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CHAPTER 9: Application of forces and transfer of energy

TYPES OF FORCES:

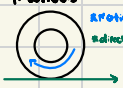
1. Contact forces—forces experienced by bodies when they are in physical contact
   - applied force → force due to the action of muscles
   - frictional force → forces acting opposite to the direction of motion

2. Non-contact forces - forces experienced by bodies even if they are not in physical contact with each other
   - magnetic → force exerted by a magnet
   - electrostatic → force exerted by a charged body on another charged body
   - gravitational → force of attraction between two masses ie that attracts objects to Earth

3. Friction - the contact force that opposes/tends to oppose motion between surfaces in contact

special cases:

1. wheels



- to move to the right, the wheels has to rotate in a clockwise direction
- friction opposes motion, therefore it acts to the right

2. feet walking

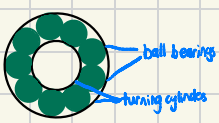
- to move to right, the foot has to push backwards to the ground
- friction opposes motion, therefore it acts to the right

Reducing negative effects of friction

wheels

instead of dragging the box over the ground, the circular shape of the wheels rotate and prevents direct contact with the ground. With less friction, a smaller force is needed to move a shopping trolley

ball bearings



spherical ball bearings work like wheels. They roll around, and prevent moving surfaces in machines from rubbing against each other directly

lubricant

with lubricant added, engine surfaces in contact experience less friction when they move against each other. A rough surface generates more friction compared to the smooth surface

air cushion

a layer of air between surfaces reduces friction, so a hovercraft can travel faster

Enhancing positive effects of friction

Treads → channel water out from under tyres, which improves the tyres' grip on the road surface, and prevents vehicles from skidding

Parachute → the large air resistance created by the canopy of an open parachute slows down a descending parachutist, so that he may land safely

Chalk → rock climbers apply chalk powder to their palms to absorb sweat, and hence improve their grip

Comparing weight and mass

	weight	mass
definition	the measure of the gravitational force acting on an object	amount of matter in an object
changes/does not change	can have different values depending on gravitational field strength	value remains unchanged, independent of gravitational field strength

S.I. unit: Newton (N) | Kilogram (kg)

instrument to measure: Spring balance | electronic mass balance, beam balance

formula to calculate: (N) weight = (kg) mass × (N/kg) gravitational field strength

(kg) mass = (N) weight ÷ (N/kg) gravitational field strength

Gravitational field

gravitational field is a region in which a mass experiences a gravitational force of attraction

gravitational field strength, g, is the gravitational force acting per unit mass

gravitational field gets stronger as the object moves closer to earth

	On Earth	On Moon
gravitational field strength, g:	10N/kg	1.66 N/kg
	→ an object with a mass of 1kg would be attracted towards the centre of the earth by a force of 10N	→ an object with a mass of 1kg would be attracted towards the centre of the Earth by a force of 1.66N

The force of gravity on the moon is less than on Earth. Any object will weigh less on Moon than on Earth. However, the object would have the same mass on Moon and Earth

What happens when two or more objects interact?

Forces applied on an object can cause:
- changes in the state of rest or motion of an object
- changes due to the turning effect of a force on an object (must have a pivot)
- changes in size/ shape of an object
- changes in pressure on an object
- transfer of energy due to application of forces

Changes in the state of rest or motion on an object

when two or more forces are acting on an object, the overall force acting on the object is called resultant force

- if the resultant force is 0N, the forces are equal
- if the resultant force is >0N, the forces are unequal and it will result in an effect on the objects
- a resultant force is represented by a double-headed arrow →→

When there is a resultant force, energy is transferred between objects, which may:
- cause a stationary object to start moving
- change the speed of an object (move faster/slower)
- change the direction in which an object moves
- cause a moving object to stop moving

Changes due to the turning effect of a force on an object

a force applied on an object can cause a turning effect about a fixed point called the pivot. This turning effect is called the moment of a force. S.I. unit is Newton-metre (Nm).

Example of moments in our daily life

a larger steering wheel enables the driver to turn the steering wheel more easily; this is why large buses and heavy vehicles normally has larger steering wheels.

in order to produce the same turning effect, more force needs to be applied to move the oars over a long distance so that the canoe can move a longer distance

the seesaw is pivoted in the centre. In order to balance it completely, the sum of clockwise moment must be equal to the sum of anti-clockwise moment

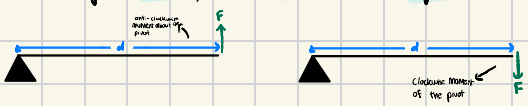
Calculating moments

moments of a force = force x perpendicular distance from the pivot to the line of action of the force

(Nm) M = (N) f x (m) d

moment of a force has a direction, either clockwise or anti-clockwise

when an object is balanced, the sum of clockwise moment is equivalent to the anti-clockwise moment



Changes in size/shape of an object

Examples: kneading plasticine

when we apply a force to knead plasticine, the shape of the plasticine changes

moulding clay

when we mould a lump of wet clay, the size and shape of the clay changes

Changes in pressure of an object

Pressure is an effect of force acting on an object and is defined as the amount of force acting per unit area

Examples:

we use our fingers to apply force on the head of a pin. A large pressure is created at the sharp point. This allows the pin to pierce through paper and wooden boards.

The spikes on the soles of football shoes have a small area. The large pressure produced by the spikes increases the shoes' grip on the ground.

The cutting edges of knives and scissors have very small areas. A small force produces a large pressure on the cutting edges. This allows the edges to cut through objects easily.

Stiletto heels often leave unsightly marks in carpets. This is because the weight of the wearer exerts a large pressure on a small area of ground.

When we hammer a nail, we may accidentally hammer our finger. This causes a large force to act on a small area of our finger. The large pressure on our finger bursts the blood vessels and produces a bruise.

When a car tyre rolls over the sharp pointed end of a nail, the nail exerts a large pressure on the tyre as the tip of the nail has a very small area. This may puncture the tire.

Calculating pressure

(Pa) Pressure = Force (N) / area (m²)

Pressure in liquids

The greater the depth, the higher the pressure. This is because at a greater depth, there is a greater amount of water above a specific point as compared to a part that is at a shallower depth. The greater amount of water results in a larger weight of water above that point, hence force exerted is greater.

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Examples:

Building water supply

- water is delivered to and stored in tanks at the top of most high rise buildings
- this causes water in pipes below the tanks to be at a higher pressure and ensures that water flows to the units down

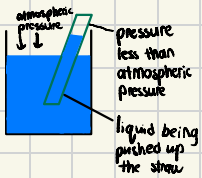
Submarine

- Submarines dive very deep underwater where there is high pressure
- a strong submarine body is needed to withstand the high pressure
- submarine have a depth limit to ensure that it keeps to a safe depth where the pressure is not high enough to damage the submarine or cause an implosion

Atmospheric pressure

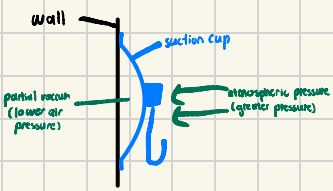
- the earth is surrounded by a layer of air (molecules) called the atmosphere
- although we cannot see or feel the air molecules, they take up space and have weight
- thus, the atmosphere exerts a pressure on the Earth's surface and on us
- the pressure exerted by the air in the earth's atmosphere is called atmospheric pressure
- atmospheric pressure is approximately 100 000 Pa at sea level, and decrease with increasing height from sea level

Example 1 - drinking straw



- when we suck through a straw, we are reducing the pressure in the straw
- this causes a pressure difference to be set up between the straw and the atmosphere
- as the atmospheric pressure is greater, it pushes on the surface of the liquid, forcing the liquid to rise up the straw into our mouth

Example 2 - suction cup



- when we press a suction cup against a flat surface, air is pushed out from under the cup
- this reduces the air pressure between the cup and the wall
- the atmospheric pressure around the suction cup is higher than inside the cup and hence holds it in place

Transfer of energy due to application of forces

- energy is transferred when a force applied causes an object to move in the same direction as the force
- when energy is transferred, work is done through application of the force
- SI unit of energy and work done: Joule (J)
- conditions for work done: 1) a force is applied on the object
  2) object moves
  3) object moves in the same direction as force applied
- work done by a constant force on an object is the product of the force and the distance moved by the object in the direction of the force
- formula for work done: $W = F \times s$ (W in J, F in N, s in m)

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Forms of energy

kinetic energy (KE) – energy of a body due to its motion

potential energy – stored energy in a system due to the state, shape or position of the system
- chemical potential energy (CPE)
- gravitational potential energy (GPE)
- elastic potential energy (EPE)

chemical potential energy – the energy stored in substance due to the position of of the atoms or electrons in the substance. Sources include food, fossil fuels and batteries

gravitational potential energy – the energy stored in a body due to its height from the ground

elastic potential energy – the energy stored in a body due to its elastic deformation
eg. a spring or rubber band possesses elastic potential energy when it is compressed or stretched

electrical energy (EE) – the energy of an electric charge due to its motion and position

light energy (LE) – light is an electromagnetic wave that is visible to the eye

thermal energy (TE) – the energy stored in a body due to its temperature

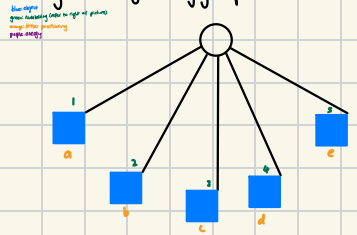
nuclear energy (NE) – the energy released during a nuclear reaction. There are two types of nuclear energy – nuclear fusion and nuclear fission

Principle of conservation of energy

- states that energy cannot be created or destroyed, but can be converted from one form to another. The total energy in an isolated system is constant
- the total energy in the system remains the same; energy is only converted from one form to another or transferred from one body to another

Examples of energy conversion

a) sitting on a swing (or swinging a pendulum)



1. at its highest point, a, the swing has gpe only
2. at b, some of the gpe of the swing at a is converted to ke
3. at its lowest point, c, all the gpe of the swing at a is now converted to ke
4. at d, some of the ke of the swing at c is converted back to gpe
5. ke of the swing moves the swing to e. Here, the swing has gpe only

gravitational potential energy (a to c / e to c) → kinetic energy (c to e / c to a) → gravitational potential energy

* when there is no air resistance, all gpe will convert to ke and back to gpe ∴ pendulum goes on forever
with air resistance, energy is lost to surroundings and pendulum will eventually stop

b) Hammering a nail

- a hammer possesses gpe when it is in a raised position
- as the hammer falls, gpe is converted to ke

- the force is used to do work by driving the nail into wood. In the process, thermal and sound energy are also produced.

c) Burning of fossil fuels

- fossil fuels such as charcoal contain cpe
- as the charcoal burns, cpe is converted to thermal and light energy
- the thermal energy is used to cook food

How is work done related to kinetic energy?

- a stationary object does not have kinetic energy, while a moving object does
- a force needs to be applied to make a stationary object move, and the force does work on the object causing it to move
- the object gains kinetic energy because of the work done on it by the force
- kinetic energy of an object depends on its mass and the speed at which it is moving
- kinetic energy of an object: $KE = \frac{1}{2}mv^2$ (KE in J, m in kg, v in m/s)

How is work done related to gravitational potential energy?

- an object held above the ground has a gravitational potential energy, which is due to it's position above the ground.
- gpe can be converted to KE when the object is released and allowed to fall to the ground
- gpe of an object depends on its mass, the height of the object above the ground and the gravitational field strength. We consider the work done in lifting an object of mass, m, vertically to a height, h, above the ground.

gpe of an object: $gpe = mgh$ (gpe in J, m in kg, g in m/s² or N/kg, h in m)

*note: gravitational field strength on Earth is taken as 10m/s²

What are the sources of energy that we use?

non-renewable sources of energy

- non-renewable sources of energy are energy that are finite and will run out one day
- much of the energy we use today come from non-renewable sources
- fossil fuels such as crude oil, coal and natural gas are non-renewable sources of energy. Fossil fuels are formed by the remains of dead plants and animal, which takes millions of years to form

renewable sources of energy

- renewable sources of energy are sources of energy that can be reused or renewed indefinitely
- unlimited supplies or new growth of organisms allow us to use these sources of energy continuously
- examples include biofuels, geothermal energy, solar energy, wind energy and hydroelectric energy

Fossil fuels - non-renewable

- petrol is a fuel for cars and motorcycles, while diesel is a fuel for buses, vans and lorries
- kerosene and natural gas are fuels for cooking
- most power stations generate electrical energy by burning coal or natural gas

energy conversion: chemical potential energy in coal is converted to thermal energy as it burns, which is converted to thermal energy as it burns, which is converted to kinetic energy of steam to drive the turbine generate electrical energy cpe → te → ke → ee

impact: produces carbon dioxide gas which is a greenhouse gas that traps heat from the sun in the earth's atmosphere. This will result in global warming. ✗

solar energy - renewable

- energy in sunlight can be directly converted into electrical energy by photovoltaic or solar cells
- the energy in sunlight can be used to heat water, and the heated water can be channeled to drive a turbine to generate electrical energy

energy conversion: light energy from the sun is converted to electrical energy le → ee

impact: - no harmful substances or pollutants are produced when solar cells generate electricity ✓

- sufficient care needs to be taken to reduce the amount of toxic waste generated during the production and disposal of solar panels ✗

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