Chapter 8

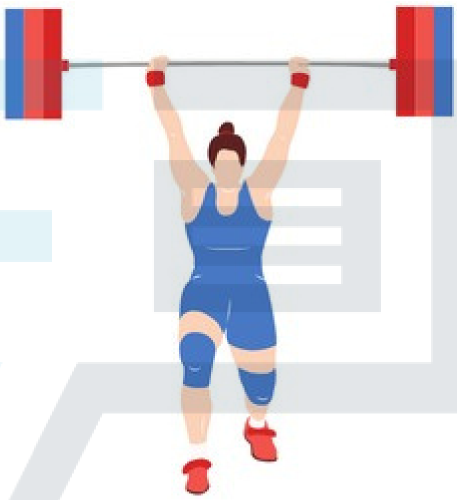
Work and Power

8.1 Work done

1. Work done is the amount of energy transferred.

Work done is the transfer of energy from one system to another or the transformation of energy within a system, typically measured as the product of force and displacement in the direction of the force.

2. Example: Lifting



a. When lifting an object, energy stored in your muscles (chemical energy) is required.

b. The object gains gravitational potential energy (GPE) during the process.

c. Force is applied to convert the chemical energy into gravitational potential energy.

3. Factors affecting the amount of energy transferred by a force are:

   a. The size of the force – the greater the force, the more work it does

   b. The distance moved in the direction of the force – the further it moves, the more work it does

8.2 Calculating work done

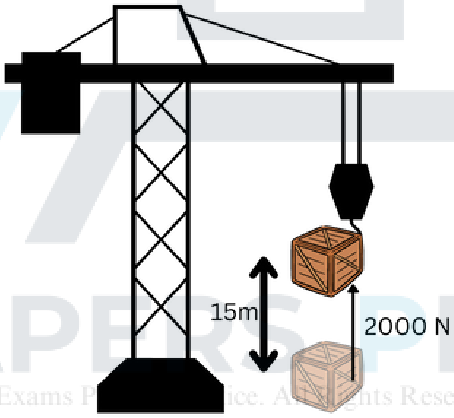
1. Work done equation:

Work done = Force x Distance moved by the force in the direction of the force
Work done = energy transferred

Unit: Joules

Worked Example 1:

The crane exerts a force of 2000 N to lift a crate upward by a distance of 15 meters.



a. How much work is done by the force?

b. How much energy is transferred to the crate?

Worked Example 2:

The child slides down the ramp due to gravity.

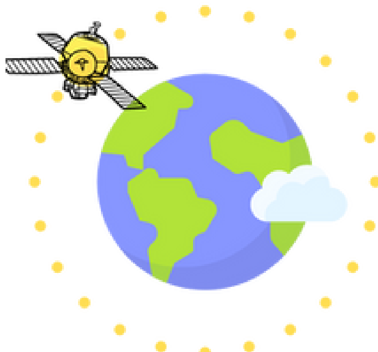
Hence, when computing the work done, it is crucial to consider the vertical distance *h*, as this represents the distance traveled in the direction of the force, such as when a child slides down a ramp under the influence of gravity.

2. Examples to illustrate forces that do no works:

a. Sitting on a chair

Explanation: The forces of gravity pulling downward and the upward contact force from the chair do not cause any movement. When sitting on a chair, there is no change in your energy level due to these forces.

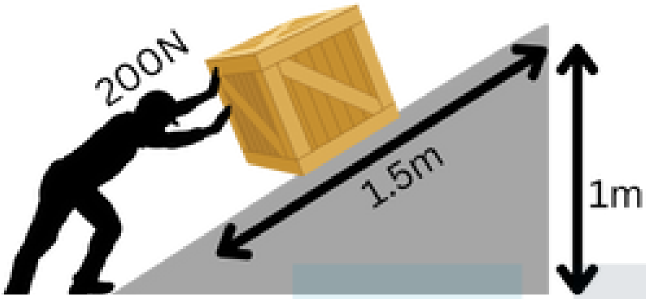
b. A spacecraft is travelling around the Earth in a circular orbit.



Explanation: Gravity exerts a force towards the center of the Earth, but if there is no movement in the direction of this force, gravity does not perform any work.

Worked Example 3:

A construction worker can provide a maximum pushing force of 200 N. To move a box weighing 100N onto a platform, he uses a plank as a ramp.



a. How much work does she do in raising the box?

b. How much g.p.e does the box gain?

Worked Example 4:

A 1kg durian falls from a tree and lands on the ground 5m below.

a. What force is attracting the durian, and what is its magnitude?
b. Determine the amount of work done by gravity on the durian during its descent.
c. Identify the type of energy transfer occurring during this process.

8.3 Power

1. Power is the rate at which work is done or energy is transferred or converted, measured as the amount of energy per unit time.

8.4 Calculating Power

1. Equations for Power:

$P = \frac{W}{t}$
$P = \frac{\Delta E}{t}$

2. Power is quantified in watts (W). A watt corresponds to the power generated when one joule of work is completed per unit time.
3. The concept of power can be extended to various energy transfers, such as in the case of electricity.
4. We can express the efficiency of any energy-changing device in terms of the power it supplies:

Efficiency = Useful power output / Total power input

Worked Example 5:

A train with a mass of 30,000 kg accelerates from rest to a speed of 45 m/s in 15 seconds. What is the power exerted by the train during this acceleration?

Past Year Question (1)

Fig. 2.1 shows a conveyor belt transporting a package to a raised platform. The belt is driven by a motor.

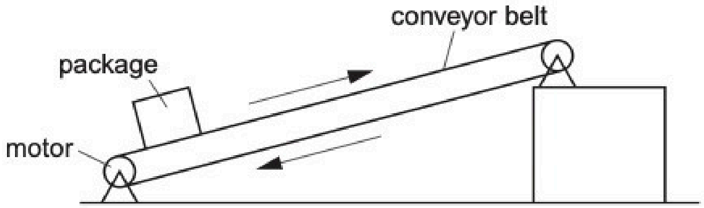


Fig. 2.1

(a) The mass of the package is 36 kg.

Calculate the increase in the gravitational potential energy (g.p.e.) of the package when it is raised through a vertical height of 2.4 m.

increase in g.p.e. = ... [2]

(b) The package is raised through the vertical height of 2.4 m in 4.4 s.

Calculate the power needed to raise the package.

power = ... [2]

(c) The electrical power supplied to the motor is much greater than the answer to **(b)**.

Explain how the principle of conservation of energy applies to this system.

....

....

.... [2]

(a	*mgh* OR 36 × 10 × 2.4	[1]
	864 J OR N m (2 or 3 sig. figs.)	[1]
(b)	(*P* =) *E*/*t* in any form, words, symbols or numbers OR 864 / 4.4	[1]
	196 W OR J / s (2 or 3 sig. figs.)	[1]
(c)	evidence that candidate understands the principle of energy conservation, expressed in words or as an equation (e.g. total energy is constant OR initial energy = final energy) or implied by statement accounting for difference	[1]
	some energy is dissipated into the surroundings OR difference due to increase in internal energy/heating/thermal energy (of belt, motor, surroundings) owtte note: do not accept kinetic energy / sound / friction if no mention of heating	[1]
(d)	increase in potential energy of mass is greater OR work done/energy used (to raise mass) is greater	[1]
	t = *E*/*P* OR *P* = *E*/*t* in any form, words or symbols AND power is constant	[1]
	speed reduced / time taken is longer	[1]

[Total: 9]

Past Year Question (2)

An electric train is initially at rest at a railway station. The motor causes a constant force of 360 000 N to act on the train and the train begins to move.

(a) State the form of energy gained by the train as it begins to move.

....[1]

(b) The train travels a distance of 4.0 km along a straight, horizontal track.

(i) Calculate the work done on the train during this part of the journey.

work done = ...[2]

(ii) The mass of the train is 450 000 kg.

Calculate the maximum possible speed of the train at the end of the first 4.0 km of the journey.

maximum possible speed = ...[3]

(iii) In practice, the speed of the train is much less than the value calculated in **(ii)**.

Suggest **one** reason why this is the case.

....

....[1]

(c) After travelling 4.0 km, the train reaches its maximum speed. It continues at this constant speed on the next section of the track where the track follows a curve which is part of a circle.

State the direction of the resultant force on the train as it follows the curved path.

....[1]

[Total: 8]

(a	kinetic (energy)	B1
(b) (i)	(work done =) $F \times x$ in any form: words, symbols, numbers	C1
	1.4×10^9 J	A1
(ii)	work done = kinetic energy OR $\frac{1}{2}mv^2$ seen	C1
	$(v^2 =) 2WD \div m$ OR $2 \times 1.4(4) \times 10^9 \div 4.5 \times 10^5$ OR 6400	C1
	80 m / s ecf **(i)**	A1
(iii)	(work done against) friction / (air) resistance / drag ACCEPT energy converted to thermal energy	B1
(c)	perpendicular (to curved path) OR centripetal OR towards centre (of circle)	B1
		[Total: 8]

Past Year Question (3)

Fig. 3.1 shows a skier taking part in a downhill race.

Fig. 3.1

(a) The mass of the skier, including his equipment, is 75 kg. In the ski race, the total vertical change in height is 880 m.

Calculate the decrease in the gravitational potential energy (g.p.e.) of the skier.

decrease in g.p.e. = ...[2]

(b) The skier starts from rest. The total distance travelled by the skier during the descent is 2800 m. The average resistive force on the skier is 220 N.

Calculate

(i) the work done against the resistive force,

work done = ...[2]

(ii) the kinetic energy of the skier as he crosses the finishing line at the end of the race.

kinetic energy = ...[2]

(c) Suggest why the skier bends his body as shown in Fig. 3.1.

....[1]

[Total: 7]

(a	(g.p.e.=) mgh OR 75 × 10 × 880 = 6.6×10^5 J / Nm OR 660 kJ / kNm	C1
(b)	(work =) Fs / Fd OR 220 × 2800 = 6.2×10^5 J / Nm OR 620 kJ / kNm	C1
(ii)	answer to **(a)** – answer to **(b)(i)** e.g. (k.e.=) $6.6 \times 10^5 - 6.2 \times 10^5 = 4.0 \times 10^4$ J OR 44 kJ OR $6.6 \times 10^5 - 6.16 \times 10^5 = 4.0 \times 10^4$ J OR 44 kJ	C1
(c)	(to go faster by) reduced air resistance / drag / resistive force OR to lower centre of mass OR increase stability / balance	

[Total: 7]