S1 New Curriculum Physics

Theme: Mechanics and properties of matter

Chapter 4 –Effects of forces

Force

Force is a pull or push that changes or tends to change the body’s state of rest or uniform motion in a straight line
The SI unit of force is Newton (N)

Effects of force on bodies

(i) **Causes Motion:** A force applied to a stationary object can **make it move**. Example: Pushing a ball makes it roll.

(ii) **Changes the Speed of an Object:** A force can **increase or decrease** an object's speed. Example: Pressing the brakes slows down a car.

(iii) **Changes the Direction of Motion:** When force acts at an angle, it can alter the **direction** of movement. Example: A football changes direction when kicked in a different way.

(iv) **Causes Deformation (Changes Shape or Size):** Force can **compress, stretch, or bend** an object. Example: Squeezing a sponge changes its shape.

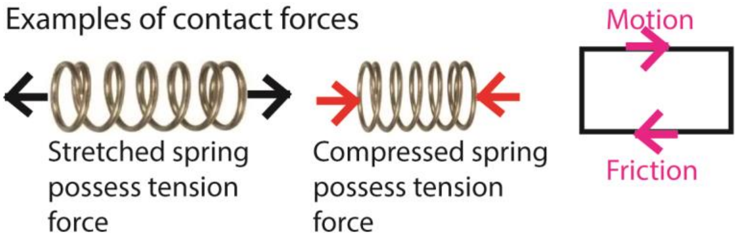
(v) **Can Cause Rotation:** If a force is applied off-center, it can make an object **rotate**. Example: Turning a wrench to tighten a bolt.

(vi) **Affects Pressure:** Force exerted over an area influences **pressure**. Example: Pressing harder on a knife increases its cutting ability.

Types of forces

Contact forces

These **are forces** that require physical contact between objects for them to act,



(i) **Tension force** is a force possessed by a spring, rubber band or wire when pulled a part. It is applied when towing a vehicle, ring beam maintains the shape of a house

(ii) **Compression force** is a force possessed by compressed string, rod. It is applied in shock absorbers.

(iii) **Frictional force** is a force that opposes relative motion between two bodies in contact.

Types of friction

- **Static friction** is that occur when an object is not moving i.e. it's friction that prevents motion.

  Applications of static friction

  - Enables the feet to grip the ground, preventing slipping while running or walking.
  - Enables us to grasp and hold objects like a pen while writing
  - Allows nails, screws, and bolts to hold materials together securely.
  - Keeps objects stationary on conveyor belts until pushed forward.

- **Dynamic/kinetic friction** is a type of friction that slows down already moving bodies. It is lower than static friction but still opposes motion.

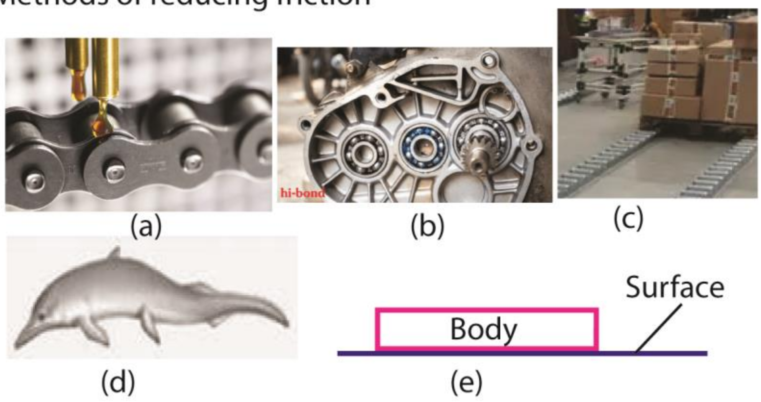
  Applications of dynamic friction

  - Braking of moving car, when a driver applies brakes, dynamic friction between the brake pads and the wheel slows down the car.
  - Writing with Pens and Pencils, dynamic friction helps deposit ink or graphite onto the surface.
  - Sanding and Polishing, wearing down rough areas is due to kinetic friction. This process creates smooth surfaces in furniture, jewelry, and automotive parts.
  - Rubbing Hands for Warmth, dynamic friction generates heat.
  - Walking and Running; kinetic friction between shoes and the ground provides grip. It prevents slipping and aids in maintaining balance.
  - Sparks fire when a match stick strikes the match box

  Disadvantages of friction

  - Causes unnecessary heat
  - Reduces the efficiency of machines
  - Causes things like tyres, soles of shoes to ear out
  - Causes parts of machines to break

Methods of reducing friction



Trial 1: Identify the methods of reducing friction in the figure above.

(iv) Centripetal force

Centripetal force is a force that maintains a moving body in a curved path. It is directed towards the centre of rotation. For instance, when swinging an object attached to a string the, tension in the rope that tends to pull it towards the centre is the centripetal force.

Application of centripetal force

(a) **Vehicle Turns on Roads:** When a car turns around a curve, centripetal force is provided by **friction** between the tires and the road. Without this force, the car would continue moving in a straight line and skid off the road.

(b) **Motion of Planets & Satellites:** Gravity acts as **centripetal force**, keeping planets in orbit around the Sun. Artificial satellites stay in their orbits due to the balance between their speed and Earth's gravitational pull.

(c) **Washing Machine Spin Cycle:** Clothes inside a washing machine move in a **circular path**. Water is forced out through small holes by **centripetal force**, helping in drying.

(d) **Cyclists & Motorbike Riders on Curves:** Riders lean into turns to balance the **centripetal force**, preventing them from falling over. Racing tracks are often banked to help generate the necessary force.

(e) **Electron Motion in Atoms:** Electrons orbit the nucleus due to an **electrostatic centripetal force** between the positively charged nucleus and negatively charged electrons.

(v) Centrifugal force

Centrifugal force is the force that is felt by an object moving in a curved path. It’s directed away from the centre of rotation. For instance, when swinging an object attached to the rope, the centrifugal force through the rope tends to pull it away from the centre.

Application of centrifugal forces

(a) **Washing Machines:** Centrifugal force helps in spin drying by pushing water out of clothes as the drum rotates at high speed.

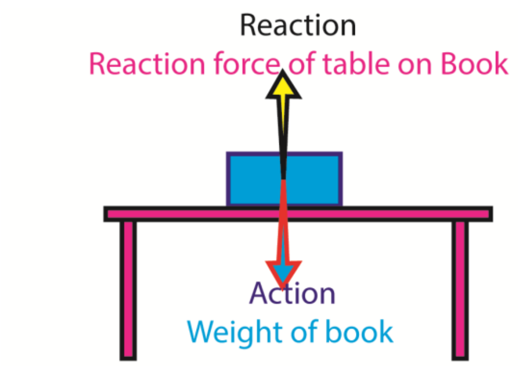
(b) **Centrifuges in Laboratories:** Used in medical and research settings to separate substances based on density, such as spinning blood samples to separate plasma from other components.

(c) **Industrial Separators:** Used in machines that separate different substances, such as oil from water or cream from milk in dairy processing.

(d) **Oil & Gas Industry:** Used in cyclone separators to remove unwanted particles and purify fluids.

(vi) Action and reaction force

Action and reaction forces are two forces that are generated together and happen at the same time. They have the same strength but act in opposite direction. For example, when a book is placed on the table, the book exerts a downward force. The table in turn exerts an equal upward force on the book



For Every Action Force there is an equal (in size) and opposite (in direction) Reaction force

Other examples of action and reaction forces include

- **Walking or Running** – When you push backward with your foot (action), the ground pushes you forward (reaction), allowing you to move.
- **Jumping Off a Boat onto a Dock** – As you jump forward (action), the boat moves slightly backward (reaction).
- **Birds Flying** – A bird's wings push air downward (action), and the air pushes the bird upward (reaction).
- **Rowing a Boat** – The oars push water backward (action), and the water pushes the boat forward (reaction).
- **Rocket Launch** – Exhaust gases push downward (action), and the rocket moves upward (reaction).
- **Playing Basketball** – When the ball hits the ground (action), the ground pushes it back up (reaction).

- **Swimming** – Your hands push the water backward (action), and the water pushes you forward (reaction).

(vii) Cohesive and adhesive forces

Cohesive forces are the attractive forces between molecules of the same substance while **Adhesive forces** are the attractive forces between molecules of **different** substances. For example when a drop water is put on glass, it spreads out because adhesive forces are stronger than cohesive forces. While when mercury is placed on glass it form spherical drops because cohesive forces among mercury molecules are stronger than the adhesive forces between mercury molecules and glass.

Applications of Cohesive Forces

- **Surface Tension** – Used in small-scale liquid transport systems, such as ink in pens or microfluidic devices.
- **Raindrop Formation** – Water molecules stick together due to cohesion, leading to the formation of raindrops.
- **Mercury Handling** – Cohesive forces prevent mercury from spreading, making it useful in thermometers.
- **Biological Fluids** – Blood and other fluids maintain their consistency due to cohesive forces between molecules.

Applications of Adhesive Forces

- **Glue and Tape** – Adhesive forces allow bonding materials to stick to surfaces.
- **Paint and Coatings** – Adhesion ensures paints and coatings stay on walls and objects.
- **Water Uptake in Plants (Capillary Action)** – Adhesion helps water travel up plant roots and stems.
- **Biomedical Applications** – Adhesive forces play a role in wound dressings, bandages, and medical adhesives.

(viii) Capillarity

Capillarity, also known as **capillary action**, is the ability of a liquid to flow in narrow spaces **without** the assistance of external forces like gravity. This phenomenon occurs due to the interplay between **cohesive** and **adhesive** forces.

How It Works:

- **Adhesive Forces** – The liquid molecules are attracted to the surface of a solid (like the walls of a thin tube).
- **Cohesive Forces** – The liquid molecules stick together and pull each other along.
- **Surface Tension** – Helps maintain the liquid’s shape as it moves upward.

Application of capillarity

- **Water Rising in Plant Roots** – Plants use capillary action to transport water from roots to leaves.
- A **damp proof course (DPC)** is a protective layer in buildings designed to prevent moisture from rising through walls and floors due to **capillary action**.
- **Ink in a Pen** – Ink flows smoothly through tiny tubes due to capillarity.
- **Paper Towels & Sponges** – Absorb liquid due to adhesive forces pulling water into tiny spaces.
- **Medical Tests (Blood Sample Wicking)** – Thin tubes draw blood for tests using capillary action.

Disadvantages of capillarity

- Make walls damp and ugly due to growth of algae and moss

(ix) Surface tension

Surface tension is the property of a liquid that makes its surface behave like a stretched elastic sheet. It occurs due to the **cohesive forces** between the liquid molecules, which pull them together and create resistance to external force.

Key Aspects of Surface Tension:

- Liquids minimize their surface area because molecules at the surface experience an imbalance in attractive forces.
- The stronger the intermolecular forces (like hydrogen bonding in water), the higher the surface tension.

Application of surface tension

- **Water Droplets** – Water naturally forms spherical droplets due to surface tension.
- **Floating Needles or Paperclips** – A light object can rest on water without sinking because surface tension supports it.
- **Insects Walking on Water** – Some insects, like water striders, use surface tension to stay on top of water.
- **Soap & Detergents Breaking Surface Tension** – Soap reduces water's surface tension, helping it spread and clean better.

Non-contact forces

These are forces that do not require physical contact between objects for them to act.

(i) Gravitational Force

Gravitation force i the force that pulls objects toward the Earth, like how a dropped apple falls to the ground.

Mass of an object is the quantity of matter a body contains. It is constant across the globe.

Acceleration due to gravity, often denoted as **g**, is the rate at which objects accelerate toward the ground due to Earth's gravitational pull. On Earth, this acceleration is approximately **9.81 m/s²**—meaning that an object's velocity increases by **9.81 meters per second** every second it falls.

Weight is the force exerted on an object due to gravity. It's calculated using the formula:

Weight =Mass (kg) ×Acceleration due to gravity(g)

Trial 2: Identify the methods of reducing friction in the figure above. Taking acceleration due to gravity = $10ms^{-2}$. Calculate the weight the following masses

(a) 10kg
(b) 5g
(c) 6mg

(ii) **Magnetic Force** – The force between magnets or between a magnet and a metal object, like how a fridge magnet sticks to the door.

Application of magnetism

- **Electronics & Computing** – Hard drives, speakers, and microphones rely on magnets to store and transmit data.
- **Industrial Uses** – Magnets help with sorting materials, lifting heavy metal objects, and even aiding in waste management.
- **Energy Generation** – Turbines in power plants use magnets to generate electricity by converting mechanical energy into electrical energy.

- **Medicine (MRI Scanners)** – Magnetic Resonance Imaging (MRI) uses strong magnets to create detailed images of the body, aiding in diagnosis.
- **Security & Navigation** – Magnets are essential in card readers, compasses, and many security devices
- **Transportation (Maglev Trains)** – Magnetic levitation technology allows trains to float above tracks, reducing friction and enabling high-speed travel.

(iii) **Electrostatic Force** – The force between charged objects, such as when your hair stands up after rubbing it with a balloon.

(iv) **Nuclear Force** – The force that holds the nucleus of an atom together, even though the particles don't physically touch.

Resultant force

A force is a vector in that it has magnitude and direction. This helps is in addition, subtraction and manipulation of forces on an object.

A **resultant force** is the overall force acting on an object when multiple forces are applied. It is found by combining all the forces acting on the object, taking both **magnitude** and **direction** into account.

If forces are balanced (equal and opposite), the resultant force is **zero**, meaning the object stays at rest or moves at a constant speed.

If forces are unbalanced, the object accelerates in the direction of the resultant force.

How to Calculate Resultant Force

(a) If forces act in the **same direction**, add them together.
For example, If two people push a box with forces of **30 N** and **50 N** in the same direction, the resultant force is: 30N+50N = 80 N

(b) If forces act in **opposite directions**, subtract the smaller force from the larger force.

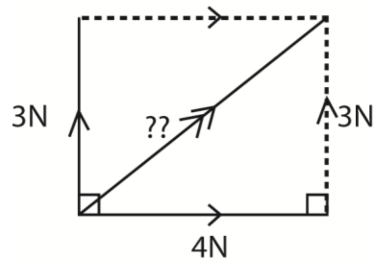
For example when person pushes a box with 30N to the left while another pushing the box at 50N to the right; the resultant force = 50 – 30 = 20N to the right

Or

For example when person pushes a box with 50N to the left while another pushing the box at 30N to the right; the resultant force = 50 – 30 = 20N to the left.

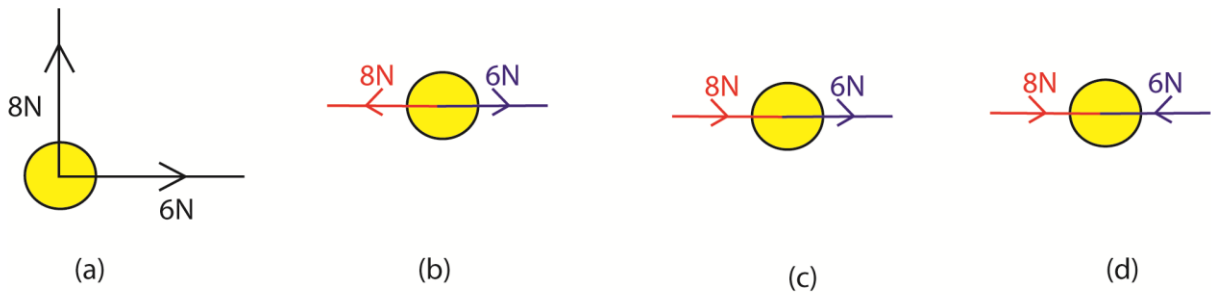
(c) If forces act at angles, use vector addition (like the Pythagorean Theorem or trigonometry) to find the net force.

For example, find the resultant force when two forces of 3N and 4N act on an object at right angles



Using Pythagorean Theorem the resultant force $\sqrt{3^2 + 4^2}$ = 5N

Trial 3: Find the resultant forces on each object in the figure below.



PRESSURE

Pressure is force acting normally per unit area of the **surface.**

Or

Pressure $= \frac{\textbf{Force (N)}}{\textbf{Area of base } (m^2)}$

The SI unit of pressure is Nm^{-2} or Pascal (Pa).

1Pa =1 Nm^{-2}

A Pascal is the unit of pressure equal to 1Nm^{-2}.

Larger unit of pressure

1kPa = 1kNm^{-2}=1000Pa

Example: Change 0.7kPa to SI unit.

1kPa = 1000Pa

0.7kPa = 0.7 x 1000 =700Pa.

Note:

(a) In case mass is given, then first calculate the weight from:

Weight = mass (kg) x acceleration due to gravity.

Weight = volume (m^3) x density (kg m^{-3}) x acceleration due to gravity.

(b) Area of base should be in m^2

- If the area of contact for the base is circular then Area of base$(A) = \pi r^2$.Where **r** is radius of circle in contact.

-If the area of contact for the base is a square (square) then Area of base(A)=**L^2.** Where **L** is the length of the side.

-If the area of contact for the base is a rectangularthen Area of base(A)=**L x W.**Where L is the length and W is the width or breadth.

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Example 1. Calculate the pressure exerted by a force of 500N acting on the surface of $2m^2$.

Force(F)= 500N Area of base(A)= $2m^2$

Pressure $=\frac{\textbf{Force}}{\textbf{Area of base}} = \frac{\textbf{500}}{\textbf{2}} =$**$250Nm^{-2}$**

Example 2. Calculate the pressure exerted by a 500kg block of base area $2cm^2$.

Weight = mass (kg) x acceleration due to gravity.

=500 x 10 = 5000N

Area of base(A)= $2cm^2 = \frac{\textbf{2}}{\textbf{100X100}}$**= $0.0002m^2$**

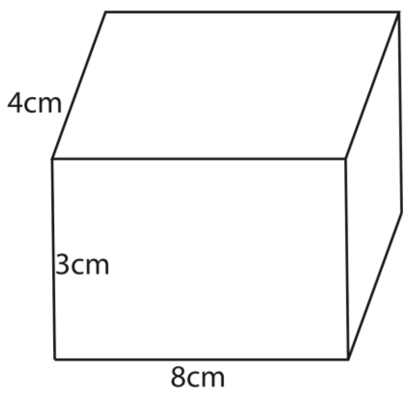
Pressure $=\frac{\textbf{Force}}{\textbf{Area of base}} = \frac{\textbf{5000}}{\textbf{0.0002}}$**=25000000 = $2.5 \times 10^7Nm^{-2}$**

Example 3.A block of concrete of 0.9kN and its base is a square of 200cm. Calculate the pressure it exerts.

Force (F) = 0.9kN = 0.9 x 1000 =**900N**

Area of base = 200 x 200 = **$40000cm^2$ = $\frac{\textbf{40000}}{\textbf{100 x 100}}$ m^2 = $4m^2$**

Trial 4: The weight of the cube below is 600g; find the maximum and minimum pressure it can exert.



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Thanks

Dr. Bbosa Science