3.1 Physics: Kinematics, Dynamics I & II)

Kinematics:

Definitions:

- Distance: total length covered by a moving object irrespective of the direction of the motion
- Displacement: Distance moved in a specified direction
- Speed: Rate of change of distance with respect to time
- Velocity: Rate of change of displacement with respect to time
- Instantaneous velocity: rate of change of displacement at a particular instant of time (change s/change t)
- Average velocity: Total displacement divided by total time taken (u+v / 2)
- Instantaneous Acceleration: Rate of change in velocity at a particular instant of time
- Average acceleration: Total change in velocity divided by the total time taken
- Acceleration of Gravity: it is always 9.81 ms-2

Gradient and Graph:

- Gradient of the displacement-time graph: velocity of object
- Gradient of velocity-time graph gives acceleration (area is under the graph gives displacement)

Formulas:

- $V^2 = u^2 + 2as$
- $S=ut + ½ at^2$
- $V= u + at$
- $S= ½ (u+v) t$
- $S= vt – ½ at^2$

Air Resistance:

- Increases with surface area
- Increases with the speed of the object
- Increases with the density of the object

Terminal Velocity:

- Achieved when the force of the air resistance is the same as the weight of the object
- Object will cease to accelerate and move with constant velocity
- Longer time taken for heavier objects to reach terminal velocity
- Longer time taken for objects with less surface area

- Longer time taken for objects that are denser

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 as a useful force: walking, holding an object, braking
    - Friction as a nuisance: loss in useful energy, wear and tear
    - 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)
- 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
- Tension: The pulling force acting in a string or rod
- 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

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)

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
  - 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

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 Moments:

- 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