 50 J of potential energy, how high is the pickup truck?

Solution:

$E_p = mgh$

$50 = 2.5(9.81)(h)$

$h = \dfrac{50}{24.525}$

$h = 2.04\ m$

Example 2

A 5 kg cat is lifted above the ground 1 m by a small boy. How much the potential energy is gained?

Solution:

$E_p = mgh = 5(9.81)(1) = 49.05\ J$

QUIZ

A boy is carrying a pail of water up a flight of stairs. The work done by the boy is 29.43 J. An old woman also carrying a same pail of water up a flight of stairs, exactly as the boy. How much is the potential energy gained by the old woman?

Answer: $29.43\ J$

Exercise 1

A large block of cement block has been raised to a height of 10 m has gained 5500 J of potential energy. How much is the mass of the cement block?

Answer: $56.07 \, kg$

Exercise 2

Object A and object B is located at a different heights. Object A is at 10 m while object B is at 12 m. Which object have the highest potential energy if the mass of object A is 5 times than object B ? Provide your answer with a calculation.

Answer: $E_{p \, (A)} = 490.5 \, mJ$, $E_{p \, (B)} = 117.72 \, mJ$

Highest Potential Energy is object A is due to its weight even though the height is lesser than object B

Velocity, v

$$Kinetic\ Energy\ (Ek) = Work\ done\ (W)$$

$$E_k = Fs$$

$$E_k = mas$$

$$E_k = m\left[\frac{v^2}{2}\right]$$

$$E_k = \frac{1}{2}mv^2$$

1. Kinetic Energy is the energy of an object own due to its motion.

2. The maximum of the kinetic energy is depending on the acceleration of the object.

3. To speed up the acceleration, more force needs to be applied. This system involves work done by the object.

4. The transferred energy then changed it to kinetic energy.

5. A baseball is thrown toward the player resulting the ball to shift its movement to the other side. The baseball is moved because of the effect of force. Force is determined by the acceleration and mass of an object. The bigger force hits the baseball, making its to accelerate fast. Thus, maximum kinetic energy is gained.

6. The S.I unit for kinetic energy is Joule (J).

Example 1

An object has a kinetic energy of 30 J and a mass of 50 kg, how fast is the object moving ?

Solution:

$E_k = \frac{1}{2}mv^2$

$30 = \frac{1}{2}(50)v^2$

$v^2 = 1.2$

$v = 1.0954 \; m/s$

Example 2

What is the Kinetic Energy of a 1000 kg object that is moving with a velocity of 25 m/s ?

Solution:

$E_k = \frac{1}{2}mv^2 = \frac{1}{2}(1000)(25^2) = 315\,500 \; J$

QUIZ

SCAN ME   OR   CLICK HERE

What is the mass of a wind turbine blade with a kinetic energy of 110 200 J, rotating at 5.5 m/s ?

Answer: $7285.95\ kg$

What is the kinetic energy of a runner with a mass of 65 kg sprint at a velocity of 0.75 m/s ?

Answer: $18.2812\ J$

1. Figure shows a durian of mass, m kg falling from a height of h meters to the ground.

2. The durian while is still hanging at the branches is at its highest position level, giving the durian to possessed Potential Energy, E_p at the maximum energy (100 % E_p).

3. Kinetic Energy, E_k is at minimum energy (0 % E_p) because the durian is at rest.

4. At this point A, Total energy = Potential Energy + Kinetic Energy.

5. A ripe durian will fall to the ground. At this stage, total energy will remain constant during a falling durian before it hits the ground.

6. During movement of a falling durian, shifting potential energy to kinetic energy will happen. At point B, possibility the energy will be equal.

7. Once the durian hits the ground, at point C, potential energy will totally shift to kinetic energy. The durian will possess Kinetic Energy at maximum energy (100 % E_k).

8. The system is called Principle of Conservation of Energy. It states that **energy can neither be created nor destroy but only converted from one form of energy to another.**

Example I

A coconut with a mass of 1 kg falls from a tree which is 15 m high from the ground. Calculate :

Solution:

a) Potential energy while the coconut is still on the tree.

$$E_p = mgh$$
$$= 1(9.81)(15)$$
$$= 147.15 \, J$$

10 m

b) Potential energy and kinetic energy when the coconut falls 10 m from the tree.

$$E_p = mgh$$
$$= 1(9.81)(5)$$
$$= 49.05 \, J$$

$$E_K = Total \ energy - E_p$$
$$= 147.15 - 49.05$$
$$= 98.1 \, J$$

c) Velocity of the coconut just before it touches the ground.

$$E_k = \frac{1}{2}(m)(v^2)$$

$$147.15 = \frac{1}{2}(1)v^2$$

$$294.3 = v^2$$

$$v = \sqrt{294.3}$$

$$v = 17.15 \, m/s$$

DON'T FORGET!

Assume maximum energy is 100%, therefore, the total amount of energy, can be put in this simple formula

$$E_p + E_K = 100\%$$

Example 2

A man who has a mass of 90 kg rides on a rollercoaster as shown in the figure above. Calculate:
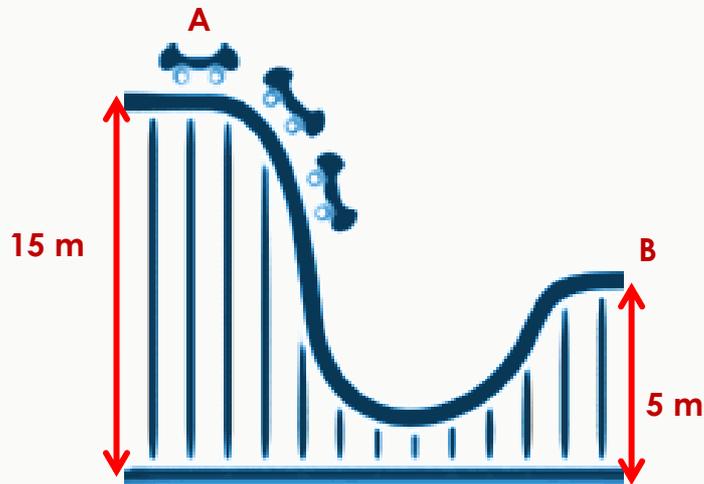
Solution:

a) Total energy at point A

$$Total\ energy = Potential\ Energy$$

$$E_p = mgh = 90 \times 9.81 \times 15 = 13\ 243.5\ J$$

b) Kinetic Energy and Potential Energy at point B .

$$Potential\ Energy = Kinetic\ Energy$$

$$E_p = mgh = 90 \times 9.81 \times 5 = 4414.5\ J$$

Since Total Energy is 13 243.5 J , therefore Kinetic Energy can determine by

$$E_k = Total\ Energy - Potential\ Energy\ at\ point\ B$$

$$= 13\ 243.5 - 4414.5$$

$$= 8829\ J$$

A 90 kg paraglider has a speed of 62 m/s at an altitude of 850 m above the ground. Determine,

a) The kinetic energy possessed by the paraglider

b) The potential energy possessed by the paraglider

Answer: 172 980 J, 750 465 J

A boy on the street wants to throw a rose with mass of 50 g up to a girl learning out of the window 3 m above street level. How much velocity must the boy throw the rose so that it reaches the girl in the window?

Answer: $7.6720 \frac{m}{s}$

Power

Vertical height, h

Weight, W =mg
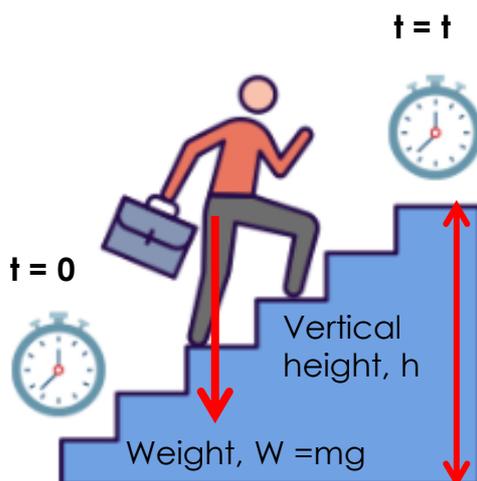
1. While walking up a flight of stairs, work is done due to gravitational force.

2. Work done happened when applied force is acted on an object causing the object or subject matter to change its position.

3. Work done has nothing to do with time. For example, a young boy and an old lady both carrying a pail full of water walking up a flight of stairs. Although both are different in strength but they both are doing the same amount of work.

4. The only make them different is the amount time taken to complete the task. The young boy may be the first to complete the task as he is much stronger compared to the old lady.

5. In this situation, the expression of power use to compare the two individuals. It is because the quantity is measured at the rate of work done.

6. Therefore, to calculate power is

$$Work\ done = mg \times h$$

$$Power = \frac{Work\ done}{Time\ taken} = \frac{mgh}{t}$$

7. Power can also be calculated as

$$Power = \frac{Force \times displacement}{time}$$

$$Power = Force \times velocity$$

8. The SI unit for power is Watt (W).

Example 1

A motor is used to pump water from a river with a depth of 4 m at a rate of 35 N per minute. Calculate the power of the pump.

Solution:

$$P = \frac{Fs}{t} = \frac{35(4)}{60} = \frac{140}{60} = 2.333 \text{ W}$$

Example 2

A man lifts a bucket with 60 N force in 1 minute out of a well. The bucket is lifted at 15 m.

a) How much work is done on the bucket by the man?

b) How much power is exerted by the man?

Solution:

a) $W = Fs = 60 \times 15 = 900 \, J$

b) $P = \dfrac{Work\ done}{Time} = \dfrac{900}{60} = \mathbf{15 \, W}$

Exercise 1

A maintenance guy with a mass of 90 kg climbs up unto the roof of a building of 30 m high. If the power generated by the maintenance guy is 1000 W, how long does it take him to complete the task?

Answer: $26.487\ s$

Exercise 2

A paraglider with a mass of 70 kg at an altitude of 700 m above the ground in 38 seconds. Determine the power of the paraglider.

Answer: $12649.74\ W$

Efficiency

Energy in, E_i

Energy out, E_o

Power in, P_i

Power out, P_o
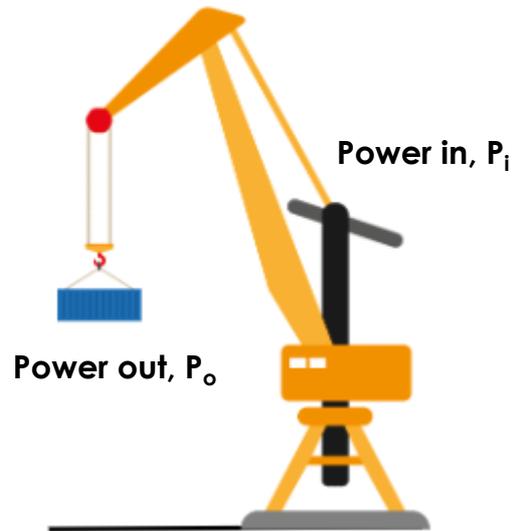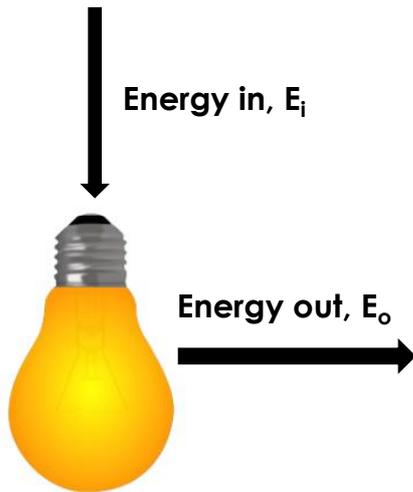
1. Efficiency is used to compare energy output to the energy input.

2. A good device or machinery is often depending on the transfer energy input to energy output.

3. A device or machinery with less waste of energy input considered more efficient. While a device or machinery with more waste of energy input considered less efficient.

4. The efficiency of a device:

$$Efficiency = \frac{Energy\ Output}{Energy\ Input} \times 100\%$$

5. The efficiency of a device can also be calculated in terms of power:

$$Efficiency = \frac{\dfrac{Work\ Output}{time}}{\dfrac{Work\ input}{time}} \times 100\%$$

$$Efficiency = \frac{Power\ Output}{Power\ Input} \times 100\%$$

6. Efficiency of a device or machinery is expressed in percentage (%).

Example I

A water pump is running at an efficiency of 85% with power output 5kW to deliver clean water to water supply tank. Calculate the power input of the water pump.

Solution:

E = 85 %

$P_o = 5\ kW$

$E = \dfrac{P_0}{P_i} \times 100\%$

$0.85 = \dfrac{5000}{P_i}$

$P_i = 5882.35\ W$

Example 2

A crane lifts a load of 700 kg to a height of 150 m in 20 s. If the power input is 60 000 W, what is the efficiency of the motor used in the crane?

Solution:

$Power\ output, P_o = \dfrac{700(9.81)(150)}{20} = 51502.5\ W$

$Power\ input = 47\ 000\ W$

$E = \dfrac{P_o}{P_i} \times 100\ \%$

$\quad = \dfrac{51502.5}{60000} \times 100\ \%$

$\quad = 85.84\ \%$

An engine has a work output of 100 kJ per 60 s. What is the power input if the efficiency of the engine is 25 % ?

Answer: 6666.68 W

A hydraulic machinery lifts a load of 1000 kg to a height of 100 m in a minute. If the power input is 20 000 W, what is the efficiency of the system used in the hydraulic machinery ?

Answer: 81.75 %
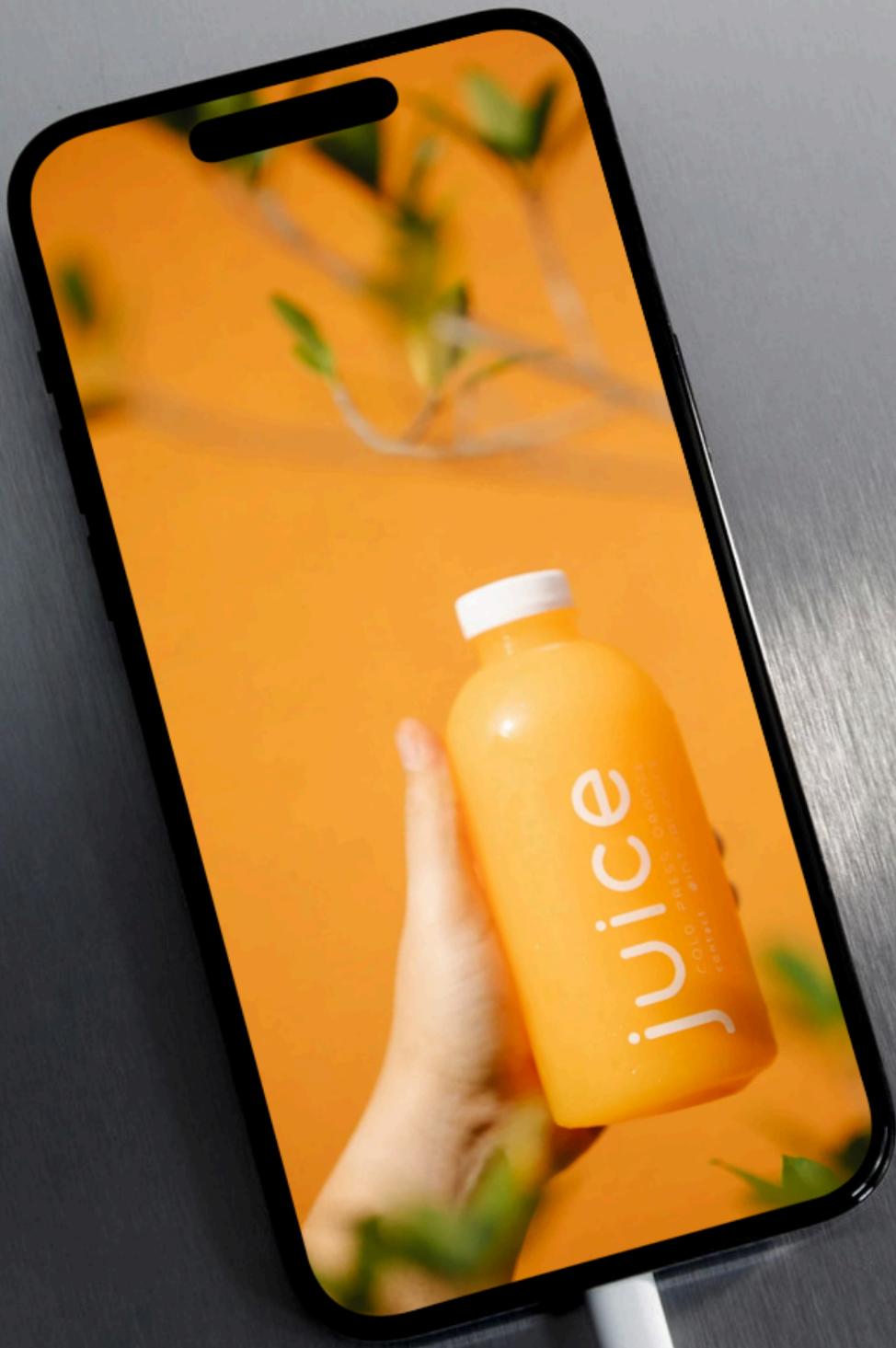
Solid & Fluid

Noorain binti Ithnin

1. All objects/ materials in the world are composed of elements that possess mass and occupy space. This composition is known as matter.

2. Matter is made up of atoms. The arrangement and types of atoms determine the properties of different kinds of matter.

3. All matter can exist in a forms of
   i. Solid
   ii. Liquid
   iii. Gas

Gas

Solid

Liquid

4. Matter can change states when it undergoes a phase transition between each other through heating or cooling when it reaches boiling or freezing points.

Deposition

Sublimation

Solid

Melting

Vaporization

Gas

Freezing

Condensation
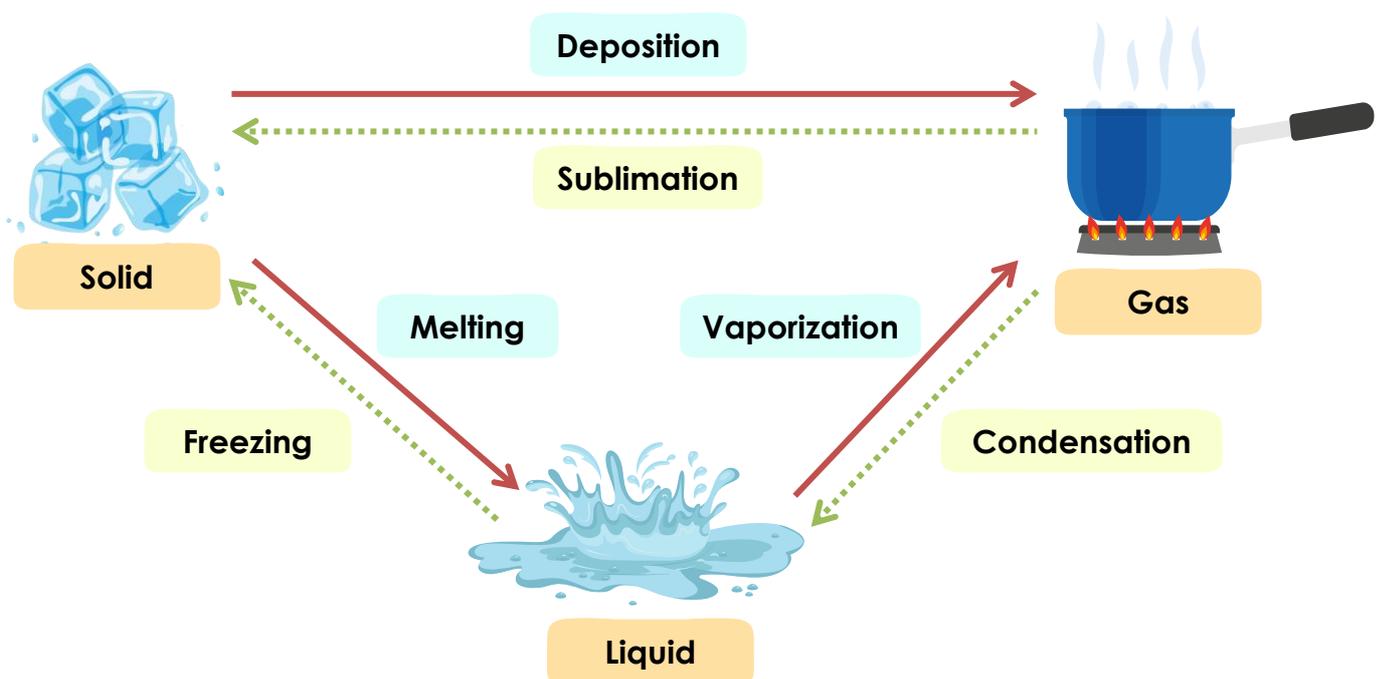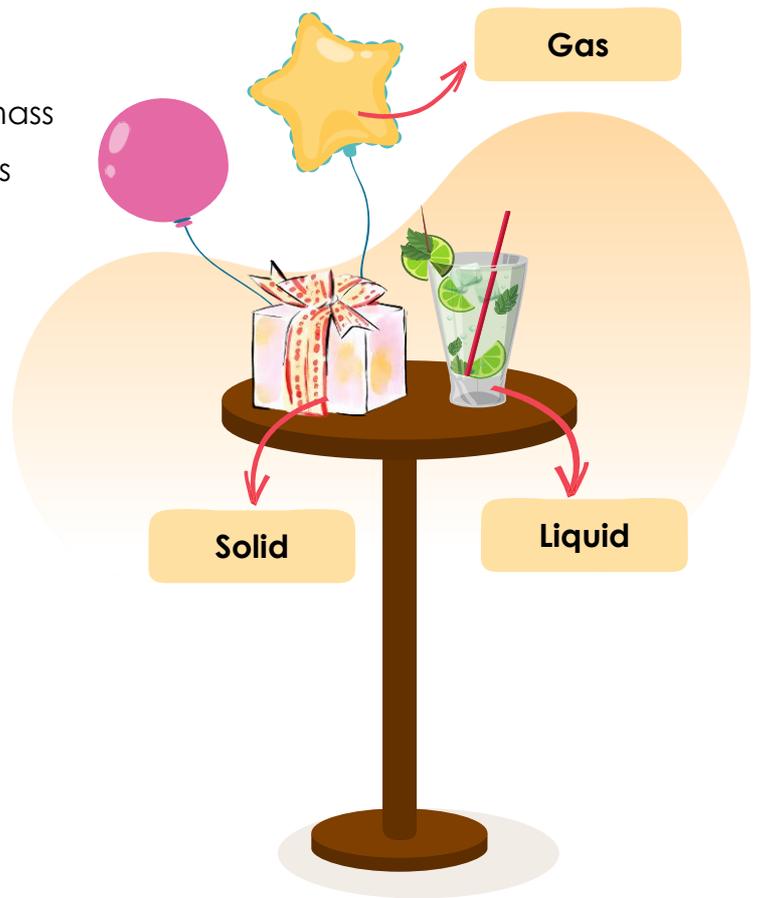
Liquid

Characteristics of Solid, Liquid & Gas

1. Particles Arrangement

SOLID	LIQUID	GAS
Molecules are closely packed	Particles are packed closely together without a specific arrangement	Particles are widely spaced with no distinct arrangement
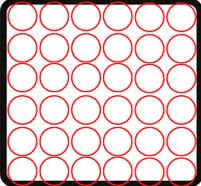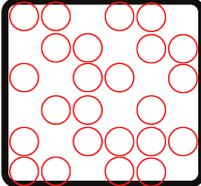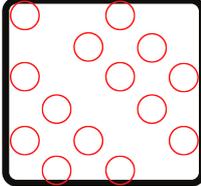
2. Particle bonding

SOLID	LIQUID	GAS
Not easily compressible	Not easily compressible	Compressible

3. Particle movement

SOLID	LIQUID	GAS
Molecules are fixed in position, vibrating around a specific point	Molecules can shift out of place and move around each other	Molecules can move freely and randomly

4. Compressible

SOLID	LIQUID	GAS
Not easily compressible	Not easily compressible	Compressible

5. Shape

SOLID	LIQUID	GAS
Holds it shape	Has no definite shape and takes the shape of its container	Has no definite shape; it takes the shape of the container

6. Volume

SOLID	LIQUID	GAS
The volume is fixed	The volume is fixed	No definite volume

QUIZ

SCAN ME

SCAN ME

SCAN ME

OR

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OR

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Density

1. Density is a measure of the amount of mass contained in a specific volume of a substance.

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

Where:

ρ is the density of a substance

m is the mass of a substance

V is the volume of a substance

2. Density is commonly expressed in units of kg/m³ or g/cm³. Table below shows a densities of common substance.

Material/ substance	Density (kg/m³)	Density (g/cm³)
Wood (oak)	0.85	0.00085
Helium	0.1785	0.0001785
Oxygen	1.429	0.001429
Ice	897	0.897
Water	1000	1
Sugar	1590	1.59
Zinc	7140	7.14
Steel	7850	7.85
Gold	19300	19.3

Do you know?

The concept of density is used in the design of life jacket to ensure buoyancy. The life jacket is made of foam and certain fibers that contain trapped air or gas bubbles. They are designed to have a lower density than water, allowing a person to float and keeping their heads above the water.

Example I

Calculate the density in kg/m³ for a 75 kg box with volume of 600 cm³.

Solution:

$$Volume, V = 600 \; cm^3 \times \frac{(10^{-2})^3 \; m^3}{1 \; cm^3} = 600 \times 10^{-6} \; m^3$$

$$Density, \rho = \frac{m}{V} = \frac{75 \; kg}{600 \times 10^{-6} \; m^3} = 125 \times 10^3 \; \frac{kg}{m^3}$$

Example 2

A 2 g cube with dimension of 7 cm x 5 cm x 5 cm is submerged in a container filled with water. Calculate the density of the cube.

Solution:

$$Volume, V = 7 \; cm \times 5 \; cm \times 5 \; cm = 175 \; cm^3$$

$$= 175 \; cm^3 \times \frac{(10^{-2})^3 \; m^3}{1 \; cm^3} = 175 \times 10^{-6} \; m^3$$

$$Mass, m = 2 \; g \times \frac{1 \; kg}{10^3 \; g} = 2 \times 10^{-3} kg$$

$$Density, \rho = \frac{m}{V} = \frac{2 \times 10^{-3} kg}{175 \times 10^{-6} \; m^3} = 11.429 \frac{kg}{m^3}$$

Exercise I

A plastic block has a dimension of 1 cm x 2 cm x 2 cm. If the mass of the block is 4.7 g, calculate the density of the cube.

Answer: $1175 \; \frac{kg}{m^3}$

1. Density can be used to identify a substance and its properties. For instance, an object with higher density will sink, whereas an object with lower density will float in a fluid.

Oil
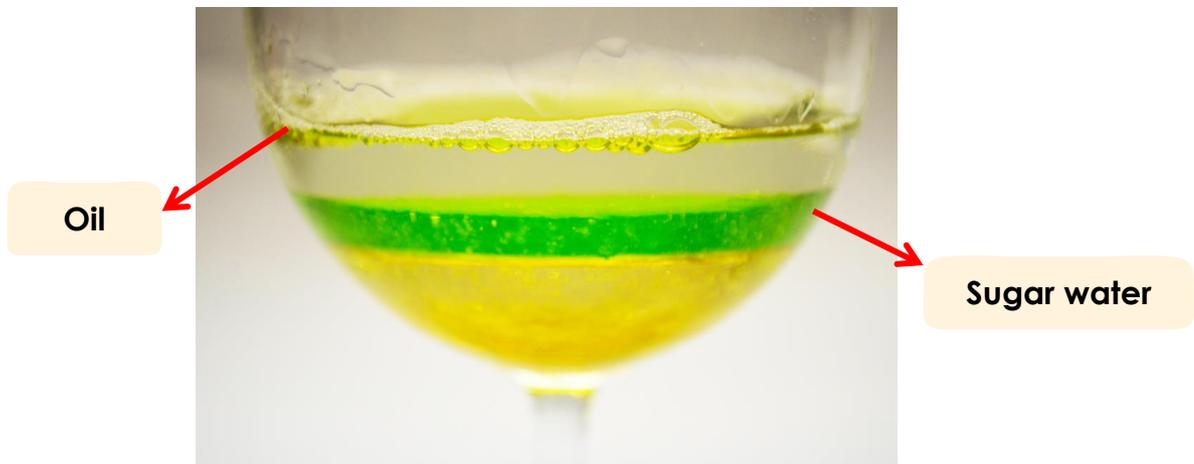
Sugar water

💡 The sugar water is denser than the oil, so the oil will float when it mixes with the sugar water.
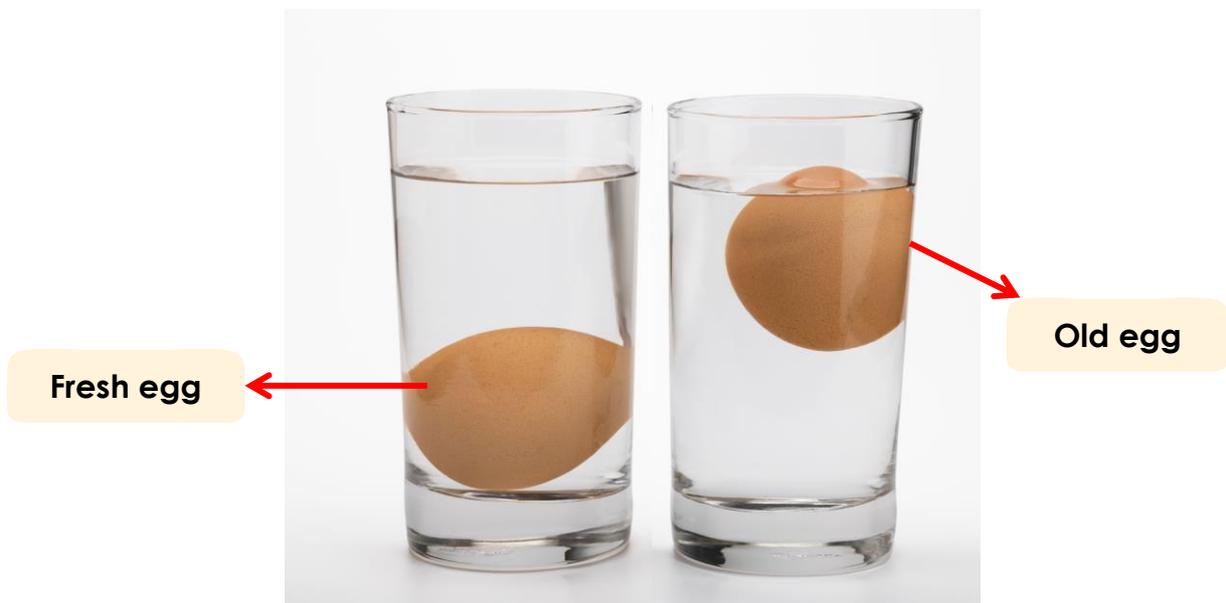
Fresh egg

Old egg

💡 A fresh egg is denser than water, causing it to sink . The old egg is less dense than the water because moisture and carbon dioxide in the egg escape through the shell and replaced by the air.

Relative Density

1. Relative density is also known as specific gravity. It is a dimensionless quantity that describes the ratio of a substance's density to the density of water.

> Density of water = 1000 kg/m³ = 1 g/cm³

2. Since it is dimensionless quantity, this ratio is a pure number containing no units.

$$\rho_{relative} = \frac{\rho_{material}}{\rho_{water}}$$

Where:

ρ is the density

3. The value of relative density shows the comparison of density of material to the density of water.

Relative density, $\rho_{relative}$	Interpretation
$\rho_{relative} > 1$	The material is less than the water
$\rho_{relative} = 1$	The material has the same density as the water
$\rho_{relative} < 1$	The material is denser than the water

Example I

Liquid X has a density of 0.45 g/cm³ . What is the relative density of liquid X?

Solution:

$$\rho_{relative} = \frac{\rho_{material}}{\rho_{water}} = \frac{0.45 \frac{g}{cm^3}}{1 \frac{g}{cm^3}} = 0.45$$

This means, liquid X is less dense than the water because the $\rho_{relative} < 1$ and will float on water

Example 2

A 49.3 kg of cylindrical steel has a radius of 0.05 m and 0.8 m height. Find the density and specific gravity of the steel. ($V_{cylinder} = \pi r^2 h$, $\rho_{water} = 1000 \frac{kg}{m^3}$)

Solution:

$Volume\ of\ cylinder, V_{cylinder} = \pi r^2 h = \pi(0.05\ m)^2(0.8\ m) = 6.2832 \times 10^{-3}\ m^3$

$Density, \rho = \dfrac{m}{V} = \dfrac{49.3\ kg}{6.2832 \times 10^{-3}\ m^3} = 7846.3203\ \dfrac{kg}{m^3}$

$Specific\ gravity\ @\ Relative\ density, \rho_{relative} = \dfrac{\rho_{material}}{\rho_{water}} = \dfrac{7846.3203\ \frac{kg}{m^3}}{1000\ \frac{kg}{m^3}} = 7.846$

Exercise 1

A 2.8 N of wooden block has a dimension of 8 cm x 10 cm x 8 cm. Calculate the density and relative density of the wooden block. ($\rho_{water} = 1000 \frac{kg}{m^3}$)

Answer: $445.973 \frac{kg}{m^3}, 0.446$

Exercise 2

The density of gold is $19320 \frac{kg}{m^3}$. What is the relative density of the gold if the density of water is $1000 \frac{kg}{m^3}$?

Answer: 19.32

Pressure

1. Pressure is the measure of the force per unit area. Pressure describes how much force is exerted on a surface area.

2. Common units for pressure is N/m^2 and Pascal (Pa).

3. There are other pressure units such as atmosphere (atm), bar or per square inch (psi).

4. The basic formula for pressure is

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

Where:

P is the pressure on the object

F is the force exerted

A is the surface area

5. The practical examples of pressure on surface area is like a cutting tools that we used in the kitchen.

P↑ A↓

The sharp edge has a smaller surface area, creating a higher pressure to slice the fish when the force is applied.
A sharp knife cuts more effectively and easier than using the dull part.

6. Have you ever wondered why trucks have more tires than a car?

P↓ A↑

A trucks have more tires to distribute the heavy loads they carry. By increasing the number of tires, the total surface area in contact with the ground increases. The distribution of force over a large area reduces the pressure on each tire.

Example 1

A butcher use a knife with a cross-sectional area of 0.3 cm² to cut a meat into slices. Calculate the pressure exerted by the knife if the force applied on the knife is 14 N.

Solution:

$$Area, A = 0.3 \; cm^2 \times \frac{(10^{-2})^2 \; m^2}{1 \; cm^2} = 0.3 \times 10^{-4} \; m^2$$

$$Pressure, P = \frac{F}{A} = \frac{14 \; N}{0.3 \times 10^{-4} \; m^2} = 466.667 \times 10^3 \; \frac{N}{m^2} \; @ \; Pa$$

Example 2

Baby Yusuff is sitting on a 4-legged chair of mass 8 kg. If baby Yusuff's mass is 7 kg, and each leg of the chair has a surface area of 3 x 10⁻⁴ m², what is the pressure exerted on the ground?

Solution:

$$Force, F = mg = (m_1 + m_2)g = (8 + 7)(9.81) = 147.15 \; N$$

$$Area \; on \; contact \; with \; ground \; for \; 4 \; legged \; chair, A = 4(3 \times 10^{-4} \; m^2) = 12 \times 10^{-4} \; m^2$$

$$Pressure, P = \frac{F}{A} = \frac{147.15 \; N}{12 \times 10^{-4} \; m^2} = 122625 \; \frac{N}{m^2} \; @ \; Pa$$

QUIZ

SCAN ME   OR   CLICK HERE

Exercise 1

A fruit seller use a knife with a cross-sectional area of 0.45 cm² to cut open a pineapple. If the force applied on the knife is 30 N, calculate the pressure exerted by the knife on the pineapple.

Answer: $666.667 \times 10^3 \ Pa$

Exercise 2

4 kids with combined weight of 750 N are sitting on a bench at the playground. If the contact area of the bench with the ground is 15 m², calculate the pressure exerted on the bench.

Answer: $50 \ Pa$

Exercise 3

A cuboid with dimension of 0.2 m x 0.3 m x 0.3 m has a mass of 2 kg. Calculate the maximum pressure exerted by the cuboid when it is placed on the floor.

Answer: $327 \ Pa$

Fluid Pressure

1. Fluid (liquid and gas) can also exert pressure. When an object is immersed in a liquid, the object experience a pressure from the liquid.

2. The force exerted on the object is from the weight of the liquid.

3. In a fluid that is not moving (at rest), the pressure exerted on the object is isotropic.

4. Isotropic means that the pressure exerted on the object is equal in all direction at any point of the fluid.

5. Pressure in liquid increases uniformly at increasing depth of the liquid.

Depth, h

P↓ h↓

Pressure, P

P↑ h↑
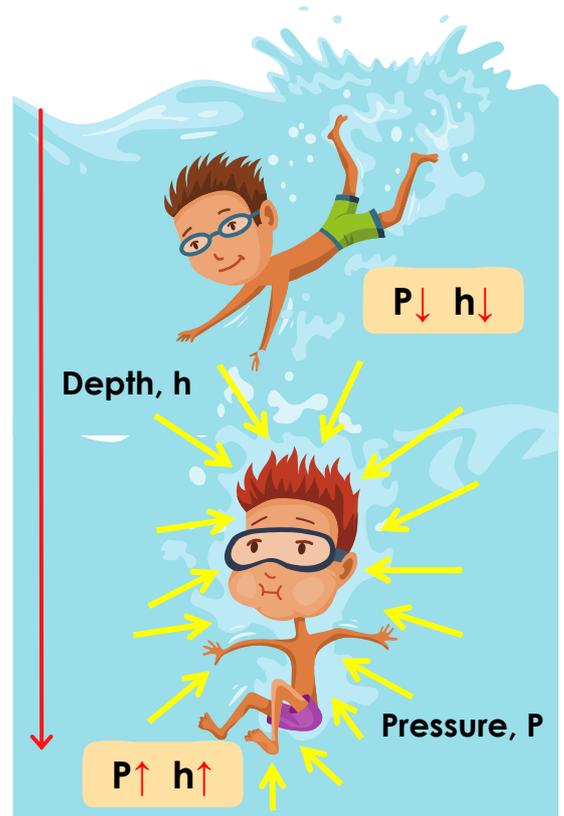
> The water above will be pushing down on the boy because of the force of the gravity. Therefore, the pressure is exerted on the boy's body. If they go deeper down the pool, the weight and the pressure will increase as there will be more water above.

6. From the formula of pressure, the formula of pressure in fluid at any depth can be represented as

$$P = \rho g h$$

Where:

P is the pressure on the object

ρ is the density of the fluid

g is the acceleration of gravity

h is the depth below the water surface

Do you know?

A submarine dive below the surface of the water by filling the ballast tank with water so that the submarine's overall density increases. This make the submarine heavier than the surrounding water.

7. The practical example of fluid pressure can be seen in the concept of water supply.

A water tower is constructed at a high elevation to ensure that water has enough pressure to travel through the pipes and reach consumers' homes. The taller the water tower, the greater the pressure at its base

8. Another example is for the construction of submarine
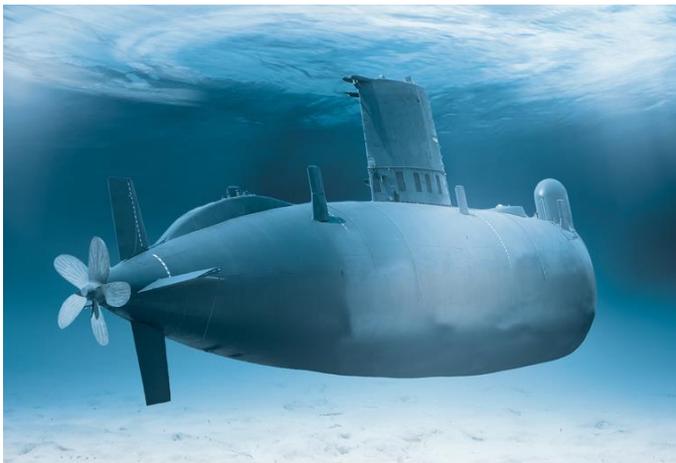
As the submarine descends underwater, the depth is increases and consequently the pressure increases. The submarine's body is thick and constructed from durable materials to endure the high pressure in the deep sea.

Example I

Calculate the water pressure acting on a boy who dive at a depth of 5 m below the water surface of the pool. ($\rho_{water} = 1000 \frac{kg}{m^3}$)

Solution:

$Pressure, P = \rho g h = (1000)(9.81)(5) = 49050 \, Pa$

Example 2

A container contains water to a depth of 15 cm and oil of 7 cm. The density of the water is 1000 $\frac{kg}{m^3}$ and oil is 850 $\frac{kg}{m^3}$. Calculate the total pressure at the base of the container.

Solution:

$Pressure, P_{oil} = \rho_{oil}gh = (850)(9.81)(7 \times 10^{-2}) = 583.695\ Pa$

$Pressure, P_{water} = \rho_{water}gh = (1000)(9.81)(15 \times 10^{-2}) = 1471.5\ Pa$

$Total\ pressure = P_{oil} + P_{water} = 583.695 + 1471.5 = 2055.195\ Pa$

Exercise 1

Calculate the pressure experience by a swimmer 15 m below the surface of the ocean. Given that the density of the sea water is 1.025 x 10³ $\frac{kg}{m^3}$.

Answer: 150.829 kPa

Exercise 2

A tank with a diameter of 1.5 cm is filled with oil. Calculate the pressure at the bottom of the tank if the depth of the tank is 2.5 m from the surface. ($P_{oil} = 850\ \frac{kg}{m^3}$)

Answer: 20.846 kPa

1. Pascal's principle states that when pressure is applied to an enclosed fluid, it is evenly transmitted throughout the fluid and to the walls of the container.

2. This means that any variation in pressure at one location in the fluid will result in a proportional change (either an increase or a decrease) throughout the entire fluid.

3. The concept of Pascal's principle can be applied to the hydraulic system. Considering there are two piston with different sizes, the pressure on both piston is the same.

$$P_1 = P_2$$

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

Where:

P is the pressure on the object

F is the force

A is the surface area

** the surface area of the piston can also be calculated using the formula of circle, $A = \pi r^2 h$
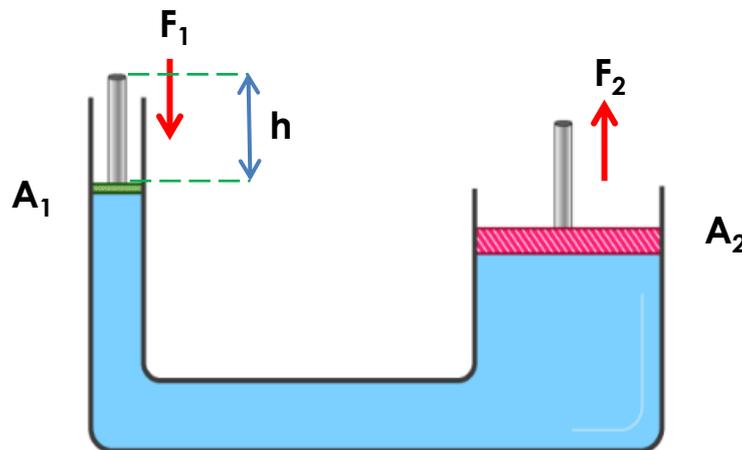
4. The volume of fluid being pushed down under the small piston equals to the volume of fluid that lifts the larger piston upward.

5. The formula can also be expressed as

$$P_1 = P_2$$

$$V_1 = V_2$$

$$A_1 h_1 = A_2 h_2$$

Where:

V is the volume

h is the depth below the water surface

Application of Pascal's Principle

1. In the field of engineering, Pascal's concept is widely applied especially in hydraulic and pneumatic systems.

2. A hydraulic lift is used to lift heavy objects using a hydraulic system.

> A force is applied to the smaller piston that creates pressure in the hydraulic fluid and generated a larger force in the larger piston. This enable the lift to raise a heavy loads with minimal input effort.

3. Other than that, an automotive hydraulic brake system also use the concept of Pascal's principle.

> When the brake pedal is pressed, the pressure in the brake fluid rises. This pressure is evenly distributed to the brake pads on each wheel, generating a force that gradually slows the vehicle down.

4. The concept of Pascal's principle is also applied in medical devices such as hydraulic stretches, hospital beds and syringes.

Ouch! Vaccination Day: The Science Behind The Shot

Who's next??

Don't worry! I will be as gentle as possible.

When the nurse giving an injection, you will feel a small pinch. Since the needle is very thin, so the pressure is concentrated on a tiny area. Do you remember the pressure concept? When **Area↓ Pressure↑**

So how does the syringe work smoothly?
It is because the syringe operates based on Pascal's principle. When the nurse push the plunger, it applies pressure to fluid inside and transmitted the pressure equally. This help to ensure that the right amount of medication is delivered smoothly and accurately.

Example 1

A hydraulic jack features a cylindrical piston with a cross-sectional area of 0.15 m²
and a plunger with a cross-sectional area of 0.05 m². The upward force for lifting a
load placed on top of the large piston is 6000 N.

    a) Calculate the downward force required on the plunger

    b) If the plunger moves 45 cm, calculate the distance moved by the large
       piston

$F_2 = 6000$ N

F_1

h = 45 cm

$A_1 = 0.05$ m²

Plunger

Load
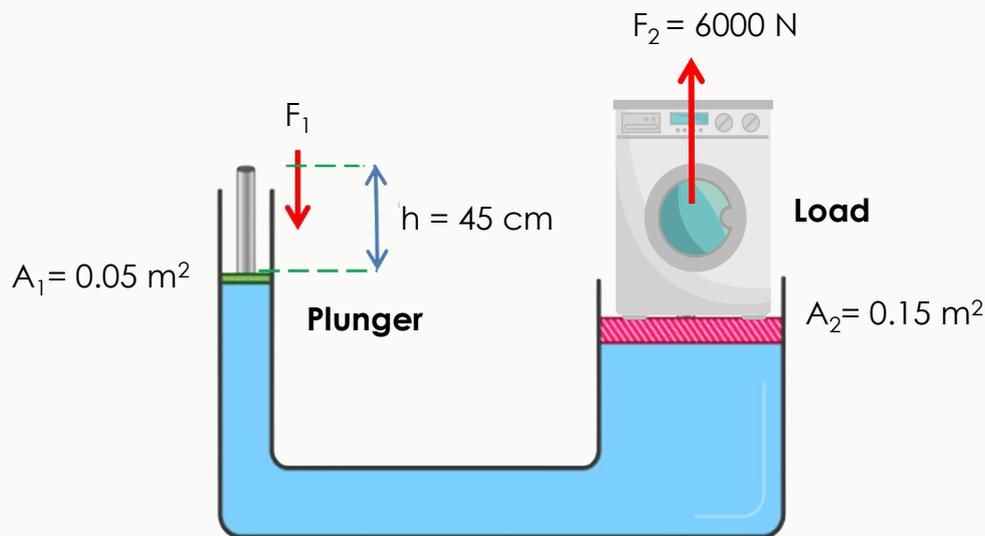
$A_2 = 0.15$ m²

Solution:

a) $\dfrac{F_1}{A_1} = \dfrac{F_2}{A_2}$

$Output\ force, F_1 = \dfrac{F_2}{A_2} \times A_1 = \dfrac{6000\ N}{0.15\ m^2} \times 0.05\ m^2 = 2000\ N$

b) $A_1 h_1 = A_2 h_2$

$Distance, h_1 = 45\ cm \times \dfrac{10^{-2}\ m}{1\ cm} = 0.45\ cm$

$Distance, h_2 = \dfrac{A_1 h_1}{A_2} = \dfrac{0.05\ m^2\ (0.45\ m)}{0.15\ m^2} = 0.15\ m$

Example 2

In a hydraulic system, the radius of the input piston is 0.25 m, while the output piston is 0.6 m. Calculate the force on the input piston to lift a 2500 N load on the output piston.

Solution:

$$Area, A_1 = \pi r_1^2 = \pi(0.25\ m)^2 = 0.196\ m^2$$

$$Area, A_2 = \pi r_2^2 = \pi(0.6\ m)^2 = 1.131\ m^2$$

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

$$Output\ force, F_1 = \frac{F_2}{A_2} \times A_1 = \frac{2500}{1.131} \times 0.196 = 433.245\ N$$

Exercise 1

A dentist raises a patient's chair by applying a force of 120 N to a hydraulic piston with an area of 0.01 m². If the chair is connected to a piston with an area of 0.2 m², calculate the resulting output force.

Answer: 2400 N

Exercise 2

Given that the cross-sectional area of input piston of a hydraulic jack is 0.02 m² and 0.09 m² respectively. If the input piston is pushed by a 700 N force, calculate the mass of the load on the output piston. If the displacement of input piston is 23 cm, calculate the displacement on the output piston in cm.

Answer: 321.1 kg, 5.111 cm

1. Archimedes states that a part or whole body immersed in a fluid is buoyed up by a force equal to the weight of the fluid displaced by the object.

2. Buoyancy is the upward force (or upthrust force) that opposes the weight of an object caused by the pressure exerted by the fluid in which the object is immersed.

Weight of object, W_o

Density of object, ρ_{object}

Weight of fluid displaced

Density of fluid, ρ_{fluid}

Buoyancy, F_b
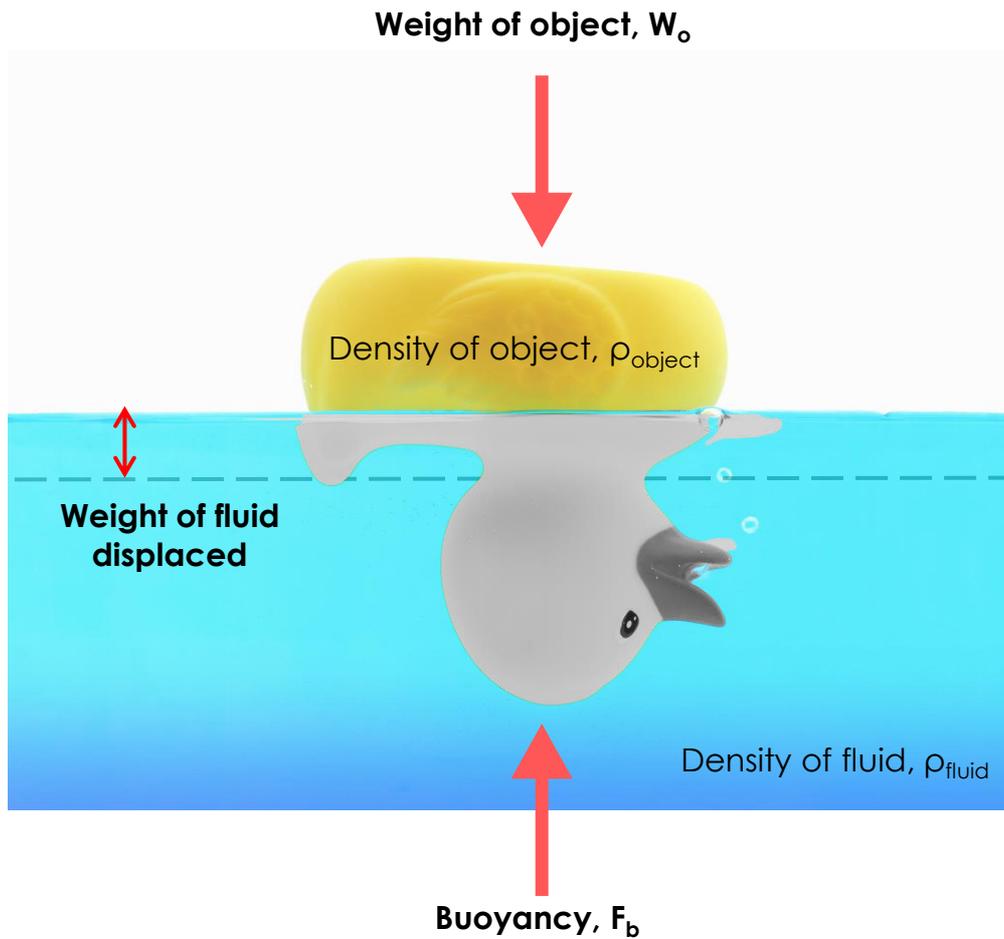
3. The statement can be expressed in mathematical equation as below

$$F_b = Weight\ of\ fluid\ displaced$$
$$= mg$$
$$= \rho V g$$

Where:

m is the mass of liquid displaced

ρ is the density of the fluid

V is the volume of fluid displaced

g is the acceleration of gravity

4. There are 2 situation of buoyancy:

   a) Floating object

Buoyant force, F$_b$

Weight of object, W$_o$
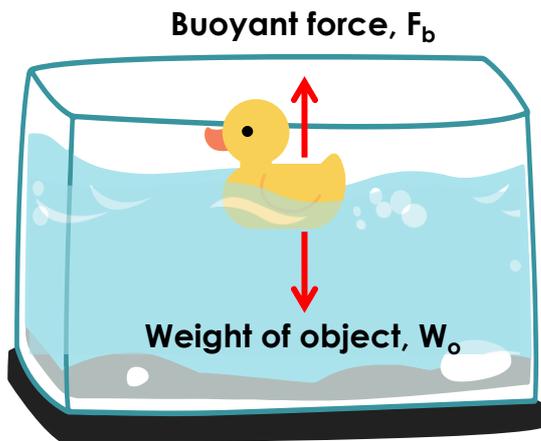
$$W_{object} < F_b$$

So, the object will float

$$V_{fluid\ displaced} = V_{immersed\ object}$$

$$F_b = \rho_{fluid} \times V_{immersed\ object} \times g$$

   b) Submerged object

Buoyant force, F$_b$
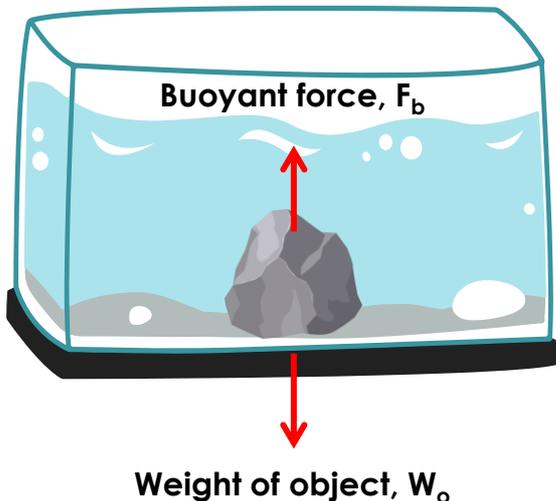
Weight of object, W$_o$

$$W_{object} > F_b$$

So, the object will sink

$$V_{fluid\ displaced} = V_{object}$$

$$F_b = \rho_{fluid} \times V_{immersed\ object} \times g$$

5. When an object is immersed in the water, the apparent loss in weight of the object is equal to the weight of fluid displaced.

Actual weight, W$_{actual}$

Apparent weight, W$_{apparent}$

$$F_b = Apparent\ loss$$
$$= W_{actual} - W_{apparent}$$

In the air

In the water

Example 1

A rubber duck is floating in a bathtub filled with water. The mass of the rubber duck is 0.05 kg, and the its volume is 293 cm³. Calculate

    a) The buoyant force acting on the rubber duck

    b) The volume displaced by the rubber duck

Solution:

a) $Buoyant\ force, F_b = W_{object} = m_{object} \times g = 0.05(9.81) = 0.4905\ N$
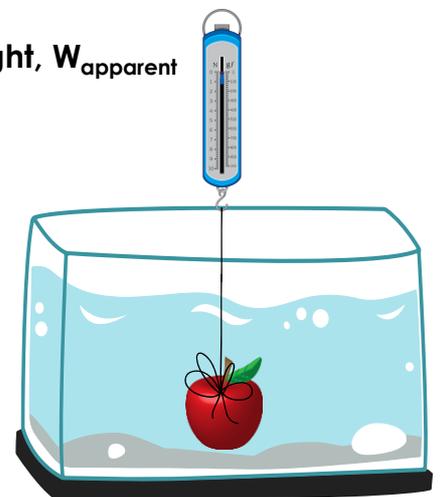
b) $V_{fluid\ displaced} = V_{immersed\ object}$

$$F_b = \rho_{fluid} \times V_{immersed\ object} \times g$$

$$V_{immersed\ object} = \frac{F_b}{\rho_{fluid} \times g} = \frac{0.4905\ N}{(1000\frac{kg}{m^3})(9.81\frac{m}{s^2})} = 5 \times 10^{-5}\ m^3$$

Example 2

A piece of 6.5 kg river rocks with density of $2.7\frac{kg}{m^3}$ is placed inside an aquarium filled with water. Calculate the volume displaced by the river rocks.

Solution:

$$V_{fluid\ displaced} = V_{immersed\ object} = V_{object}$$

$$\rho_{object} = \frac{m_{object}}{V_{object}}$$

$$V_{fluid\ displaced} = V_{object} = \frac{m_{object}}{\rho_{object}} = \frac{6.5\ kg}{2.7\frac{kg}{m^3}} = 2.407\ m^3$$

Example 3

A ship's anchor made of cast steel has a weight of 579 N. The ship is floating in the sea water of density 1029 $\frac{kg}{m^3}$. Calculate the apparent weight of the anchor when it is under the sea. ($\rho_{anchor}= 7850 \frac{kg}{m^3}$)

Solution:

$Bouyant\ force, F_b = Apparent\ loss = W_{actual} - W_{apparent}$

$F_b = \rho_{fluid} \times V_{immersed\ object} \times g = \rho_{sea\ water} \times V_{anchor} \times g$

$V_{immersed\ object} = V_{anchor}$

$\rho_{anchor} = \dfrac{m_{anchor}}{V_{anchor}}$

$m_{anchor} = \dfrac{W_{anchor}}{g} = \dfrac{579}{9.81} = 59.021\ kg$

$V_{anchor} = \dfrac{m_{anchor}}{\rho_{anchor}} = \dfrac{59.021\ kg}{7850 \frac{kg}{m^3}} = 7.519 \times 10^{-3}\ m^3$

$F_b = \rho_{sea\ water} \times V_{anchor} \times g$

$\quad = 1029 \frac{kg}{m^3} \times 7.519 \times 10^{-3}\ m^3 \times 9.81 \frac{m}{s^2}$

$\quad = 75.9\ N$

$W_{apparent} = W_{actual} - Apparent\ loss$

$\qquad\qquad = W_{actual} - F_b$

$\qquad\qquad = 579 - 75.9$

$\qquad\qquad = 503.1\ N$

Exercise 1

An object with a density of $78 \frac{kg}{m^3}$ and mass of 34 kg is fully immersed in liquid X. The

density of liquid X is $750 \frac{kg}{m^3}$. Calculate

    a) The volume of liquid displaced

    b) The buoyant force experienced by the object

Answer: $435.897 \times 10^{-3} \ m^3, \ 3207.115 \ N$

Exercise 2

An object floats in water with 3/4 of its volume immersed under the water surface. Calculate the density of the object.

Answer: $750 \frac{kg}{m^3}$

Exercise 3

An object with weight 25 N is fully immersed in a container full of water. The

apparent weight of the object is 21 N. If the density of the water is $1000 \frac{kg}{m^3}$,

calculate

    a) The buoyant force of the object

    b) The volume of the object

Answer: $4 \ N, 0.408 \times 10^{-3} \ m^3$

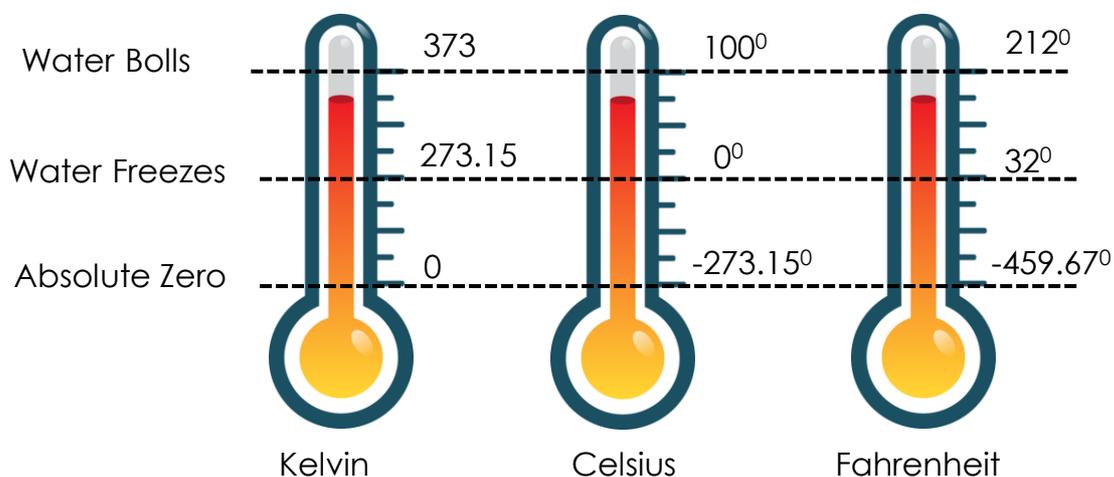# Temperature & Heat

Siti Morni binti Ab Rahman

1. Temperature is the measured degree of hotness or coldness of a body/object.

2. Definition of temperature in physic or chemistry is a measure of the average kinetic energy of the particles in an object.

3. Symbol of temperature is T or θ.

4. Unit SI for temperature is K, Kelvin.

5. Other units of temperature are °C, Celsius and °F, Fahrenheit.

6. Relation temperature in units between Kelvin, Celsius, and Fahrenheit:

	Kelvin	Celsius	Fahrenheit
Water Bolls	373	100^0	212^0
Water Freezes	273.15	0^0	32^0
Absolute Zero	0	-273.15^0	-459.67^0

7. Absolute zero is temperature at which a thermodynamic system the lowest energy.

8. Formula of conversion of unit:

From	To Celsius, °C	From	To Fahrenheit, °F
Fahrenheit, °F	$\frac{5}{9}(°F - 32)$	Celsius, °C	$\left(°C \times \frac{9}{5}\right) + 32$

From	To Kelvin, K	From	To Celsius, °C
Celsius, °C	°C + 237.15	Kelvin, K	K − 237.15

Example 1

Convert 0 °C to Kelvin.

Solution:

Formula convert from °C to Kelvin:

K= °C + 273.15

  = 0 + 273.15

  = 273.15 K

Example 2

Convert 30 °C to Kelvin.

Solution:

Formula convert from °C to Kelvin:

K= °C + 273.15

  = 30 + 273.15

  = 303.15 K

Example 3

Convert 337 K to degree Celsius, °C.

Solution:

Formula convert from Kelvin to °C

°C = K - 273.15

   = 337 - 273.15

   = 63.85 °C

Example 4

Convert 100 °C to Fahrenheit, °F.

Solution:

Formula convert from °C to °F :

$°F= \left(°C \times \frac{9}{5}\right)+32$

  = (100 x 1.8) + 32

  = 212 °F

Example 5

Convert 89 °F to Celsius, °C .

Solution:

Formula convert from °F to °C :

$°C = \frac{5}{9}(°F - 32)$

    = 0.555(89 − 32)

    = 31.635 °C

Example 6

Convert -5 °C to Fahrenheit, °F.

Solution:

Formula convert from °C to °F :

$°F= \left(°C \times \frac{9}{5}\right)+32$

  = (-5 x 1.8) + 32

  = 23 °F

Example 7

Convert 78 °F to Kelvin.

Solution:

Step 1: convert °F to °C

$°C = \frac{5}{9}(°F - 32)$

$= 0.555(78 - 32)$

$= 25.53 °C$

Step 2: convert °C to K

$K = °C + 273.15$

$= 25.53 + 273.15$

$= 298.68 K$

Example 8

Convert 450 K to Fahrenheit, °F.

Solution:

Step 1: convert K to °C

$°C = 450 - 273.15$

$= 176.85 °C$

Step 2: convert °C to °F

$°F = \left(°C \times \frac{9}{5}\right) + 32$

$= (176.85 \times 1.8) + 32$

$= 350.33 °F$

Exercise 1

Convert 20 °C to Fahrenheit, °F .

Exercise 2

Convert -10 °C to Fahrenheit, °F .

Exercise 3

Convert 120 °F to Celsius, °C .

Exercise 4

Convert 75 °F to Celsius, °C .

Exercise 5

Convert 55 °C to Kelvin, K.

Exercise 6

Convert -20 °C to Kelvin, K.

Exercise 7

Convert 250 K to Celsius, °C .

Exercise 8

Convert 415 K to Celsius, °C .

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Exercise 9

Convert 100 °F to Kelvin, K.

Exercise 10

Convert 30 °F to Kelvin, K.

Exercise 11

Convert 275 K to Fahrenheit, °F.

Exercise 12

Convert 300 K to Fahrenheit, °F.

Heat

1. Heat is a form of energy.
2. Definition of heat is energy that is transferred from one body to another when the bodies have a difference temperature.
3. Energy is transferred (heat flows) from a hotter body to the colder.
4. Symbol of heat, Q.
5. Unit SI of heat is Joule, J. Other unit of heat is Calorie (cal).
6. Conversion unit: 1 cal = 4.184 J

Transfer of Heat

1. Heat transfer occurs when there is a temperature difference between materials (solid/liquid/gas).
2. 3 processes of heat transfer:
   - Conduction process
   - Convection process
   - Radiation process

Surroundings: cooler

Coffee

Heat flows
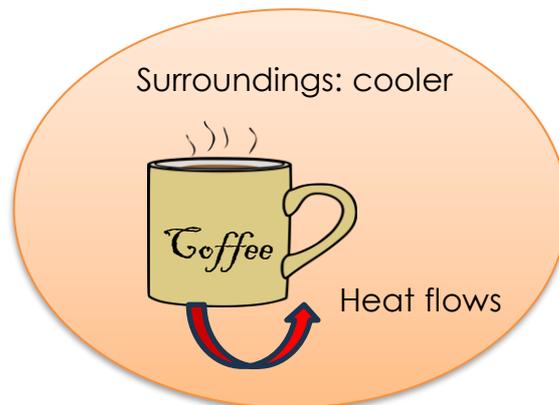
Conduction Process

1. Conduction is the transfer of heat through matter without bulk motion of matter.
2. The transfer of heat process occurs through direct contact between materials.
3. Heat conduction through this process depends on the physical properties of material.
4. Metals typically have high thermal conductivity, while insulating materials like wood or plastic have low thermal conductivity.
5. Heat movement from hot to cold.
6. Conduction is the dominant heat transfer process in solids

7. Examples:

- The heat transfer into the hand when holding a hot pot.

- A cold spoon will slowly warm up when placed in hot tea.

- Ironing of clothes where the heat is conducted from the iron to the clothes.

Convection Process

1. Convection is the transfer heat through the movement of fluid (liquid/gas) molecules from higher temperature regions to lower temperature regions.

2. Examples:

- The boiling of water, that is cold molecules are denser and move at the bottom while the hot molecules which are less dense move upwards and resulting in the circular motion of the molecules so that water gets heated.

- Turning on the air conditioner in the room.

Hot particles

Cold particles
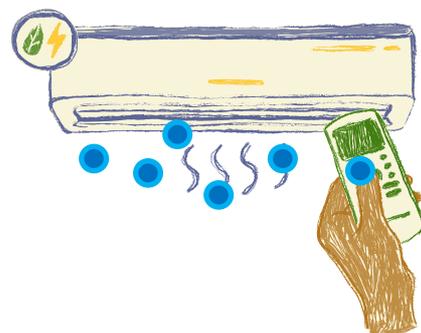
Radiation Process

1. Every object has thermal energy, also known as thermal radiation.

2. Thermal radiation is the result of the random motion of molecules in an object.

3. This thermal radiation is transferred through electromagnetic waves.

4. Heat transfer can occur through a vacuum or a transparent medium, which can be solid or liquid.

5. Heat transfer through radiation can be measured with a device known as a thermocouple.

QUIZ

SCAN ME   OR   CLICK HERE

Heat Capacity

1. Heat capacity is another term for thermal capacity.

2. It is defined as the amount of heat energy required to raise the temperature of a material by **1 ℃ (or 1 K)**

3. The symbol of Heat Capacity is c and the unit is **J**/℃.

4. Formula

$$C = \frac{Q}{\Delta T}$$

Where:

c is the Heat Capacity (J/°C)

Q is the Heat Energy (Joule)

ΔT is the change in temperature

$$\Delta T = T_{final} - T_{Initial}$$

Example 1

Calculate the heat capacity of a material when its temperature increases by 5 ℃ with heat energy of 835 J.

Solution:

Given:

- Q = 835 J
- ΔT= 5 °C

$$C = \frac{Q}{\Delta T} = \frac{835\,J}{5\,℃} = 167.0\,\frac{J}{℃}$$

This means that 167.0 J of heat energy are required to raise the temperature of the material by 1 °C.

Example 2

Material B has a heat capacity of 150 J/°C. Calculate the change in temperature if the amount of heat energy it has is 3500 J.

Solution:

Given:

- Q = 3500 J
- c= 150 J/°C

$$C = \frac{Q}{\Delta T}$$

$$150 \, \frac{J}{°C} = \frac{3500 \, J}{\Delta T}$$

$$\Delta T = \frac{3500 \, J}{150 \, \frac{J}{°C}} = 23.33 \, °C$$

The temperature change that occurs is 23.33 °C.

Example 3

Calculate the amount of energy needed to raise temperature 15 °C of substance if the heat capacity is 400 J/°C.

Solution:

Given:

- c = 400 J /°C
- ΔT= 15 °C

$$Q = c\Delta T$$

$$= 400 \, \frac{J}{°C} (15 \, °C)$$

$$= 6000 \, J$$

The temperature change that occurs is 23.33 °C.

Specific Heat Capacity

1. The specific heat capacity is the amount of heat required to raise a temperature of one unit mass (I kg) of the material by 1°C (or 1K).

2. The symbol of Specific Heat Capacity is c and the unit is $J/(kg°C)$.

3. Formula

$$C = \frac{Q}{m\Delta T}$$

Where:

c is the Heat Capacity (J/°C)

Q is the Heat Energy (Joule)

m is the mass (kg)

ΔT is the change in temperature

$$\Delta T = T_{final} - T_{Initial}$$

4. Table below show some examples of Specific Heat Capacity of different elements or materials:

Material	Specific Heat Capacity ($Jkg^{-1}°C^{-1}$)	Material	Specific Heat Capacity ($Jkg^{-1}°C^{-1}$)
Lead	129	Ice, snow (-5°C)	2090
Gold	129	Water, pure liquid (20°C)	$4182 \approx 4200$
Copper	385	Carbon Dioxide	839
Iron	449	Oxygen	918
Aluminum	897	Hydrogen	14304

QUIZ

SCAN ME

OR   CLICK HERE

5. Differences between Heat Capacity and Specific Heat Capacity

Heat Capacity	Specific Heat Capacity
The heat capacity of the substance is defined as the amount of heat required to raise the temperature of the substance by 1°C (or 1K).	Specific Heat Capacity is defined as the amount of heat required to raise the temperature of one unit mass of a substance by 1°C (or 1K).
Heat Capacity depends on the mass of a substance	Specific Heat Capacity does not depend on the mass of substances.
The units of heat capacity is $J°C^{-1}$ or J/K.	The units of specific heat capacity is $Jkg^{-1}°C^{-1}$ or $Jkg^{-1}K^{-1}$
The formula of Heat Capacity: $$C = \frac{Q}{\Delta T}$$ Where : 'Q' is the amount of heat. 'ΔT' specifically refers to the temperature.	The formula of Specific Heat Capacity: $$C = \frac{Q}{m\Delta T}$$ Where: 'Q' is the amount of heat. 'ΔT' specifically refers to the temperature. 'm' stands for mass.

6. Key Differences

    • **Heat Capacity** is an extensive property (depends on the amount of substance), while **Specific Heat Capacity** is an intensive property (independent of the amount of substance).

    • **Heat Capacity** measures the total heat needed for an object, where **Specific Heat Capacity** measures heat needed per unit mass of a substance.

Example 1

A 200 g metal block is heated from 15 °C to 50 °C. If energy needed to heat the block is 6300 J, calculate the specific heat capacity of the block in SI unit.

Solution:

Given:

- m=200 g = 0.2 kg
- Q = 6300 J
- T_{final} = 50 °C
- $T_{initial}$ =15 °C
- ΔT= 50 °C -15 °C = 35 °C

$$C = \frac{Q}{m\Delta T}$$

$$C = \frac{6300}{(0.2)(35)} = 900\,\frac{J}{kg°C}$$

The specific heat capacity of the block is 900 $\frac{J}{kg°C}$.

Example 2

A X kg ball of lead is heated 65 °C with 3000 Joules of energy. The specific heat capacity of lead is 129 $Jkg^{-1}°C^{-1}$, find value of X.

Solution:

Given:

- Q = 3000 J
- ΔT= 65 °C
- c= 129 J/kg°C

$$C = \frac{Q}{m\Delta T}$$

$$129 = \frac{3000}{m(65)}$$

$$m = \frac{3000}{(129)(65)} = 0.357\,kg$$

The value of X is 0.357 kg

Example 3

A 1 kg gold bar is cooled from 60 °C to 25 °C. Calculate the energy released to cool the gold bar. The specific heat of gold is 129 Jkg⁻¹°C⁻¹,

Solution:

Given:

- m=1 kg
- c =129 $Jkg^{-1}°C^{-1}$
- T_{final} = 25 °C
- $T_{initial}$ =60 °C
- ΔT= 25 °C - 60 °C = -35 °C

$Q = mc\Delta T$

$= (1)(129)(-35)$

$= -4515\ J$

The energy released to cool the gold bar is 4515 J.

Example 4

A hot 650 g cube of copper is allowed to cool to 70 °C. If the copper released 2.5 kJ of energy, find the the initial temperature of the copper. The specific heat of copper is 385 J/kg°C.

Solution:

Given:

- Q = -2500 J
- T_{final} = 70 °C
- c= 385 J/kg°C
- m= 650 g =0.65 kg
- ΔT= 70 - $T_{initial}$

$Q = mc\Delta T$

$-2500 = (0.65)(385)\ (70 - T_{initial})$

$-2500 = 17517.5 - 250.25\ T_{initial})$

$T_{initial} = \dfrac{-2500 - 17517.5}{-250.25}$

$= 79.99\ °C$

The initial temperature of copper is 79.99 °C

Exercise 1

A 200 g piece of copper is heated to a temperature change of 20 °C. If 1540 J of energy is absorbed, calculate the specific heat capacity of copper.

Answer:385 J/kg ℃

Exercise 2

Calculate the amount of energy required to raise temperature of a 50 g aluminium block by 5 °C. The specific heat capacity of aluminium is 897 J/kg°C.

Answer:224.25 J

Exercise 3

Calculate the heat energy released when 1.5 kg of hot water is cooled. Assume the initial temperature of the water is 120 °C and the final temperature of the water is 70 °C.

Answer:-315000 J

Exercise 4

A piece of gold is melted to form a bracelet. If 6775 J of energy is absorbed for a temperature change of 1040 °C, calculate the mass of the gold in grams. The specific heat capacity of gold is 129 J/kg°C.

Answer: 50.5 g

Exercise 5

20 g iron spoon with an initial temperature of 26 °C is placed into hot water. If the energy absorbed by the spoon is 245 J, calculate the final temperature of the spoon. Specific heat capacity if iron is 450 J/kg°C.

Answer: 53.22 ℃

Exercise 6

A 0.5 kg hot steel plate is allowed to cool until it reaches a temperature of 60 °C and releases heat amounting to 3000 J. If the specific heat capacity of steel is 420 J/kg°C, calculate the initial temperature of the plate.

Answer: 74.29 ℃

1. Also known as Latent Energy or Heat of Transformation.

2. Latent Heat is energy absorbed or released by a body to change their state (solid to liquid or liquid to gas) without changing its temperature.

3. Two types of Latent Heat

4. Latent Heat of Fusion- is energy absorbed or released by a body to change solid to liquid without changing its temperature.

5. Latent Heat of Vaporization- is energy absorbed or released by a body to change liquid to gas without changing its temperature.

6. The symbol of Latent Heat is L and the unit is J/kg.

7. Formula of Latent Heat

$$L = \frac{Q}{m}$$

Where:
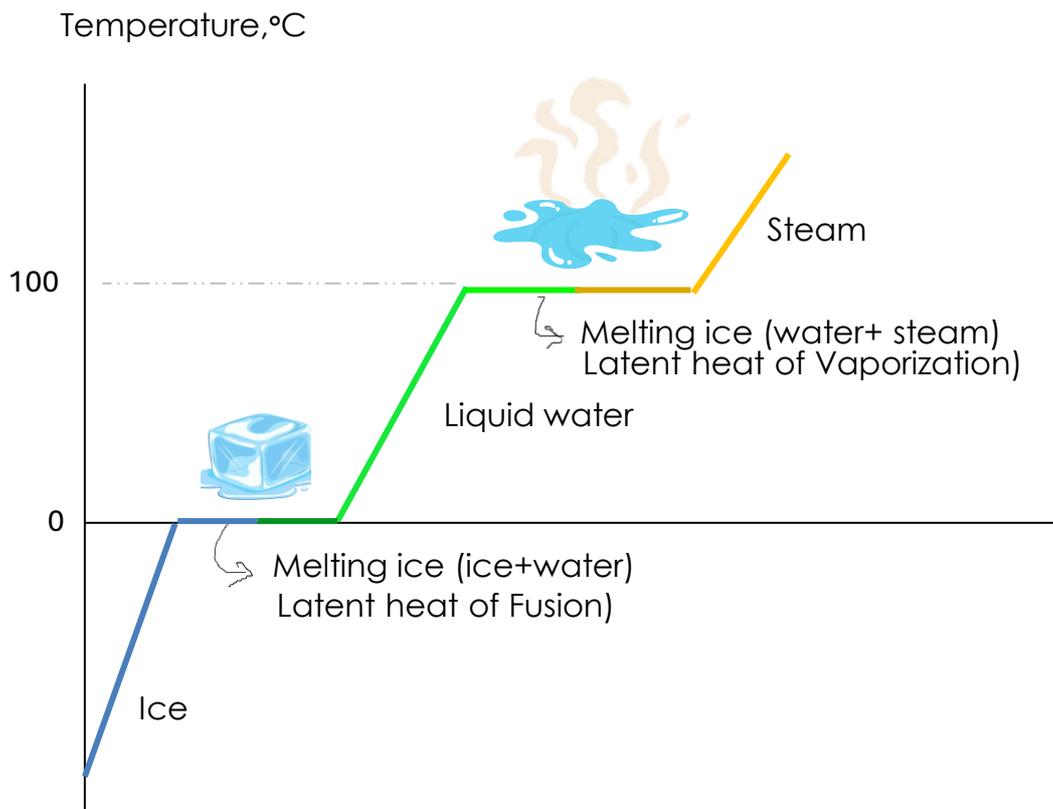L is the Latent Heat(J/kg)
Q is the Heat Energy (Joule)
m is the mass (kg)

8. Table below show some examples of Latent Heat of different elements or materials:

Material	Latent Heat of Fusion (J/kg)	Latent Heat of Vaporization (J/kg)
Aluminum	321×10^3	1140×10^4
Copper	207×10^3	506.9×10^4
Gold	67×10^3	157.8×10^4
Water	334×10^3	225.7×10^4
Carbon dioxide	184×10^3	574×10^3
Ammonia	339×10^3	136.9×10^4

9. Example of latent heat graph of water

Temperature,°C

A 50 g block aluminum at its melting point 660 °C is completely melted into liquid aluminium. Calculate the amount of heat energy required for this process. Assume the latent heat for aluminium is 397 $\frac{kJ}{kg}$

Example I

Solution:

Given:

- M = 50 g= 0.05 kg
- L = 397 kJkg^{-1} = 397 x 10^3 Jkg^{-1}
- T = 660 °C

Q = mL

= (0.05)(397 x 10^3)

= 19850 J

The amount of heat required to melt the 50 g block of aluminum at 660 °C is 19850 J.

Example 2

A 150 g block of ice at -5 °C is heated until it completely turns into liquid at 0 °C . Calculate the total amount of heat energy required for the process. Assume the specific heat capacity of ice is 2.1 kJ/kg°C and latent heat of fusion for ice is 334 x 10^3 Jkg^{-1}.

Solution:

Given:

- m =150 g= 0.15 kg
- L =334 x 10^3 Jkg^{-1}
- c= 2.1 kJ/kg°C
- ΔT= 0°C −(-5) °C
   = 5 °C

$Q = Q1 + Q2$

$= mc \, \Delta T + mL$

$= (0.15)(2.1 \times 10^3)(5) + (0.15)(334 \times 10^3)$

$=1575 + 50100$

$= 51675$ J

The total amount of heat required to melt the 150 g block of ice from -5 °C to 0 °C is 51675 J.
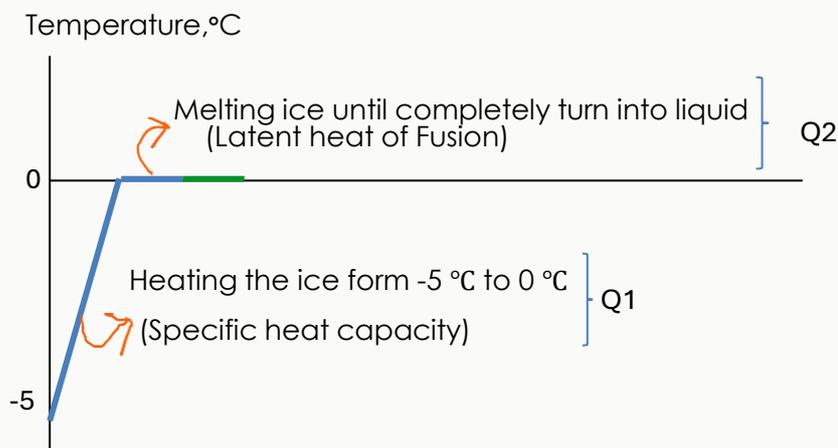
Example 3

A 200 g block of ice at -3 °C is heated until it reaches temperature at 20 °C . Calculate the total amount of heat energy required for the ice to change and reach that temperature. Assume the specific heat capacity of ice is 2.1 kJ/kg°C, specific heat capacity of water is 4.18 kJ/kg°C and latent heat of fusion for ice is 334×10^3 Jkg^{-1}

Solution:

Given:

- m=200 g= 0.2 kg
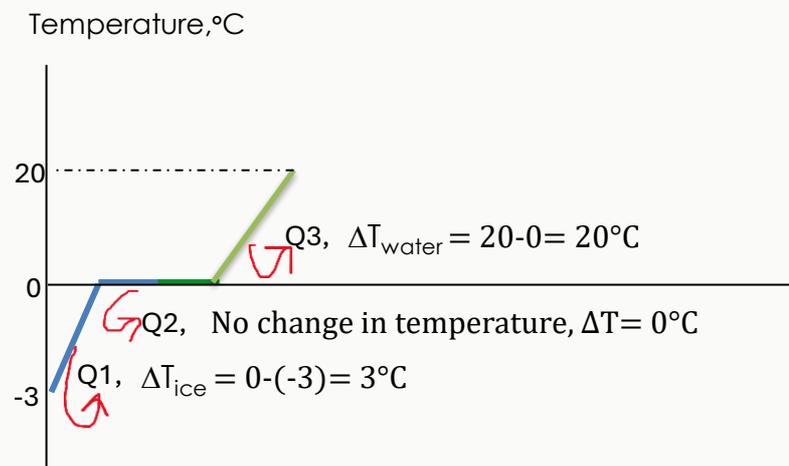- L = 334×10^3 Jkg^{-1}
- c_{ice}= 2.1 kJ/kg°C
- c_{water}= 4.18 kJ/kg°C
- T= 0 °C
- ΔT_{ice} = 0-(-3)= 3°C
- ΔT_{water}= 20-0= 20°C

$Q = Q1 + Q2 + Q3$
$\quad = mc\,\Delta T + mL + mc\,\Delta T$
$\quad =(0.2)(2.1 \times 10^3)(3) + (0.2)(334 \times 10^3) + (0.2)(4.18 \times 10^3)(20)$

$\quad =1260 + 66800 + 16720$

$\quad =84780J$

Temperature,°C

Q3, $\Delta T_{water} = 20-0 = 20°C$

Q2, No change in temperature, $\Delta T = 0°C$

Q1, $\Delta T_{ice} = 0-(-3) = 3°C$

The amount of heat required is 84780J.

Exercise 1

Calculate the energy required to completely melt 0.3 kg of block silver at its melting point. (Latent heat of silver = 88 kJkg⁻¹)

Answer: 26400 J

Exercise 2

Calculate the heat energy released to convert 3 kg of water at 0 °C. (Latent heat of fusion of ice = 334 kJkg⁻¹).

Answer: 1.002×10^6 J

Exercise 3

Calculate the heat energy released to convert 2 kg of water at 0 °C into an ice cube at -10 °C. (specific heat capacity of water = 4.2 kJ kg⁻¹ °C⁻¹; latent heat of fusion of ice = 334 kJkg⁻¹, specific heat capacity of ice = 2.1 kJ/(kg°C)

Answer: 710 kJ

The melting point of PVC is 120 °C. If 1.5 kg of PVC is completely melted, calculate the energy required for this process when the initial temperature of the PVC is 30 °C. Assume the specific heat capacity of PVC is 0.9 kJ/kg°C and latent heat of PVC is 150 kJ/kg.

Answer: 346500 J

Calculate the total of heat must be removed by a refrigerator from 2.5 kg of water at 70 °C to convert it to ice cubes at -15°C. Assume the specific heat capacity of water = 4200 Jkg^{-1} °C^{-1}; specific latent heat of fusion of ice = 334,000 Jkg^{-1}, specific heat capacity of ice = 2100 Jkg^{-1} °C^{-1}.

Answer: 1648570 J

Thermal Equilibrium

Hot metal, T_1 + Cool water, T_2 → Temperature metal and water are same, T

$T_1 < T > T_2$
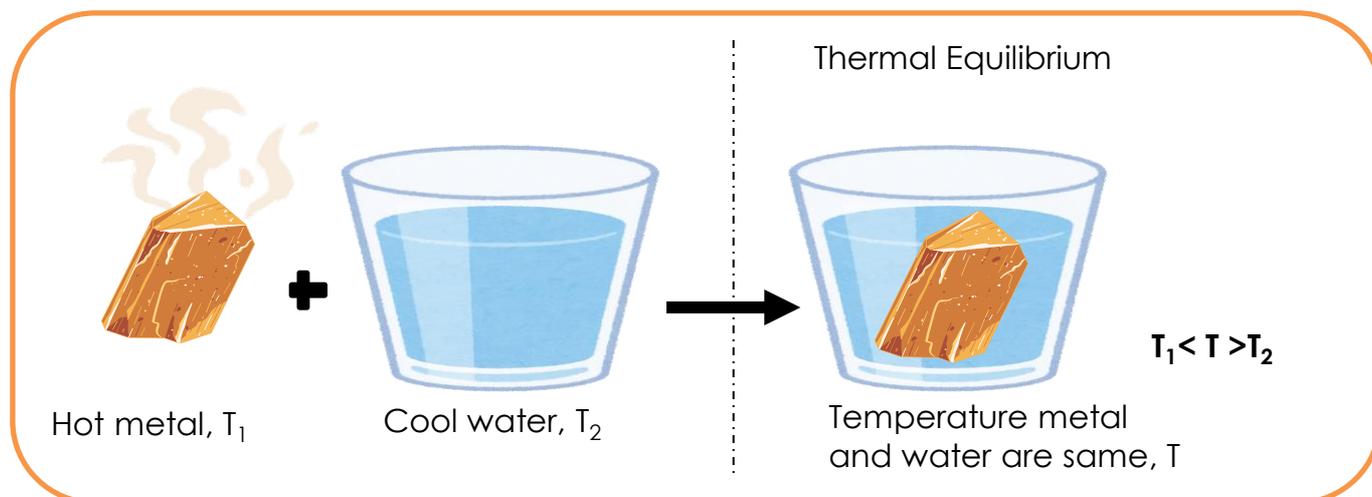
1. Thermal equilibrium is a condition when two or more substances (have different temperature), when placed in thermal contact each other, the heat from the hot substance will transfer to the colder substance. This heat transfer process will stop when both substance reach the same temperature.

2. Key points about thermal equilibrium:
   - No net heat flow- the amount of heat energy transferred between the substances is equal in both directions.
   - Equal temperature- for two or more substances to be in thermal equilibrium, it must be at the same temperature.

3. The equation involved in thermal equilibrium is

4. Qloss refer to substance that loss heat. That means value of heat is negative, -Q

$$Q_{loss} = Q_{gained}$$

$$m_1 c_1 \Delta T_1 = m_2 c_2 \Delta T_2$$

or

$$Q_{loss} + Q_{gained} = 0$$

$$m_1 c_1 \Delta T_1 + m_2 c_2 \Delta T_2 = 0$$

Example 1

A hot piece of copper is placed in 500 g of water at 27 °C. Calculate the heat loss in the copper when the equilibrium temperature is 30 °C. Assuming no heat is lost to the surrounding. Specific Heat Capacity water is 4200 J/kg°C.

Solution:

Item	Water, Q$_{gained}$
m	500 g = 0.5 kg
c	4200 J/kg°C
ΔT	30-27= 3 °C

$$Q_{gained} = m_2 c_2 \Delta T_2 = 0.5 \times 4200 \times 3 = 6300\,J$$

Since no heat is lost to the surrounding, the heat lost by the copper is equal to the heat gained by the water.

$$Q_{loss} = Q_{gained}$$

The heat lost by the copper is 6300J.

Example 2

A 0.2 kg piece of aluminum at 160 ℃ is placed in water at 25 °C. Calculate the mass of water when the final temperature of the mixture is 40 °C. Assuming no heat is lost to the surrounding.

Specific Heat Capacity: Aluminium= $897 \dfrac{J}{kg\ ℃}$ and water= 4200 J/kg℃

Solution:

Item	Aluminium Q$_{loss}$	Water Q$_{gained}$
m	0.2 kg	m
c	897 J/kg°C	4200 J/kg°C
ΔT	40-160=-120 °C	40-25= 15 °C

$$Q_{loss} = Q_{gained}$$

$$-m_1 c_1 \Delta T_1 = m_2 c_2 \Delta T_2$$

$$-(0.2 \times 897 \times -120) = (m \times 4200 \times 15)$$

$$21528 = 63000\,m$$

$$m = 0.3417\,kg$$

The mass of water is approximately 0.3417 kg

Example 3

A 0.01kg of hot water at 90 °C is placed in 0.01kg of cool water at 25 °C. Calculate the final temperature of the mixture water. Assuming no heat is lost to the surrounding. Specific Heat Capacity of water= 4200 J/kg°C.

Solution:

Item	Hot Water, Q_{loss}	Cool Water, Q_{gained}
m	0.01 kg	0.01kg
c	4200 J/kg°C	4200 J/kg°C
ΔT	T-90	T-25

$$Q_{loss} + Q_{gained} = 0$$

$$m_1 c_1 \Delta T_1 + m_2 c_2 \Delta T_2 = 0$$

$$\big(0.01 \times 4200 \times (T-90)\big) + \big(0.01 \times 4200 \times (T-25)\big) = 0$$

$$42T - 3780 + 42T - 1050 = 0$$

$$84\,T = 4830$$

$$T = 57.5\ °C$$

The final temperature of the mixture is 57.5 °C

Exercise 1

A 0.05 kg metal bolt is heated to an unknown initial temperature. After that it was dropped into a beaker containing 0.15 kg of water with initial temperature of 21 °C. The metal bolt then reaches a final temperature of 25 °C, calculate the value of initial temperature of the metal bolt.

(Specific heat capacity of metal bolt is 889 J kg^{-1} °C^{-1}, Specific heat capacity of water is 4200 J kg^{-1} °C^{-1}).   **Final Exam 1-2023/2024**

Answer: 81.69 ℃

Exercise 2

A 65 kg mass of water at a temperature of 60 °C is poured into a vessel containing 105 kg of water with temperature of 27 °C. Calculated the final temperature after the system comes to thermal equilibrium.

(Given: Specific heat capacity of water is 4200 J/kg °C). **Final Exam 2-2023/2024**

Answer: 39.617 ℃

A spoon at a temperature of 25 °C is placed into a cup of hot coffee at temperature of 60 °C. Calculate the mass of the spoon if the mass of the coffee is 200 g and the equilibrium temperature is 57 °C. Give answer in kilogram and gram. (specific heat capacity of the spoon is 900 J kg⁻¹ °C⁻¹, specific heat capacity of coffee is 4200 J kg⁻¹ °C⁻¹). Assume that no heat lost to the surrounding.

Answer: $0.087\ kg, 87\ g$

300 g of hot water is poured into a ceramic cup of mass of 0.6 kg at 20 °C, and allowed to reach an equilibrium temperature of 60 °C. Calculate the initial temperature of the hot water. The specific heat capacity of ceramic is 900 J/kg°C and that of water is 4200 J/kg°C. Assume that no heat lost to the surrounding.

Answer: $77.14\ ℃$

1 kg of sand at a temperature of 50 °C is placed into a hot pot. The mass of the pot is 1kg and its temperature is 150 °C. Calculate the specific heat capacity of the sand if the combination reaches a final temperature of 80°C. The specific heat capacity of the pot is 449 J/kg°C. Assume no heat loss to the surroundings.

Answer: $1047.667 \frac{J}{kg\,°C}$

A hot water at a temperature of 91 °C is poured into a styrofoam cup containing 154 g of water with temperature of 27 °C. Calculated the mass of hot water when the final temperature of the mixture reaches thermal equilibrium at 54 °C.
(Given: Specific heat capacity of water is 4200 J/kg °C). Answer in unit kilogram.

Answer: $0.112\ kg$

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