

Gravitational Potential Energy

Mark Scheme



www.scienceexamssorted.co.uk

1. Gravitational potential energy is simply the energy an object has due to its height above the ground.

a) An object has a mass of 5 kg and a gravitational potential energy of 500 J.

If the gravitational field strength is 10 N/kg, at what height is the object located?

A – is the only correct answer.	1 mark
	Total: 1 mark

b) If the height of an object is doubled while its mass remains constant, what happens to its gravitational potential energy?

C – is the only correct answer.	1 mark
	Total: 1 mark

c) A tennis ball is dropped from a height.

C – is the only correct answer.	1 mark
	Total: 1 mark

d) The figure below shows a hydroelectric system in a hilly region.

D – is the only correct answer.	1 mark
	Total: 1 mark

e) A drone with a gravitational potential energy of 120 J is hovering at a height of 6 m.

B – is the only correct answer.	1 mark
	Total: 1 mark

f) A crane lifts a 500 kg steel beam from the ground to a height of 20 m.

C – is the only correct answer.	1 mark
	Total: 1 mark

(Total for Question 1 is 6 marks)

2. Calculate the gravitational potential energy for each of the following questions.

- a) A cat with a mass of 4 kg climbs a tree to a height of 3 m.
Calculate the gravitational potential energy gained by the cat.

$E_p = 4 \times 9.8 \times 3$	1 mark
$E_p = 117.6 \text{ J}$	1 mark
	Total: 2 marks

- b) A box of mass 0.5 kg is lifted 1.2 m onto a table.
Calculate the gravitational potential energy stored in the box.

$E_p = 0.5 \times 9.8 \times 1.2$	1 mark
$E_p = 5.88 \text{ J}$	1 mark
	Total: 2 marks

- c) An elevator lifts a person with a mass of 70 kg through a vertical height of 20 m.
Calculate the increase in gravitational potential energy.

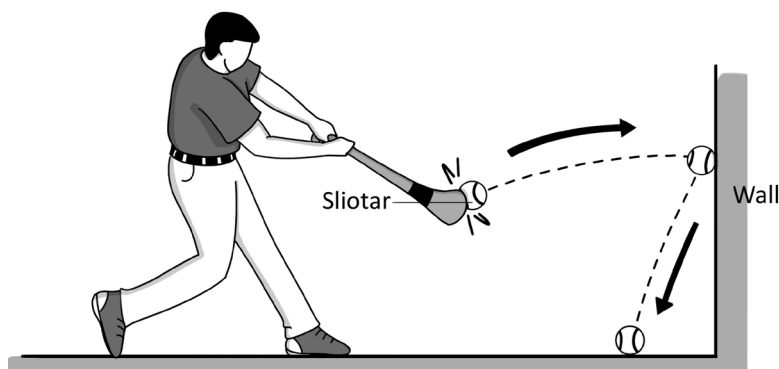
$E_p = 70 \times 9.8 \times 20$	1 mark
$E_p = 13720 \text{ J}$	1 mark
	Total: 2 marks

- d) A 2500 kg roller coaster carriage is raised 40 m to the top of the first drop.
Calculate the gravitational potential energy gained.

$E_p = 2500 \times 9.8 \times 40$	1 mark
$E_p = 980000 \text{ J}$	1 mark
	Total: 2 marks

(Total for Question 2 is 8 marks)

3. The figure below shows a sliotar (ball) being hit against a wall.



- a) The ball gains 5.5 J of gravitational potential energy as it rises from the fielder's hand to its maximum height. The sliotar has a mass of 110 grams. Calculate the maximum height reached by the ball.

Gravitational field strength = 10 m/s^2

Use the equation:

$$\text{GPE} = m \times g \times \Delta h$$

$5.5 = 0.11 \times 10 \times h$	1 mark
$h = 5.5 \div 1.1$	1 mark
$h = 5.0 \text{ m}$	1 mark
	Total: 3 marks

- b) Calculate the kinetic energy of the sliotar when it is travelling at a velocity of 20 m/s.

$E_k = 0.5 \times 0.11 \times 20^2$	1 mark
$E_k = 22 \text{ J}$	1 mark
	Total: 2 marks

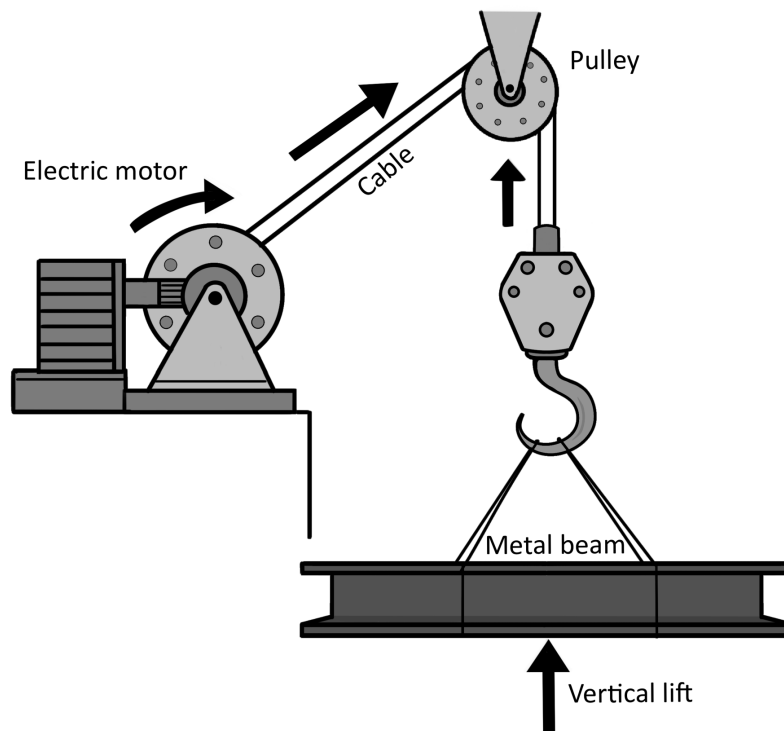
- c) The actual height reached by the ball is slightly less than the height calculated in part (a).

Suggest **one** reason why.

A suggestion to include one of the following:	
Energy is transferred to the thermal store of the surroundings / ball.	1 mark
Allow: transferred as heat or sound.	
Energy is lost due to air resistance.	1 mark
	Total: 1 mark

(Total for Question 3 is 6 marks)

4. An electric motor is used to lift a metal beam vertically. The figure below shows the motor in action.

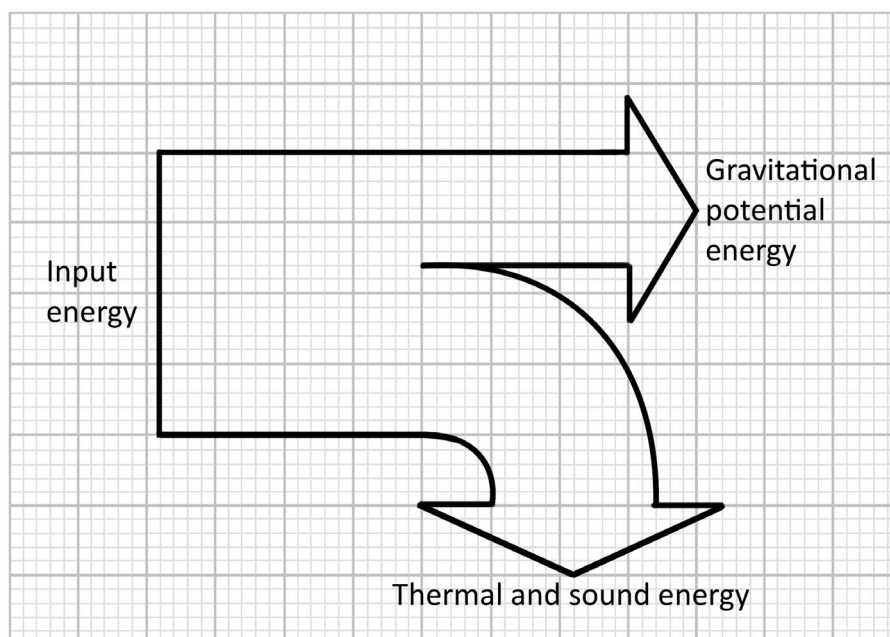


- a) The motor has a power rating of 2.5 kW. The motor runs for 4 seconds.

Calculate the total energy supplied to the motor in this time.

Power = 2500 W	1 mark
Energy = $2500 \times 4 = 10\,000$ J	1 mark
	Total: 2 marks

- b) The figure shows a Sankey diagram representing the energy transfer of the motor. The useful energy output is gravitational potential energy (GPE). The wasted energy is transferred as sound and thermal energy.



Using your answer from part (a) and the Sankey diagram, calculate the value of the gravitational potential energy.

Useful energy is 8 small squares (out of 10 total input squares).	1 mark
$(8 \div 10) \times 10000 = 8000 \text{ J}$	1 mark
	Total: 2 marks

- c) The metal beam has a mass of 85 kg.
Using the gravitational potential energy calculated in part (b), determine the height the beam was lifted. Gravitational field strength = 9.8 N/kg

$8000 = 85 \times 9.8 \times h$	1 mark
$h = 8000 \div 833$	1 mark
$h = 9.6 \text{ m}$	1 mark
	Total: 2 marks

- d) The motor is very noisy when it lifts the beam.
Explain how the Sankey diagram above would change if the motor were lubricated and replaced with a quieter model.

An explanation to include the following:	
The wasted energy (thermal and sound) arrow would become narrower / thinner.	1 mark
Allow: less energy wasted as heat and sound.	
The useful energy (GPE) arrow would become wider / thicker.	1 mark
Allow: the efficiency would increase.	
	Total: 2 marks

(Total for Question 4 is 9 marks)

5. An electric crane is used on a building site to lift a pallet of bricks from the ground to the top of a wall. The figure below shows the crane lifting the pallet of bricks.

- a) State the **equation** linking gravitational potential energy, mass, gravitational field strength and height.

Gravitational potential energy = mass $\times$ gravitational field strength $\times$ height	1 mark
Accept any correct version of this equation.	
	Total: 1 mark

- b) The pallet of bricks has a mass of 150 kg.

Calculate the increase in gravitational potential energy when the crane lifts the pallet to a vertical height of 12 m.

$E_p = 150 \times 9.8 \times 12$	1 mark
$E_p = 17\,640\text{ J}$	1 mark
	Total: 2 marks

- c) It takes 24 seconds for the crane to lift the bricks to the top of the wall.

Calculate the useful power output of the motor during this lift.

Power = (energy $\div$ time) $\times$ 100	
Power = $17640 \div 24$	1 mark
Power = 735 W	1 mark
	Total: 2 marks

- d) The electric motor is supplied with more power than you calculated in part (c).

Explain why the input power must be higher than the useful output power.

An explanation to include:	
Some energy is lost or wasted to the surroundings (as thermal energy or sound)	1 mark
Total energy input must equal useful energy output plus wasted energy output.	1 mark
	Total: 2 marks

- e) Suggest **one** way the efficiency of the crane motor could be increased.

Lubricate or oil the moving parts / crane cable.	1 mark
	Total: 1 mark

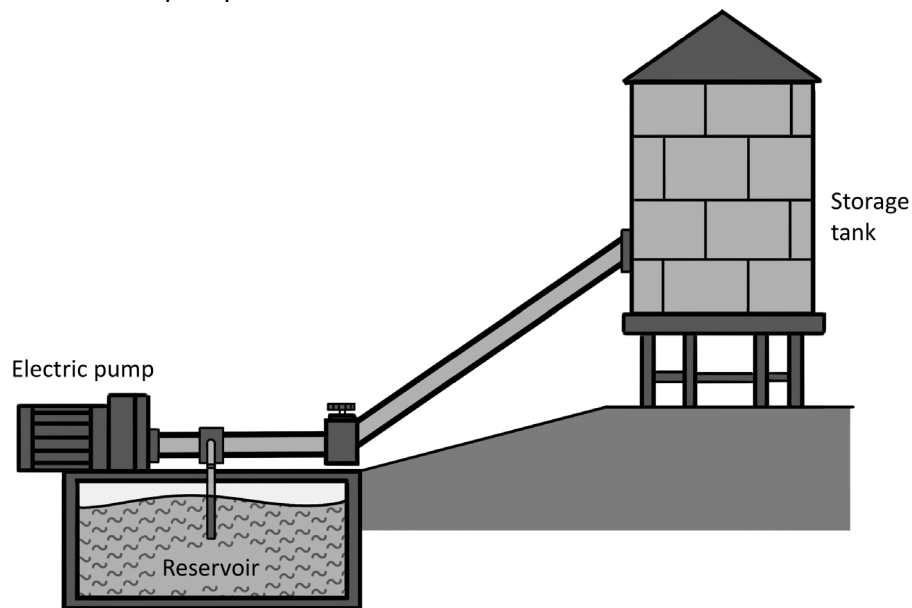
- f) The crane motor operates at a constant power output.

Explain how this increase in mass affects the time taken to lift the load.

The work done / energy required to lift the load doubles (because mass doubles)	1 mark
Power is the rate of energy transfer ($P = E \div t$)	1 mark
Therefore the time taken must also double / increase.	1 mark
	Total: 3 marks

(Total for Question 5 is 11 marks)

6. An electric water pump is used to raise water from a reservoir into a high storage tank. The figure below shows the pump and reservoir.



The pump is connected to a 230 V mains supply and draws a current of 8.0 A. The pump runs for 2.5 minutes.

In this time, it pumps a volume of 1.8 m^3 of water. The pump has an efficiency of 72%. Calculate the vertical height the water is lifted.

Gravitational field strength = 9.8 N/kg . Density of water = 1000 kg/m^3

$P = V \times I$	$P = 230 \times 8.0$	$P = 1840 \text{ W}$	1 mark
$t = 2.5 \times 60 = 150 \text{ s}$			1 mark
$E = P \times t$	$E = 1840 \times 150$	$E = 276\,000 \text{ J}$	1 mark
Useful energy = $276000 \times 0.72 = 198720 \text{ J}$			1 mark
$m = 1000 \times 1.8 = 1800 \text{ kg}$			1 mark
$198720 = 1800 \times 9.8 \times h$			
$h = 11.3 \text{ (m)}$			1 mark
			Total: 6 marks

(Total for Question 6 is 6 marks)