Physics EOY Notes

Semester 2 Material

Ryan Sam Class 3P

Content Page

Dynamics I:

Types of Forces:

- Weight: The gravitational force exerted by the Earth on an object
- Friction: When two surfaces are in contact, they exert forces on each other. The component parallel to the surfaces is the friction. It acts in a direction so as to resist relative motion between the surfaces
    - Friction is the force that opposes the relative motion, or the tendency toward such motion of two surfaces in contact
    - When surfaces are in contact, the molecules of the surfaces will attract each other
    - If not, the unevenness of the surfaces causes the molecules to interlock
    - Friction as a useful force: walking, holding an object, braking
    - Friction as a nuisance: loss in useful energy, wear and tear, generation of heat
    - How to reduce friction: ball bearings, lubricants, air layer
        - Ball bearings: rolling friction requires less force to overcome
        - Lubricants: prevents direct contact between 2 surfaces
    - The amount of frictional force depends on:
        1. The material in contact (glass vs wood)
        2. Nature of the surfaces in contact (rough vs smooth)
        3. Proportional to the force pressing the surfaces together (weight)
        4. Independent of the area of contact
    - Static Friction: occurs when two objects are not moving relative to each other
        - For motion, the force must be greater than the static frictional force, which has a limiting value
    - Kinetic/Dynamic Friction: occurs when two objects are moving relative to each other and rub together
- Normal Reaction: This is the perpendicular component of the contact force. It acts outward from the surfaces
- Air resistance: The resistive force exerted by air on object moving through it. Air resistance increases as speed increases, and is zero when the object is at rest
- Tension: The pulling force acting in a string or rod
- Upthrust (buoyant force): The upward force exerted by a fluid on an object immersed in it
- Magnetic Force: The forces exerted by magnets on magnetic materials such as iron and nickel (originated from moving charges)
- Electric Force: The forces exerted by electric charges on each other

Newton's Three Laws of Motion:

Newton's First Law (Also known as the Law of Inertia)

- Definition: An object at rest will remain at rest and an object in motion will continue in motion at constant velocity in the absence of a resultant force acting on it
    - No resultant force does not mean that there are no forces acting on the body
    - It only means that all the forces are equally balanced, resulting in no movement
- It implies that every body has a property called inertia: a measure of its resistance to a change in its state of motion (it is proportional to an object's mass)
- Quantitative measure of inertia: mass

Newton's Second Law

- The rate of change of momentum of a body is directly proportional to the resultant force acting on it and the direction of the change is in the direction of the resultant force.
- In equation form:
    - Resultant Force = Change in momentum over time = (mass x velocity)/time
    - (Mass x velocity) / time = mass x (velocity/time) = mass x acceleration
    - Hence $F_{resultant}$ = ma (mass x acceleration)

- Momentum: product of its mass and its velocity (how much force is required to stop the object from moving)
- Rate of change: how fast a quantity (momentum in this case) changes over time
- Direction of change: momentum is a vector quantity, so the change in momentum must be a vector and have a direction (therefore, the direction of the change is in the direction of the resultant force experienced by the object)

Newton's Third Law

- For every action there is an equal and opposite reaction

Mass and Weight:

- Mass is a scalar measure of the amount of substance in the object (based on the Second Law and the Law of Inertia: which is the reluctance of the object to change its state of motion)
  - The mass of an object remains constant regardless of its location
  - Measured using a balance scale: any change in gravitational field will affect both the unknown mass and the standard mass on both the pans equally, so when balance Is achieved, the unknown and standard masses will be equal
- Weight is a vector and is represented by the formula (W=mg)
  - The Earth sets up a gravitational field and the weight of an object depends on the force of gravity exerted on the object
  - A 10 kg mass will have a weight of 98.1N on Earth but 16N on the Moon
  - The gravitational field strength is identical to the acceleration of free-fall (in a vacuum) since both values are 9.81
  - Measured with a spring, where the extension of the spring will be proportional to the gravitational pull on the object

Gravitational Fields:

- A region in which a mass experiences a force due to gravitational attraction
- The closer the field lines are packed together, the greater the strength of the gravitational field
- Force field: it can exert a force from a distance without touching

SI Units:

- Mass: kg
- Newton (N): kg m s^{-2}

Dynamics II:

Moments:

- The turning effect of a force is called its moment
- It is mathematically equal to the product of the force, and the perpendicular distance from the point to the line of action of the force.
- F x d
- SI Unit: Nm (kg $m^2 s^{-2}$)
- The magnitude of the moment of a force depends on:
    - The magnitude of the force
    - The perpendicular distance between the reference point and the force
- Even though Joules also has the SI base unit of Nm, moment is a very different physical quantity from work or energy (moment is a vector quantity while work and energy are scalar quantities)

Principle of Moment:

- For a body in equilibrium, the algebraic sum of the moments of all the external forces acting on the body about any axis is equal to zero
    - Explanation: algebraic sum refers to summing with the signs of the quantities taken into account. Moments are usually divided into those that cause the object to turn clockwise, and those that cause the object to turn anticlockwise. If we assign a positive sign to clockwise, and negative sign to anticlockwise, the sum of the moments must be 0

Centre of Gravity: The centre of gravity is the point at which the weight of the entire object appears to act

- For any uniform or regular object, the CG is at its centre

Equilibrium:

- Ability to maintain its original position

An object is in equilibrium if it is in

a) Translational equilibrium (resultant force acting on it is zero)
b) Rotational equilibrium (resultant moment acting on it is zero)

Equilibrium of Objects

A. Stable Equilibrium: if tilted by a very small angle from its original position and released, it returns to its original position
    - The moment of the weight of the body about the point of contact will cause the body to return back to its original position when tilted slightly
    - The CG is raised when tilted
    - Vertical line through its CG still falls within its base
B. Neutral Equilibrium: If tilted by any angle from its original position and released, it stays at its new position
    - Neutral equilibrium is only exhibited by round objects such as spheres and cylinders
    - No moment is resulted from the displacement
    - The CG remains at the same height when displaced
C. Unstable Equilibrium: When tilted at a very small angle form its original position and released, it topples to a new position
    - Usually with a small base area to increase instability
    - The CG is lowered when tilted
    - The vertical line through its CG falls out of its base
    - The moment of the weight of the body about the point of contact turns away from stable position when tilted

Exam Questions:

- If the centre of gravity is within the area of its base upon tilting (while drawing a vertical line downwards from the CG to the base), it will remain to the same position (assuming that the object is of the same density)
- If an object is balanced, the centre of gravity should be directly below the pivot (or it should be a straight line towards the ground compared to the pivot)
- The joint CG of two objects will be on the line connecting the two CGs of the individual objects
- The weight is not necessarily divided equally around an object, thus the CG may be more difficult to find

Work, Energy and Power:

Work Done:
- Work is said to be done when an object moves in the direction of the force applied
- Work done by a constant force = force x distance object moved in the direction of the force
- Work is said to be done when a force produces motion (d)
- Work done = F x d = Fscosθ (where s refers to the displacement)
- SI unit of work is the joule (kgm^2s^{-2})

Energy:
- Defined as the capacity to do work

Kinetic Energy: $\frac{1}{2}mv^2$
- The energy a body possess due to its motion

Potential Energy: mgh (GPE on Earth)
- Potential energy is the energy stored in an object due to its position, shape or state, which gives it the stored ability to do work
- GPE: energy a body possesses because of its position relative to a reference plane
- Thermal Energy: represents the total kinetic energy of the particles in the body

Types of Energy

Forms of Energy	Examples
Chemical Energy (a form of potential energy related to the structural arrangement of atoms or molecules)	• Fuels such as oil, wood, coal • Electrical cells, food and explosives
Nuclear Energy (Energy released from atomic nucleus)	• Radioactive Decay • Nuclear Reactions (fusion, fission) • Nuclear weapons • Nuclear reactors
Radiant Energy (Energy of EM waves)	• Radiometry: measurement of electromagnetic radiation (visible light, radio waves, X rays) • Solar Energy • Heating and lighting
Electrical Energy (Energy provided by electricity)	• The energy associated with current in circuits and electrical appliances • Power stations
Internal (thermal energy): Sum of kinetic and potential energy of molecules	• Thermal energy of a system, such as a gas in a container, a solution in a test tube

Principle of Conservation of Energy:
- Energy can neither be created nor destroyed. It can be transformed or transferred but the total amount in any isolated system must remain constant.
- This means that the sum of the initial kinetic and potential energies of a system must be equal to the sum of the final kinetic and potential energies of the same system, without any external effects

Power:
- Defined as the rate of doing work/converting energy
- Power=work done/time taken = W/t

- From W=Fs where F is in the same direction as s, P=Fs/t and as a result, P=Fv
- SI unit of power is the watt (kgm^2s^{-3})

Pressure:

- Defined as the normal force acting per unit area
- Pressure, P=F/A
- SI unit for pressure is newton per square meter ($kgm^{-1}s^{-2}$)
- This unit is known as the pascal (Pa)
- Pressure due to a liquid column is pgh, where p is the density of the liquid, g is the gravitational field strength, and h is the depth of water from the surface

Concepts:

- Pressure acts equally in all directions
  - Pressure is exerted by particle collisions inside a closed container
  - Motion of particles are random and continuous
  - Hence, pressure will act equally in all directions
- Pressure is transmitted through liquids since it is incompressible and yet does not occupy a fixed shape
- Liquids will find their own level (regardless of the diameter or angle of the tubing, it depends on the pressure of the liquid)

Atmospheric Pressure:

- The atmospheric pressure at sea level is 1 x 10^5 Pascals (the pressure a column of water 10m will have the same pressure)
  - We do not feel the large atmospheric pressure because the pressure in our bodies is almost the same as the external pressure and will balance it
  - Higher altitudes will mean lower atmospheric pressure, where breathing becomes more difficult (while under the sea, a greater depth means a greater atmospheric pressure)
  - This is also a result of the pull of gravity, which is stronger nearer to the core of the Earth
- Humans use a barometer to calculate the atmospheric pressure
- The total pressure of liquid at a depth, h, below the liquid's surface will be (atmospheric pressure + pgh): pgh is used to determine the additional pressure due to the weight of the liquid beneath the liquid surface

Applications of atmospheric pressure:

Straw:

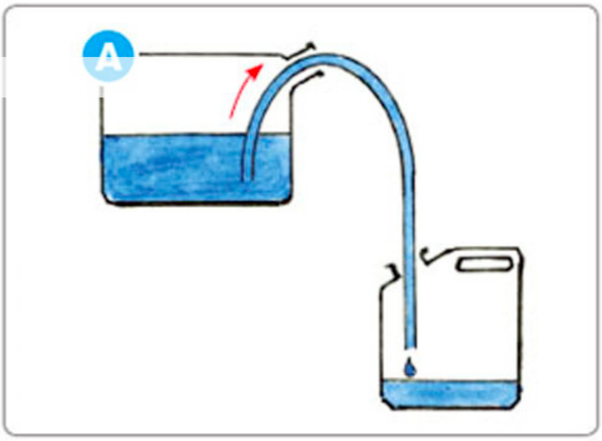
- Sucking a straw causes air pressure in the straw to decrease
- Atmospheric pressure is greater than the air pressure in the straw
- Water rises through the straw and into the mouth

Suction cup:

- When suction cup is pressed onto a smooth surface, air in the suction cup is forced out
- Creates a low-pressure space between the suction cup and the surface
- Atmospheric pressure, which is much larger on the outside, pushes on the suction cup and allows it to carry a substantial weight

Siphon:

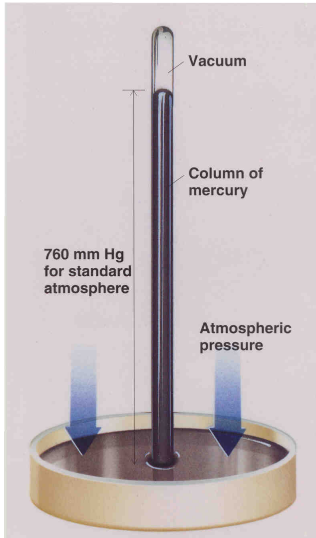
- Rubber tube used to siphon liquid from container at higher level to one at lower level
- Tube is filled with the liquid, one end placed in container A, and the other end placed at a level lower than the surface of the liquid in container A
- Pressure at lower end of tube is greater than atmospheric pressure, hence liquid flows out



<u>Pressure Measurement:</u>

Mercury Barometer:

- Description: the glass tube is completely filled with mercury, and turned upside down in a trough of mercury
- The atmospheric pressure acting on the surface of the mercury in the trough supports the mercury column (the height of the column is proportional to the atmospheric pressure)
- The atmospheric pressure is measured in terms of 'millimetres of mercury' (mm Hg)
- The atmospheric pressure is 760mm Hg at sea level (equivalent to 100 kPa)
- The height of the mercury column does not depend on the diameter or the angle of the glass tube
- When the tube is tilted at different angles, the vertical height of mercury column remains the same, as long as the mercury has not filled up the tube completely

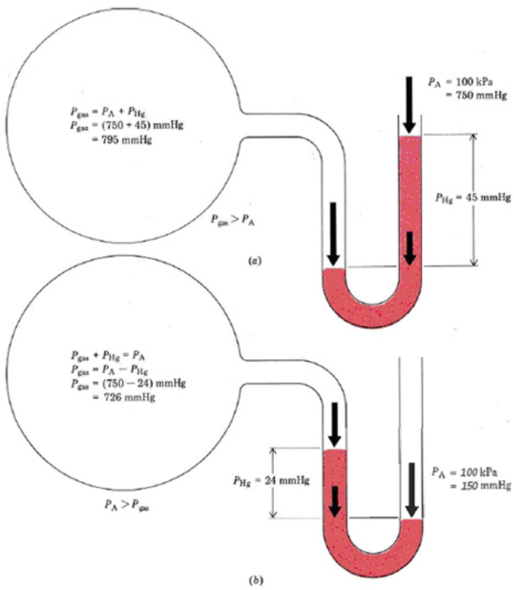


Water Barometer:

- The height of the water column supported by atmospheric pressure is more than 10m
- This is because of the density of mercury (which is a metal), more than water (1000kgm-3)

Manometer:

- A manometer consists of a U-tube filled with a liquid
    - Water has the disadvantage of evaporating
    - Mercury is poisonous
    - Oil is often used, and since it is less dense, the manometer is more sensitive (thus the oil also requires a greater length of the gas tube)
- It is used to measure gas pressure, through the pressure difference between the atmosphere and the gas of interest
- One side of the tube is connected to the gas supply, and the gas pressure will act on the surface of the liquid on that end. The other side is usually exposed to the atmosphere, so atmospheric pressure will act on that end
- In the first picture, the gas pressure is greater than the atmospheric pressure
- In the second picture, the gas pressure is lower than the atmospheric pressure
- Application: in cleanrooms, where computer chips and semiconductors are made (necessary to ensure that the pressure in the room is slightly higher than that outside, so dust is prevented from finding its way into the cleanroom through small gaps)

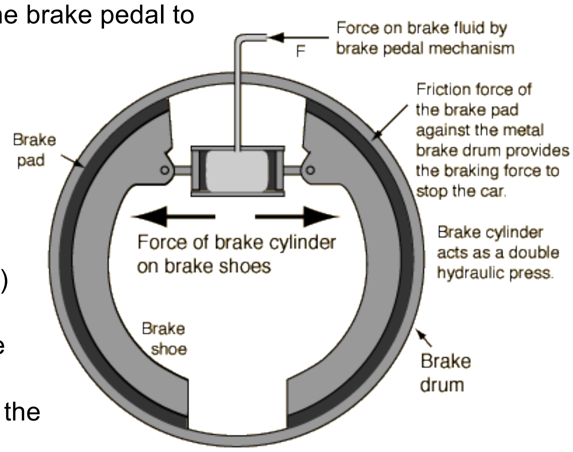


<u>Hydraulics:</u>

- Make use of the following properties:
    - Liquids are incompressible
    - If pressure is applied to an enclosed liquid, the pressure is transmitted uniformly to all parts of the liquid
- Allows a small force that is applied to a small piston to lift a greater load on a large piston (a force multiplier effect)
- Hydraulic system must not contain any air bubbles in any part of its hydraulic fluid system (air bubbles will reduce the efficiency of the system as part of the applied force will be used to compress the air bubbles)

Advantages:’
i. Use of a small effort to produce a big force
ii. Exert equal pressure on all parts of the system
iii. Exert pressures on inaccessible parts of the system (that requires hydraulic movement)

Applications:
I. Hydraulic Brakes
  - Small force applied by driver’s foot translates into a large breaking force (that allows the car to stop moving)
  - A brake fluid is used to transmit the pressure from the brake pedal to all wheels of the vehicle



- Mechanism:
  - When the brake pedal is pressed, the piston of the master cylinder applies a pressure on the brake fluid and this pressure is transmitted via a system of pipes to each cylinder at the wheels
  - The cylinder at the wheels cause a pair of pistons to push outwards on a pair of friction pads (brake shoe) which press on the surface of the brake drums (friction between the components causes the vehicle to slow down and stop)
  - When the brake pedal is released, a spring restores the brake shoes to their original position
- Special brake fluid used:
  - Water would result in corrosion
  - Water evaporates quickly and bubbles are easily trapped in water
  - Water has a lower boiling point (and cannot withstand the heat produced form friction)
- Advantages:
  a. Equal forces are simultaneously set up at all the wheels which prevents skidding
  b. The pressure is transmitted instantaneously which reduces stopping time
  c. The forces can beset up in any direction, allowing for flexible brake designs
  d. Less force is required to stop a heavy vehicle

II. Hydraulic Press
  - Allow for the lifting of a heavy load with a small force
  - A hydraulic jack which allows the user to change car tyres

<u>Boyle’s Law:</u>
- For a fixed mass of **gas** at a constant temperature, the product of its pressure and the volume of the gas remains a constant (proportionate decrease in volume leads to a proportionate increase in pressure)
- P1V1=P2V2
  - Explanation: when the volume of gas decreases, the particles in the smaller cylinder will hit the walls more frequently
  - The collisions on the walls cause pressure, and more collisions means more pressure

Kinetic Model of Matter:

Classification of Matter:

Element:

- Consists of only one type of atom
- Cannot be broken into a simpler type of matter by either physical or chemical means
- Can exist as either atoms (argon) or molecules (nitrogen)

Compound:

- Consists of atoms of two or more different elements bound together
- Can be broken down into a simpler type of matter (elements) by chemical means (but not by physical means)
- Has properties that are different from its component elements
- Component atoms are always in fixed ratios (like H2O)

Mixture:

- Consists of two or more different elements and/or compounds physically intermingled
- Can be separated into its components by physical means
- Often retains many of the properties of its components

Kinetic Model of Matter:

- All matter is made up of a very large number of particles (tiny atoms or molecules)
- These particles are in a state of continuous random motion
- A higher temperature corresponds to greater average kinetic energies of the particles

Explanation of Events:

- Particles of a solid vibrate in place
- As the temperature rises, the particles will vibrate more vigorously
- In some cases, this will lead to an expansion of the material: the particles need more space
- Eventually, the particles will have so much kinetic energy that they leave their fixed positions and start to move about: the solid melts into a liquid
- More heating may lead to vapourization of the liquid into a gas (boiling)
- As the gas particles move about and bump into each other and the container, they exert pressure

States of Matter:

	Solid	Liquid	Gas
Arrangement of Particles	Regular	Less regular	No fixed position
Distance between Particles	Very small	Slightly larger than in solid	Very large
Intermolecular Forces	Very strong	Slightly weaker than in solid	Negligible
Motion of molecules	Vibrate about fixed positions	Vibrations and random movements throughout the liquid but particles cling along together	On top of vibrational motion, particles can move about freely
Shape	Fixed shape	No fixed shape (takes the shape of container)	No fixed shape (takes shape of container)
Volume	Fixed volume	Fixed volume	No fixed volume (gases are compressible)

Diffusion:

- Diffusion is the random movement of particles from a region of higher concentration to a region of lower concentration
- In solids, particles can only vibrate about fixed positions, so no diffusion can take place

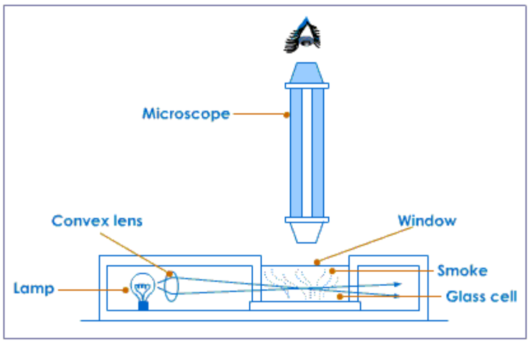
- In liquids, particles can move around and diffusion will take place
- In gases, particles move faster and there is more space available, thus diffusion will be faster
- Particles of larger mass will move more slowly, therefore more massive particles diffuse slower

<u>Brownian Motion:</u>

- The haphazard movement of microscopic particles suspended in a fluid (liquid or gas) due to uneven bombardment of suspended particles by the fluid's molecules

Procedure:

- The smoke cell is a transparent container in which some smoke from a smouldering paper is enclosed
- The smoke cell is brightly illuminated and a lower power microscope is used for magnification and to focus on the smoke particles



Observation:

- The smoke particles are barely visible
- The smoke particles appear as bright specks of light moving around in a jerky, random and erratic motion
- Smoke particles do not often collide with one another but appear to be knocked about by some other invisible particles in the smoke cell

Explanation:

- Random motion of smoke particles is due to air molecules bombarding them randomly and at different velocities
- CLARIFICATION: it is not the air particles are seen moving, but the smoke particles (it is difficult/impossible to see air particles using a lower-powered microscope): the bright specks of light is actually scattered by the smoke particles

Effects of Temperature:

- At higher temperatures, the motion of smoke particles will become more vigorous and agitated
- Air molecules have greater average speeds at higher temperatures
- Thermal energy is converted to greater average kinetic energy of the air molecules, causing them to move faster
- This results in the air molecules bombarding the smoke particles more vigorously and regularly

Effects of Particle Mass:

- When particles have a greater mass, and the temperature stays constants, the rate of diffusion will decrease since the average speed of the particles will decrease

<u>Change of State:</u>

Temperature and Molecules:

- As the temperature increases, molecules move faster, and collide more frequently and with a greater velocity
- Thermal energy becomes molecular kinetic energy
- Temperature is a measurement of the average kinetic energies of particles in a system

Melting:

- When heated, particles gain kinetic energy
- The particles vibrate faster and move further apart
- Melting point: the particles have enough kinetic energy to overcome intermolecular forces and particles start to break away from one another
- The solid becomes a liquid

Boiling:

- When heated, the particles gain kinetic energy
- The particles slide over one another more rapidly and move further apart

- Boiling point: the particles have enough kinetic energy to overcome intermolecular forces and particles start to break away from one another
- The liquid becomes a gas

Freezing:

- When cooled, particles lose kinetic energy
- The particles slid over one another more slowly and move closer together
- Freezing point: particles do not have enough kinetic energy to overcome intermolecular forces
- Particles start to come together in a regular arrangement
- Liquid becomes a solid

Pressure in gases:

- Moving air molecules collide with the surface of the wall of container and exerts a force on it
- Since pressure is the force exerted per unit area, the air molecules exert a pressure on the surface of the wall of the container
- This pressure depends on the <u>force per collision</u> and <u>frequency of collision</u>, with respect to the wall of the container

Pressure-Temperature Relationship

- Consider the air molecules in a fixed volume container with temperature gradually increased
- The air molecules have greater average speeds at higher temperatures
- The air molecules will have more frequent and forceful collisions with the walls of the container, increasing the pressure within the container
- Pressure is directly proportional to temperature

Volume-Temperature Relationship:

- When air is heated, the temperature rises, causing the air to move at higher average speeds
- This results in more frequent and forceful collisions between the gas molecules and walls of the container
- Hence, greater pressure is exerted and to keep the pressure constant, the gas will expand, increasing the volume of the fixed mass of gas
- Volume is directly proportional to temperature

Pressure-Volume Relationship:

- Boyle's Law
- $P_1V_1=P_2V_2$
- When volume of the container is halved, the number of molecules per unit volume is doubled
- The frequency of collisions between molecules and walls would theoretically double
- Hence the pressure will be doubled
- Pressure is inversely proportionate to volume

Temperature:

- Refers to a measure of how hot or cold an object is (EOY)
- The quantity which is the same for both systems when they are in thermal equilibrium
- Also refers to: average kinetic energy of all the particles in the system

Heat:

- The amount of thermal energy that is being transferred from a hotter to a colder region
- Temperature vs Heat:
  - Matter does not contain heat. Matter can only contain molecular kinetic energy and potential energy, but not heat
  - Heat is the energy transferred from a body of higher temperature to one of a lower temperature
  - Once transferred, the energy ceases to be heat: the energy becomes part of the total energy of the molecules of the object or system

Internal Energy:

- Combination of the total kinetic energy and potential energy of the molecules in the body
  - Translational kinetic energy of jostling atoms (microscopic kinetic energy)
  - Rotational and vibrational kinetic energy of molecules (microscopic kinetic energy)
  - Kinetic energy due to internal movement of atoms within molecules (microscopic KE)
  - Potential energy due to forces between molecules (microscopic potential energy): due to the strength of the bonds
- Total KE and PE: a hot water bath has a greater thermal energy than a sparkler, but a lower temperature (due to the large mass of the water bath)

Thermal Energy:

- Formula: $Q=mc\Delta\theta$ (where m is the mass, c is the specific heat capacity and $\Delta\theta$ is the temperature)
  - Specific heat capacity: amount of thermal energy needed to change 1kg of mass by 1°K (a property to show how fast or slow a substance gains heat)
  - Water has a large heat capacity, thus it takes longer to warm up and stays warm longer (swimming pool cool in the day, yet warmer in the night)
- Solid state: lowest potential energy (since potential energy is calculated by $-(k/r^2)$ with r being the distance between the molecules)

Other Notes for Definitions:

Change of State:

- At 0°C, water transitions from a solid to a liquid state, but its temperature does not increase
- This is because the energy is transferred to increase the molecular potential energy in order to break the bonds (for thermal energy)

No Change in State:

- General increase in temperature
- Increase in internal energy, as well as the thermal energy (for kinetic energy)

Thermometers:

- An instrument used to measure temperature accurately
- Makes use of substances such as mercury
- Substances must have physical properties that vary continuously in one direction with temperature (thermometric substances)
- Physical properties of substances that varies continuously with temperature are thermometric properties

Thermometric Property	Thermometer
Volume of a liquid	Liquid in glass thermometer
Pressure of a gas held at constant volume	Constant Volume Gas Thermometer
Electrical resistance of a conductor	Resistance Thermometer
Electromotive force	Thermocouple
Length of a solid	Bimetallic Thermometer

Colour of a hot object	Thermostrips/Liquid crystal thermometer

Good Thermometers: (EOY)

- Easy to read scale
- Safe to use
- Responsive to temperature changes
  - Measures how quickly the thermometer can register changes in temperature
- Sensitive to small temperature changes
  - Measures the amount of change in thermometric property per unit change in temperature
- Able to measure wide range of temperatures
  - Denotes the maximum and minimum temperatures that the thermometer can measure

	Responsiveness	Sensitivity	Ranges
Cross Sectional Area of Bore Increases	Unchanged	Decreases	Increases
Length of Stem Increases	Unchanged	Unchanged	Increases
Size of Bulb Increases	Decreases	Increases	Decreases
Thickness of Bulb Wall Increases	Decreases	Unchanged	Unchanged

Liquid in Glass Thermometer:

- Thin glass bulb filled with liquid at the bottom of the thermometer (bulb is joined to a narrow capillary tube sealed at the other end)
- Increase in temperature: expansion of liquid and the thread of liquid in the capillary tube will increase in length
- Provision of graduations and markings to read the temperature
- Liquid used: mercury and alcohol
- Invention: 1650 when the liquid was filled with spirit from wine
- Sensitivity: based on the reversible thermal expansion characteristics of the liquid in comparison to the glass (or oil/sand)

Advantages:

- Comparatively cheaper than the other temperature measurement devices
- Handy and convenient to use
- Unlike electrical thermometers, they do not need a power supply or batteries for charging
- Frequently applied in many areas and provide very good repeatability (calibration unaffected)

Disadvantages

- Inapt for applications involving extremely high or low temperature
- Cannot be applied where highly accurate results are desirable
- Weak and delicate: made of glass and can break
- Temperature readings must be recorded instantaneously for accuracy
- Risks of mercury and exposed substances

Comparison of Liquids

Thermometric Liquid	Advantages	Disadvantages
Mercury	• Good thermal conductor • Expands uniformly as temperature increase • Has a high boiling point at 357°C • Does not wet the bore	• Has a high freezing point and therefore not suitable to measure very cold temperatures • Poisonous • Expensive
Alcohol	• Lower melting point, ability to measure low temperatures	• Lower boiling point of 78°C and cannot measure high

	• Not poisonous • Cheap and readily available	temperatures • Not a uniform expansion over a temperature change • Poor thermal conductor compared to mercury

Resistance Thermometer:

- Usually made of platinum because of its liner resistance temperature with an increase in themperature
- Platinum is also used because of its chemical inertess (the current of the cyce depends on the coil of resistance (entirely affected by mainland)
- Resistance of the platinum wire increases in proportionately with an increase in temperature

Advantages:

- High Accuracy
- Wide operating range
- Suitability for precision

Limitations:

- Can only operate below 660 degrees Celsius
- Expensive element: platinum (the preferred metal due to its linearity)

Thermocouple:

- Consists of two wires of different metals joined together to form two junctions (one hot and one cold): small tips
- If the two junctions are at different temperatures, a small electromotive force or voltage is produced by the wires (the greater the temperature difference, the larger the electromotive force produced)

Advantages:

- Response is almost instantaneous since electrical currents are being carried
- Small tips: means that even small objects can be tested for their temperature
- Ability to measure objects that other thermometers cannot
- The output of the thermometer is an electrical signal (used to operate electrical equipment)
- Can measure temperature differences of up to 1700°C

Disadvantages:

- It needs a fixed limit (such as water that is at its freezing point) as a reference
- Difficulty of calibration: the voltmeter is not the most reliable equipment

Constructing a temperature scale:

i. Choose an appropriate substance
- Choose a suitable thermometric substance and its physical properties

ii. Choose two fixed points
- Choose two standard degrees of hotness or coldness which are easily obtainable and reproducible (such as the temperature of pure melting ice as the lower fixed point, and the temperature of steam at one atmospheric pressure as the upper fixed point)

iii. Set up the scale
- Divide the temperature range between the two fixed points into a fixed number of equal parts to obtain a scale
- Centigrade scale has 100 equal parts between the upper and lower fixed points

Temperature Formula:

- $\theta°C = (X_\theta - X_L / X_H - X_L) \times (\theta_H - \theta_L) + \theta_L$
- X_L refers to the physical property at the lower fixed point
- X_H refers to the physical property at the upper fixed point
- X_θ is the physical property at θ°C

- For a mercury column: $\theta°C = (X_\theta – X_0 / X_{100} – X_0) \times 100°C + 0°C$

Kelvin Scale:

- There exists a lowest possible temperature known as absolute zero: a state where everything ceases to move due to a lack of kinetic energy
- Scale is known as the absolute scale
- Absolute zero: all possible thermal energy is transferred away from the body
- Unit is K (Kelvin): SI unit of temperature

Centigrade Scale:

- Common temperature scale based on simple experimental procedures to define two fixed points
- Ice point (lower fixed point) is 0°C
- Steam point (upper fixed point) is 100°C

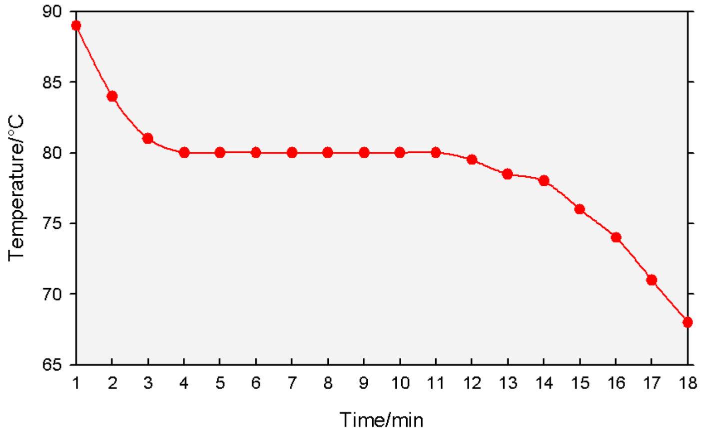
Thermal Property of Matter:

- Heat Capacity: the heat capacity of a substance is the amount of energy required to raise the temperature of the substance by 1°C or 1K
- Specific heat capacity: c, of a substance is the amount of energy required to raise the temperature of a unit mass of a substance by 1K or 1°C
  - It is represented by the formula: $Q=mc\Delta\theta$, where Q is the amount of energy transferred, m is the mass of the substance, and c is the specific heat capacity
  - $\Delta\theta$ refers to the change in temperature
  - All substances have a different specific heat capacity determined by its molecular structure and bonding
  - Ensure that J kg^{-1} C^{-1} and J g^{-1} C^{-1} are not mixed up (the specific heat capacity of water is 4200 J $kg^{-1}C^{-1}$, and 4.20 J $g^{-1}C^{-1}$
  - Solids have a lower heat capacity compared to liquids, since the molecules are packed close to each other, less energy is required to heat it up (this is why the specific latent heat of vapourization is greater than the specific latent heat of fusion)
- Transfer of energy without a change of state:
  - When two bodies of different temperatures are placed in thermal contact and reach thermal equilibrium, the Principle of Conservation of Energy means that the amount of heat lost by a hot body is equivalent to the amount of heat gained by a cold body
  - Assuming that there is no heat loss to the environment
  - $M_1C_1\Delta\theta=M_2C_2\Delta\theta$
- Latent heat: energy that is absorbed or released by a substance when there is a change of state of the substance without a change in its temperature
  - The energy is needed to overcome the intermolecular forces between the particles
- Specific Latent Heat: the amount of energy needed to change the state of a unit mass of the substance, without a change in its temperature
- Specific Latent Heat of Fusion: the amount of energy needed to change a unit mass of the substance from the solid to liquid state (or liquid to solid) without a change in its temperature
  - Indicated by the formula: $Q=ml_f$, where m is the mass of the substance and l is the specific latent heat of fusion
  - Ensure that kJ kg^{-1} and J g^{-1} are not mixed up
- Specific Latent Heat of Vaporization: the amount of energy needed to change a unit mass of the substance from liquid to gas (or gas to liquid) without a change in its temperature

Internal Energy:

- The sum of the microscopic kinetic and potential energies in a particle
- Absorbtion of heat: increase in the total internal energy of the substance (this can lead to either a change in the temperature or state in the substance)
- If the temperature increases, then the average vibrational microscopic kinetic energy of the particle increases
- If the state changes, then the microscopic potential energy of the particles are changed because of the change in the distance between the particles and their bonding

Interpretation of Cooling Curve:



- In the first section of the decrease, the temperature clearly decreases, thus energy is lost by the molecules in the form of vibrational energy (or microscopic kinetic energy)
- In the second section of the plateau, the temperature remains constant as heat loss comes from the loss of microscopic potential energies of the particles as bonds are formed to hold the particles in a more stable configuration, such as in a liquid or solid form (this means no decrease in kinetic energy)
- In the third section with the decrease, the temperature decrease thus the drop in temperature comes from the loss of average microscopic kinetic energies of the particles as the liquid/solid cools

Evaporation:
- Molecules in the liquids are in constant motion
- More energetic molecules at the liquid surface are able to break free from the surface
- Less energetic molecules are left behind
- As such, average kinetic energy of the liquid molecules decreases, thus the temperature decreases

Factors:
- Temperature of the Liquid (higher temperature=more evaporation)
- Surface Area (greater surface area=more evaporation)
- Presence of Wind (more wind=more evaporation)
- Humidity of Surrounding Air (greater humidity=less evaporation)
- Greater pressure (greater vapour pressure=more evaporation)
- Nature of liquid (greater volatility=more evaporation)

Information:
- Heat energy is absorbed during the process of melting and boiling
- Heat energy is released in the process of condensation and freezing

Evaporation	Boiling
Occurs only at the surface of the liquid (no visible signs)	Occurs throughout the liquid with visible signs
Occurs over a range of temperatures	Occurs only at a definite temperature (boiling point)
Slow Process	Quick Process
Energy Source is not required	Energy source is required