Cambridge Assessment International Education

Teaching Pack

Energy transfer in a falling object

Cambridge IGCSE™ Combined Science 0653

This *Teaching Pack* can also be used with the following syllabuses:
- Cambridge IGCSE™ (9–1) Physics **0972**
- Cambridge IGCSE™ (9–1) Co-ordinated Sciences (Double Award) **0973**
- Cambridge IGCSE™ Combined Science **0653**
- Cambridge IGCSE™ Physical Science **0652**
- Cambridge O Level Physics **5054**

Version 1.0

Cambridge Pathway

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Introduction

This pack will help you to develop your learners' experimental skills as defined by assessment objective 3 (AO3 Experimental skills and investigations) in the course syllabus.

> **Important note**
> Our *Teaching Packs* have been written by **classroom teachers** to help you deliver topics and skills that can be challenging. Use these materials to supplement your teaching and engage your learners. You can also use them to help you create lesson plans for other experiments.
>
> ***This content is designed to give you and your learners the chance to explore practical skills. It is not intended as specific practice for Paper 5 (Practical Test) or Paper 6 (Alternative to the Practical Test).***

There are two options for practising experimental skills. If you have laboratory facilities this pack will support you with the logistics of running the experiment. If you have limited access to experimental equipment and/or chemicals, this pack will help you to deliver a virtual experiment.

This is one of a range of *Teaching Packs*. Each pack is based on one experiment with a focus on specific experimental techniques. The packs can be used in any order to suit your teaching sequence.

The structure is as follows:

Briefing lesson (1 hour*)
This lesson introduces the focus experimental skills to be developed. It also introduces any content needed for your learners to understand the experiment being carried out in the *Lab lesson*.

↓

Lab lesson (1 hour*)	
Option 1 – run the experiment	**Option 2 – virtual experiment**
This lesson allows the experiment to be run with your learners, providing an opportunity to practise the experimental skills introduced in the *Briefing lesson*.	This lesson allows your learners to complete a virtual experiment, providing an opportunity to practise the experimental skills introduced in the *Briefing lesson*.

↓

Debriefing lesson (1 hour*)
This lesson consolidates and builds on the progress learners have made. In some cases, it will also provide the opportunity to practise extended writing skills.

** the timings are a guide only; you may need to adapt the lessons to suit your circumstances.*

In this pack will find the lesson plans, worksheets for learners and teacher resource sheets you will need to successfully complete this experiment.

Experiment: Energy transfer in a falling object

This *Teaching Pack* focuses on energy transfer in a falling object.

Energy is one of the fundamental concepts in physics. In this experiment, you will investigate how one energy store changes into another energy store by mechanical work. You will also gather some experimental evidence on the big idea: Conservation of energy.

This experiment has links to the following syllabus content (see syllabus for detail):

- P2.2 Energy

The experiment covers the following experimental skills, adapted from **AO3: Experimental skills and investigations** (see syllabus for assessment objectives):

- make and record observations
- interpret and evaluate experimental observations
- evaluate methods and suggest possible improvements

Prior knowledge

Knowledge from the following syllabus topics is useful for this experiment.

- P1.1 Length and time
- P1.2 Motion
- P1.3 Mass and weight
- P1.5 Effects of forces

Going forward

The knowledge and skills gained from this experiment can be used for when you teach learners about 1.7.3 Work.

Briefing lesson: Energy transfer in a falling object

Resources	• Worksheets A, B, C, D and E

Learning objectives	By the end of the lesson: • ***all*** learners should be able to plan an experiment to test the relationship between KE and GPE • ***most*** learners should be able to take into consideration what observations should be made in an experiment • ***some*** learners will be able to create a method that ensures accurate observations are completed safely and support other learners to improve their writing.

Timings	Activity
5 min	**Starter / Introduction** Ask learners to think about the image on Worksheet A. In pairs, or as a small group, can they label where on the diagram each key term applies and then describe why? You may to choose a small selection of learners to share their work.
10 min	**Main lesson** Remind learners of the definition for gravitational potential energy (GPE) of an object as *the stored ability to do work by virtue of its position*. Remind learners that: GPE = mass × gravitational field strength × height GPE = mgh One of the kinds of energy into which potential energy can change is kinetic energy (KE) (energy of motion). Ask learners to think about what variables could be measured to calculate the KE of an object. You could ask the following: what can be measured for **movement**? (*speed*) What fundamental property can be measured about an **object**? (*mass*). Also remind learners that KE = ½mass × (speed)^2
10 min	Give learners Worksheet B and ask them to identify the pros and cons of using each of the objects shown in an experiment. Then learners should plan an experiment to show the relationship between GPE and KE using Worksheet C, Worksheet D and Worksheet E.
25 min	Learners should work individually to plan their experiment using Worksheet D or Worksheet E depending on the level of support they need. Worksheet C shows the equipment they can pick from. As well as the method, they are required to note down what observations should be recorded and how they should do this.
10 min	**Plenary** Ask your learners to swap their plans on Worksheet C or Worksheet D. They should review each other's work and provide feedback: 1. Could they follow their partner's method? Explain why / why not. 2. Is it clear what measurements are needed and how to do them? 3. Has safety been considered in the method? 4. Has accuracy been taken into account for the measurements? Ensure learners act on the feedback from their peer reviewer and update their work.

Lab lesson: Option 1 – run the experiment

Resources	• Teacher notes • *Teacher Walkthrough* video • Worksheets D, E, F and G • Equipment as outlined in the notes

Learning objectives	By the end of the lesson: • ***all*** learners should recognise that gravitational potential energy is transferred into kinetic energy during free fall as gravitational force does some mechanical work • ***most*** learners should apply the principle of conservation of energy to a falling object, considering the changes both in gravitational potential energy and kinetic energy • ***some*** learners should recall and use the expressions: KE = ½mv^2 and the change in gravitational potential energy = $mg\Delta h$, in the context of free fall.

Timings	Activity
5 min	**Starter/Introduction** Learners should compare their method on either Worksheet D or Worksheet E to the one given.
40 min	**Main lesson** Give learners the method on Worksheet F. Provide assistance where necessary to lower ability learners. Learners should work in groups (of two or three suggested). Make sure that the data logger connected to the light gate is set up to measure the speed of a 5 cm card. **Safety** Circulate the classroom at all times during the experiment so that you can make sure that your learners are safe and that the data they are collecting is accurate.
15 min	**Plenary** Give learners Worksheet G and ask learners to work in their groups. You can choose whether to go through the answers together as a class or get learners to self / peer mark their answers if time permits.

Teacher notes

Watch the *Teacher Walkthrough* video for energy transfer in a falling object and read these notes.

Each group will require:

- a top-pan balance
- a boss and clamp stand set
- a metre rule
- a ruler
- a pin
- sticky tack
- a 5 cm × 5 cm cardboard square
- a light gate (or photogate head)
- a compatible data logger.

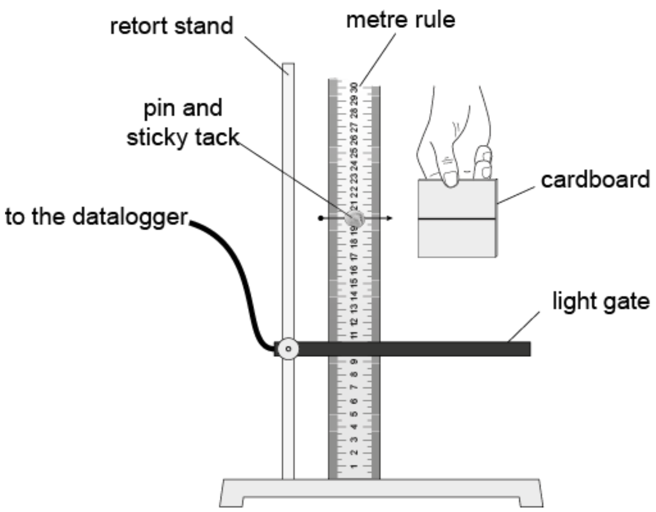
Safety

The information in the table below is a summary of the key points you should consider before undertaking this experiment with your learners.

It is your responsibility to carry out an appropriate risk assessment for this experiment.

Apparatus	Caution
Top pan balance	Do not drop. Do not press on the pan.
Metre rule	Careful as you carry it around. Carry vertically in front of body.
Pin	Pins are sharp.

Experiment set-up



Teacher method

This is your version of the method for this experiment that accompanies the *Teacher walkthrough* video.

Do not share this method with learners. Give them Worksheet F.

Before you begin
Plan how you will group your learners during the experiment session.
Think about:

- the number of groups you will need (group size 2–4 learners)
- if you prefer your students to assemble the apparatus it might be a good idea to have one set up as an example
- preparing enough 5 cm × 5 cm pieces of cardboard.

Experiment
Walk around the learners during the experiment in case they encounter any difficulties.

Steps	Notes
1. Draw a straight line across the middle of the card.	
2. Measure the mass of the card.	*Make sure learners know the importance of zero error and how to eliminate it. Check if the scale setting is in grams.*
3. When setting up the equipment, make sure that: (a) the metre rule is straight the light gate is parallel to the desktop and the beam is at 10.0 cm above the desktop (b) the light gate logger is set to measure the speed of a 5 cm flag (c) the pin is horizontal and at 20.0 cm to start with.	*You may like to see learners using either set squares, a plumb line or a spirit level to check if the rule is vertical.*
4. Align the middle line of the card with the pin.	*Remind learners about the parallax error and how to avoid it.*
5. Hold it at the middle of one edge, keeping it vertical.	
6. Do a minimum of two repeats, giving three sets of data per drop.	*Remind learners of the importance of identifying any outliers during the data collection. Have extra repeats if needed.*

7. Learners should fill in their data table as the data is collected.

8. Increase the height of the pin by 1.0 cm and repeat until learners have collected data from at least seven different heights.

9. Learners should then plot a graph: decrease in GPE on the *x*-axis, and the increase in KE on the *y*-axis.

Clean-up
After the experiment learners should tidy up and return all their apparatus.

Lab lesson: Option 2 – virtual experiment

Resources	• *Virtual Experiment video* for energy from a falling object • Worksheets H, I and J

Learning objectives	By the end of the lesson: • ***all*** learners should recognise that GPE is transferred into KE during free fall as gravitational force does some mechanical work • ***most*** learners should apply the principle of conservation of energy to a falling object, considering the changes both in GPE and KE • ***some*** learners should recall and use the expressions: KE = $\frac{1}{2}mv^2$ and change in gravitational potential energy = $mg\Delta h$, in the context of free fall.

Timings	Activity
5 min	**Starter/Introduction** Learners should compare their method to the one given.
40 min	**Main lesson** Give learners Worksheet H to work through before showing them the Virtual Experiment video. Go through the answers as a class. Now give learners Worksheet I. Learners should answer the questions as they watch the video. The video will stop when learners are required to answer a question. You could make some of the questions the subject of some class / group discussions if time permits.
15 min	**Plenary** Give learners Worksheet J. If time permits, get learners to peer review their answers with each other.

Debriefing lesson: Energy transfer in a falling object

Resources	• Worksheets K and L • For the demo: a top-pan balance, a boss and clamp stand set, a metre rule, a ruler, a pin, sticky tack, a 5 cm × 5 cm cardboard square, a light gate (or photogate head) and a compatible logger to measure the speed.

Learning objectives	By the end of the lesson: • ***all*** learners should be able to interpret and evaluate experimental observations and data to confirm if the conservation of energy principal is observed and suggest possible improvements to their experiment • ***most*** learners should be able to use the extrapolated best fit line to estimate the speed of the object if released from a different height • ***some*** learners will be able to suggest alternative practical settings to investigate the same concept.

Timings	Activity
10 min	**Starter/Introduction** Show the video here: video.nationalgeographic.com/video/i-didnt-know-that/idkt-roller-coaster-testing. This shows how a state-of-the-art roller coaster is rigorously tested every morning in order to be declared fit for use (a higher resolution copy of the video is also at https://youtu.be/3sS4nT5odP4). Discuss the energy involved.
15 min 20 min	**Main lesson** Have one experimental set up ready for demo purposes, or ideally one set up per each group of four students. Either hand out a set of real data or the sample data provided in Worksheet K, to accompany Worksheet L. Learners should work either in groups or individually to answer the questions. Learners will benefit from using the demo settings to try and see the scenarios mentioned in some of the questions. Move around the classroom and get involved with their discussions / work as facilitator. Some learners might not be able to see that increase in KE is always slightly less than the decrease in GPE. You may like to discuss the reasons (some thermal energy due to air resistance, some rotational kinetic energy, and using $10\frac{N}{kg}$ for g rather than $9.81\frac{N}{kg}$, leading to a slightly higher GPE value).
15 min	**Plenary** Ask learners to exchange their completed worksheets. Provide the model answers and ask them to mark each other's work. Allow discussions to happen between them. Move around to check their work. Some learners may need further clarifications on model answers.

Worksheets and answers

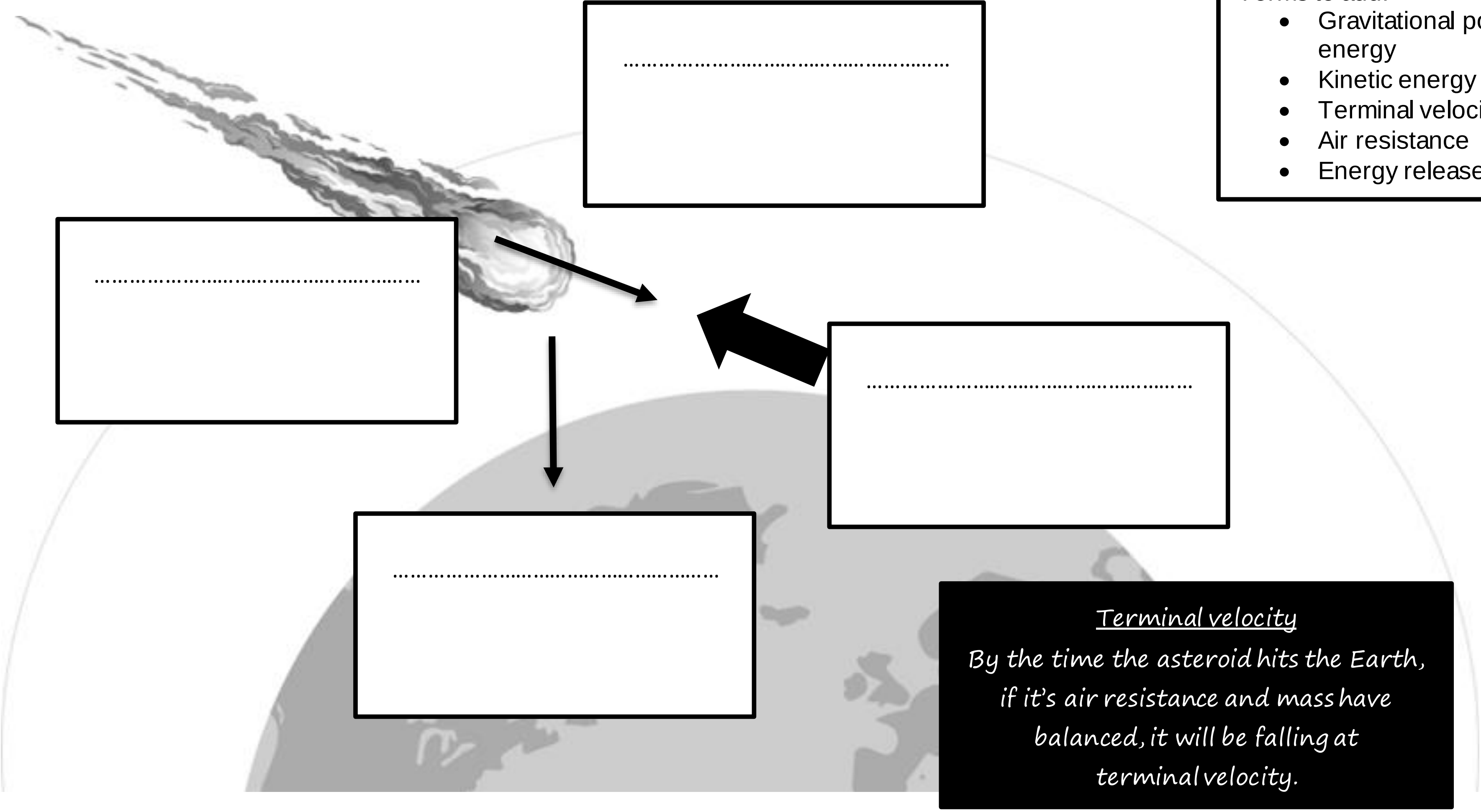
Worksheet A: A falling asteroid

Look at the diagram below which shows an asteroid falling to Earth.

There is a list of labels for you to add to the diagram. For each label add a reason explaining why you have chosen it for that part of the diagram.

The first one has been done for you.

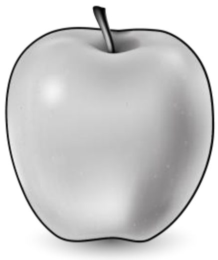
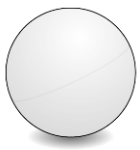
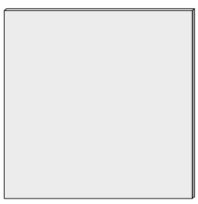
Terms to add:
- Gravitational potential energy
- Kinetic energy
- Terminal velocity
- Air resistance
- Energy released



Worksheet B: Which object to use?

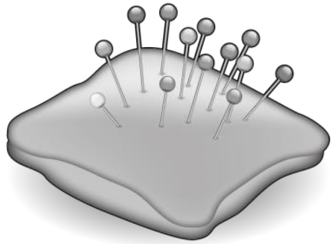
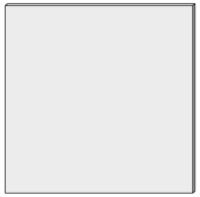
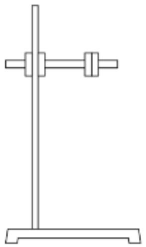
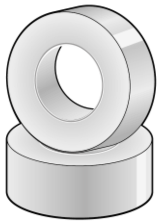
There are different objects in the table below that could be used in an experiment to test the relationship between GPE and KE.

For each one, try to think about the advantages and disadvantages of using each.

Object	Advantages	Disadvantages
 **Apple**		
 **Feathers**		
 **Table tennis ball**		
 **Tennis ball**		
 **A square of cardboard**		

Worksheet C: Equipment

Choose your equipment from the items shown below. You will not need to use them all.

		
tennis ball	**metre rule**	**pins**
		
cardboard square	**marker pen**	**stop clock**
		
reusable adhesive	**retort stand, boss and clamp**	**sticky tape**

Worksheet D: Writing a method

Use the space below to record your method.

An investigation into the relationship between KE and GPE

Equipment	Method and observations
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Don't forget to consider safety precautions

Worksheet E: Writing a method with support

Use the space below to record your method.

An investigation into the relationship between KE and GPE

Equipment	Method and observations
	Think about these questions: 1. How will you measure the speed of the falling object? 2. How will you make your measurements accurate? 3. As well as the speed, what other variable should you measure to calculate the KE? 4. How will you make sure the experiment is safe? 5. How will you vary the PE of the of the object you are dropping?
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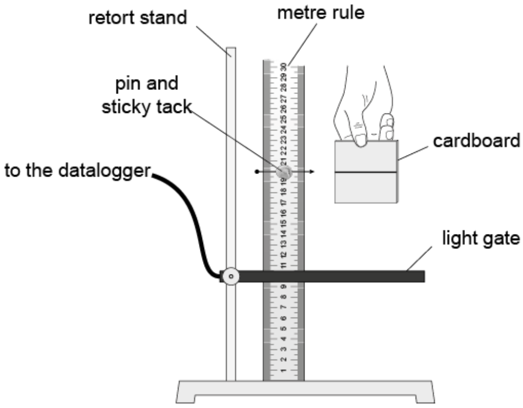
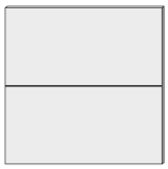
Worksheet F: Method

1. Complete the practical set up as shown on the diagram below.



2. Measure and record the mass of the card. Draw a straight line across the middle as shown below.



3. Hold the card vertical from the centre of one edge and align the straight mid-line of the card with the pin. Drop the card from different heights and measure its speed as it passes through the light gate, which is located at a height of 10.0 cm from the worktop surface. The first height will be 0.200 m. Repeat each drop at least two more times, ideally four more times. Increase the height by 0.010 m.

4. Record all measurements in a suitable table. An example table is provided on the reverse of this worksheet.

5. Use the equation KE = ½ × mass × $(\text{speed})^2$ to calculate the increase in KE.

6. The height difference is the distance between the dropped height and the location of the light gate, 0.100 m. Fill in the height difference column.

7. The decrease in GPE is found from the equation:

   change in GPE = mass × gravitational field strength × height difference

   The gravitational field strength of the Earth can be taken as 10 N/kg.

8. Plot a graph of drop in GPE (*x*-axis) against increase in KE (*y*-axis) and draw a line of best fit.

Worksheet F: Method, continued

Speed / m/s						Increase in KE, $\times10^{-3}$ / J	Pin's position / m	Height difference / m	Decrease in GPE, $\times10^{-3}$ / J
1	2	3	4	5	Average				

Worksheet G: Experiment questions

1. What is the function of the pin attached to the metre rule?

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2. Did the card fall perfectly down without any spinning / rotation? If not, what might be the reason for that?

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3. Comment on the data and the plotted graph.

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4. Energy transformation in between GPE and KE requires some mechanical work done. Describe the force responsible for the transformation in this practical.

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5. Do your findings fully support the conservation of energy? Explain.

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Worksheet H: Background questions

1. What is the name given to the acquired ability to do some work due to height and weight?

   A Kinetic energy
   B Elastic potential energy
   C Thermal energy
   D Gravitational potential energy

2. What is the name given to the acquired ability to do some work due to having mass and speed?

   A Kinetic energy
   B Elastic potential energy
   C Thermal energy
   D Gravitational potential energy

3. Which equation below express the gravitational potential energy (GPE) best?

   A GPE = mass × speed
   B GPE = mass × height
   C GPE = weight × height
   D GPE = mass × $(\text{speed})^2$

4. Which equation below express the kinetic energy (KE) best?

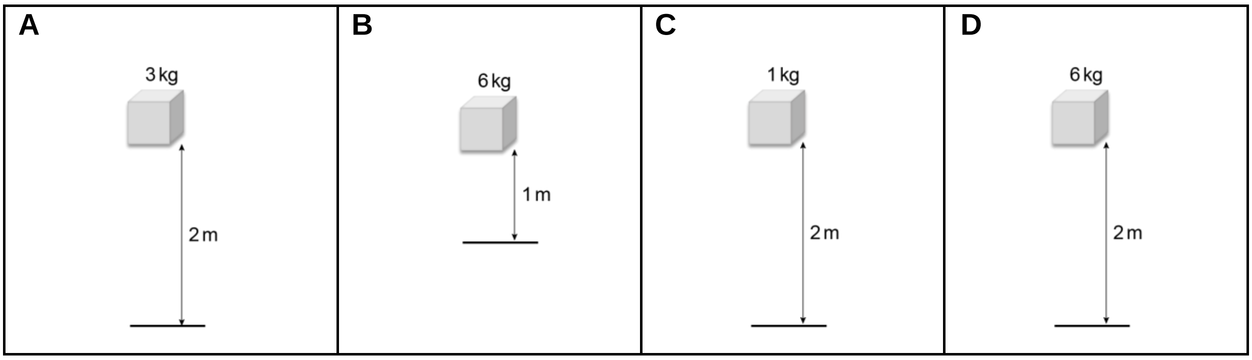
   A KE = mass × speed
   B KE = ½ × mass × $(\text{speed})^2$
   C KE = ¼ × mass × $(\text{speed})^2$
   D KE = mass × $(\text{speed})^2$

5. Which object stores the maximum kinetic energy?

   A 4 kg crate moving at 2 m/s
   B 1 kg bird flying at 4 m/s
   C 4 kg box sliding at 4 m/s
   D 1 kg fish swimming at 4 m/s

Worksheet H: Background questions, continued

6. Which object stores minimum gravitational potential energy on the same planet?



7. As an apple falls from top of the tree to the ground…

   A it speeds up but the amount of gravitational energy it has does not change.
   B its kinetic energy stays the same as it speeds up.
   C its kinetic energy decreases as it speeds up.
   D its kinetic energy increases as it speeds up, (almost) as much as the decrease in it gravitational potential energy.

8. What force is mainly responsible for the energy transformation from KE to GPE and from GPE to KE again, when an object is thrown up in the air until it hits the ground?

   A gravitational force
   B air resistance
   C initial push
   D initial pull

9. Which statement below is the best expression of the *Conservation of Energy* principle?

   A Energy cannot be created or destroyed; it may be transformed from one form into another, but the total amount of energy rarely changes.
   B Energy can be created or destroyed; it may be transformed from one form into another, but the total amount of energy never changes.
   C Energy cannot be created or destroyed; it may be transformed from one form into another, but the total amount of energy never changes.
   D Energy can be created or destroyed; it may be transformed from one form into another, and the total amount of energy always changes.

Worksheet I: Virtual experiment questions

Please read each question and the options carefully, select the best response or write your short answer.

1. What name is given to this principle?

A conservation of mass
B energy principle
C mass-energy theorem
D conservation of energy

2. Mechanical work done on a falling object causes what energy transformation?

A from kinetic energy to gravitational potential energy
B from thermal energy to gravitational potential energy
C from gravitational potential energy to kinetic energy
D from gravitational potential energy to thermal energy

3. Which option gives the correct information for a falling object?

A maximum kinetic energy and maximum gravitational potential energy is achieved at the same time
B when kinetic energy is maximum, gravitational potential energy is minimum
C minimum kinetic energy and minimum gravitational potential energy is achieved at the same time
D when kinetic energy is minimum, gravitational potential energy is minimum

4. Which equation is used by the light gate (photogate) to calculate the speed?

A 5 cm / elapsed time
B 5 m / elapsed time
C elapsed time / 5 cm
D elapsed time / 5 m

5. The main reason we repeat our measurements is

A to decrease the reliability
B to increase the precision
C to increase the reliability
D to decrease the precision

Worksheet I: Virtual experiment questions, continued

6. What variable do we change here? What of the card will change?

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7. What is the physical meaning of gradient being equal to one in this graph?

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8. What is the physical meaning of zero *y*-intercept in this graph?

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9. Why ‘almost’?

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10. Express the speed in terms of *g* and change in height.

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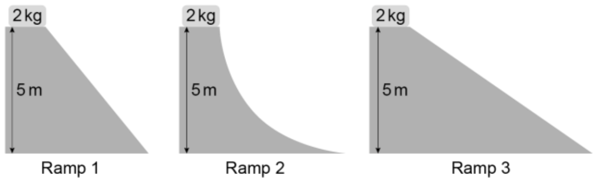
Worksheet J: Applying your knowledge

1. All the ramps below are identical, smooth and 5 m high except for the shape of their inclines. The crates at the top of each ramp are identical, with a mass of 2 kg. Initially, stationary crates are released from the top of the ramps.

   What is the initial GPE of the crates in each case? Show and explain your work.



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2. What will be the kinetic energy of each block at the bottom of each ramp? Explain.

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3. How would your answer to Question 2 change if the ramps were not smooth? Explain.

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4. What would be the maximum speed of a block at the bottom of any ramp? (Ignore any tumbling or rotation of the blocks.)

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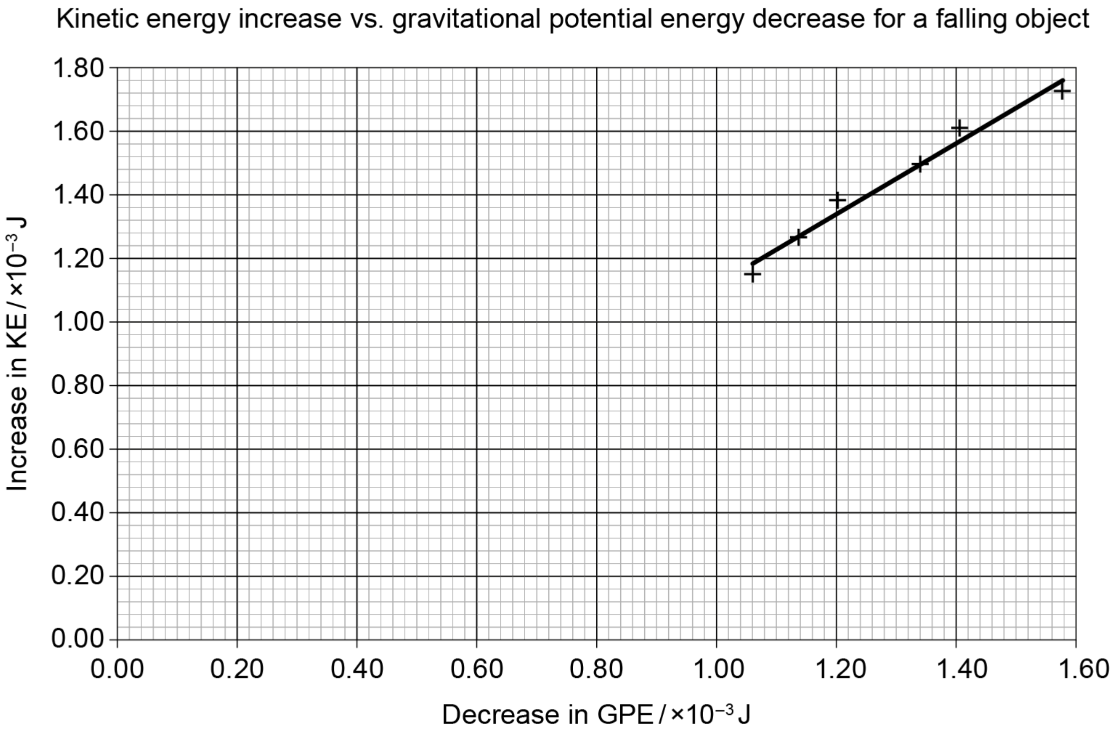
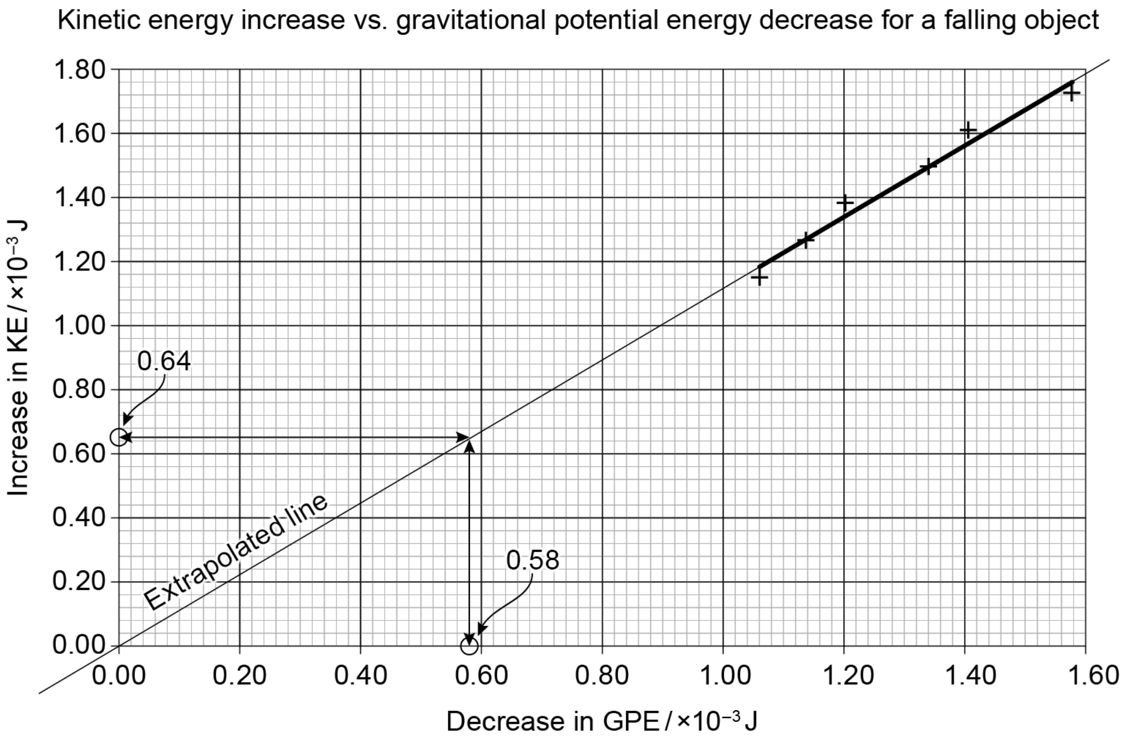
Worksheet K: Sample data

Speed / m/s						Increase in kinetic energy, $\times 10^{-3}$ / J	Pin's position / m	Height difference / m	Decrease in gravitational potential energy, $\times 10^{-3}$ / J
1	2	3	4	5	Average				
1.38	1.36	1.38	1.35	1.32	1.36	1.06	0.200	0.100	1.15
1.41	1.41	1.40	1.40	1.41	1.41	1.14	0.210	0.110	1.27
1.44	1.45	1.45	1.45	1.44	1.45	1.20	0.220	0.120	1.38
1.62	1.51	1.49	1.51	1.50	1.53	1.34	0.230	0.130	1.50
1.56	1.58	1.57	1.55	1.56	1.56	1.41	0.240	0.140	1.61
1.64	1.68	1.65	1.65	1.66	1.66	1.58	0.250	0.150	1.73

Worksheet K: Sample data, continued





Worksheet L: Making sense of data

1. A photogate monitors the motion of objects passing through its gate. When an object breaks the beam, it starts its internal timer and stops when the beam is sensed again at the opposite side of the gate.

   How do you think the data logger can find the speed of the object passing through the photogate?

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2. Why is it important that the card is released vertically for its free fall?

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3. Why is it important that the card is hold in the middle before it is released?

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4. What would you need to change in the data table calculations if the photogate was located at 5.0 cm height rather than 10.0 cm?

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5. What would be the disadvantage of having a range of from 60.0 cm to 67.0 cm as the initial drop height?

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Worksheet L: Making sense of data, continued

6. How do you compare the increase in KE values to decrease in GPE for each drop?

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7. If we ignore some experimental uncertainties, and the energy transformations into other stores such as thermal rotational kinetic energy, do you think your results agree with the conservation of energy principle? Explain briefly.

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8. Evaluate the method used in this investigation and suggest some improvements.

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9. One way of finding out the speed of the card at the end of its fall is using conservation of energy and algebra as follows:

$$mg\Delta h = ½mv^2$$
$$2g\Delta h = v^2$$
$$\sqrt{2g\Delta h} = v$$

   a) Use the above equation to find the speed of the object if the height difference is 0.05 m.

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   b) How would you use the graph to find the speed of the object if the height difference was 0.05 m?

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10. Can you think of alternative settings to investigate the same principle, that is conservation of energy?

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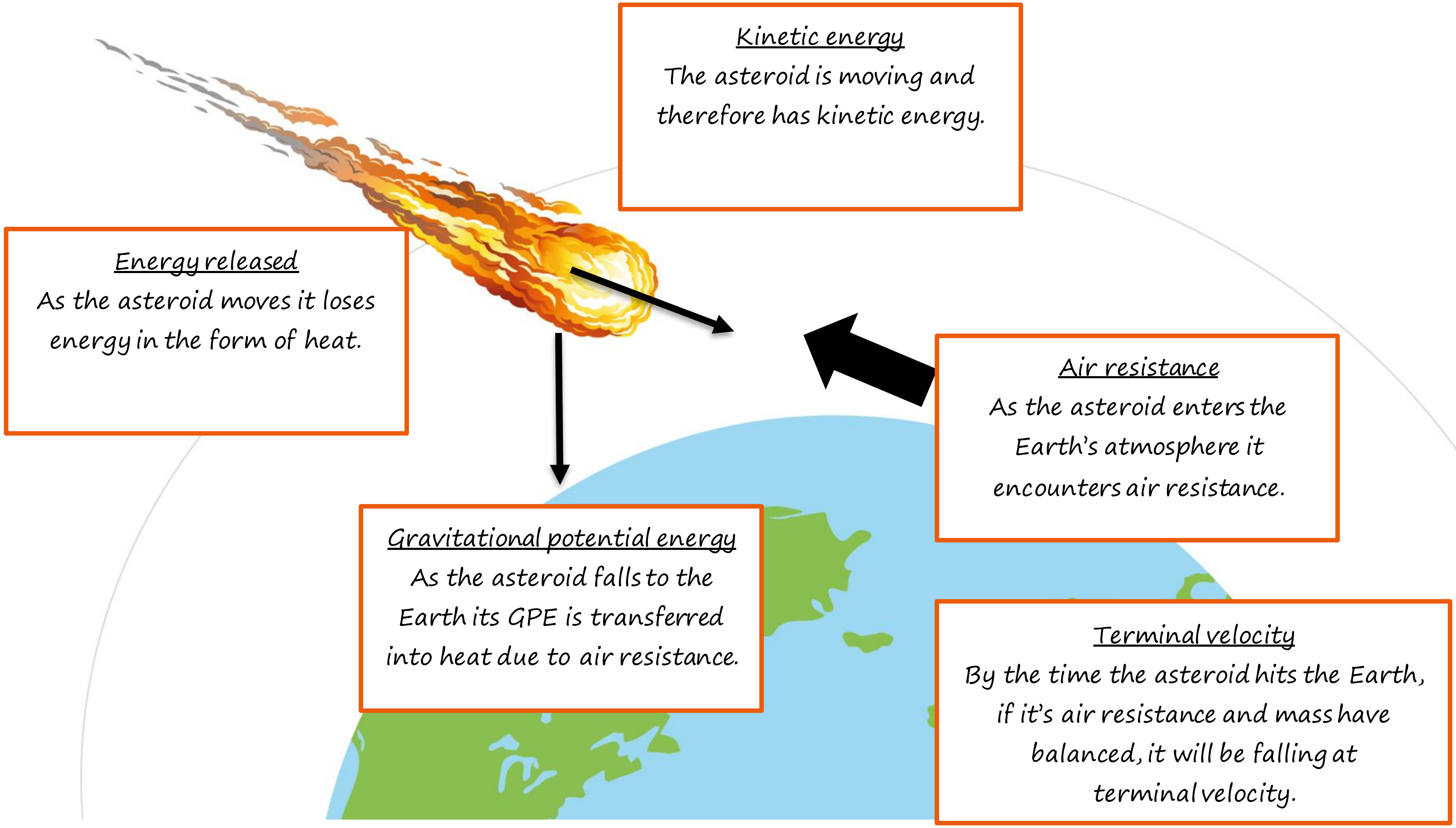
Worksheet A: Suggested answers



Worksheet G: Suggested answers

1. *To make sure that the card is released from the correct height.*

2. *(Very likely 'No')*
    - *The initial release of the card may not be perfectly vertical*
    - *Card may not be held in the middle before the drop*

3. Sensible comments such as: *Linear relationship / Direct proportionality (theoretically expected graph) / increase in KE is almost same as decrease in GPE / Gradient of the graph is almost 1.*

4. *Downward force of gravity is transforming GPE into KE*

5. *If we ignore the small difference between the decrease in GPE and increase in KE, yes. Total energy of the card is GPE plus KE. At the beginning, it is all GPE, at the end, it is all KE. GPE is transformed into KE.*

Worksheet H: Suggested answers

1 **C**
2 **A**
3 **C**
4 **B**
5 **C**
6 **C**
7 **C**
8 **A**
9 **C**

Worksheet I: Suggested answers

1 **D**
2 **C**
3 **B**
4 **A**
5 **C**

6 *Dropped height. Initial gravitational potential energy.*

7 *Change/decrease in GPE is same as change/increase in KE*

8 *When there is no change in GPE, there is no change in KE. Decrease in GPE and increase in KE are directly proportional.*

9 *Some of the initial GPE is transferred into thermal energy to the surrounding. Some is transferred into rotational kinetic energy of the card. However, those values are extremely small due to small mass and possible rotational speed of the card, and negligible air resistance.*

10 $g \times (\text{change in height}) = \frac{1}{2}(\text{speed})^2$

$2 \times g \times (\text{change in height}) = (\text{speed})^2$

$\sqrt{2 \times g \times (\text{change in height})} = \text{speed}$

Worksheet J: Suggested answers

1. Initial GPE is the same for all crates as they have the same mass at the same height

$$GPE = mgh = 2\ kg \times 10\frac{N}{kg} \times 5\ m = 100\ J$$

2. It will be the same for all crates, 100 J.
   The change in GPE is the same for all due to same change in height, 5 m
   We assume that the decrease in GPE will fully transform into increase in KE

3. Some of the initial GPE would transform into thermal energy increase of the surrounding.
   Some would change into sound energy.
   Those transfers are due to resistive forces (doing negative mechanical work on the crate) as the crate slides.
   That means the amount of KE increase would be less.

4. $\frac{1}{2}(\text{mass}) \times (\text{speed})^2 = (\text{mass}) \times (\text{gravitational field strength}) \times (\text{change in height})$

   $(\text{speed})^2 = 2 \times (\text{gravitational field strength}) \times (\text{change in height})$

   $\text{speed} = \sqrt{2 \times (\text{gravitational field strength}) \times (\text{change in height})}$

   $\text{speed} = \sqrt{2 \times 10\frac{N}{kg} \times 5\ m = 10\ m/s}$

Worksheet L: Suggested answers

1. average speed = $\frac{\text{distance travelled}}{\text{elapsed time}}$

   To find the average speed of the card as it passes through the gate, we need to know how much distance passes through and how long it takes). Distance travelled is the length of the card, which is entered to the logger. Elapsed time is measured by the photogate: time between the instant the beam is blocked and the instant the beam is sensed again. The logger can process two pieces of data, as suggested in the equation, to display the average speed. (Since the elapsed time is very small, average speed can be accepted as instantaneous speed.)

2. To minimise the air resistance and the rotation of the card. The length which will block the beam of the photogate is one side of the square surface of the card.

3. To minimise the rotation of the card.

4. The height difference would be calculated as: (pin's position) – (0.05), rather than (pin's position) – (0.10).

5. If the card is allowed to fall for a long distance (or time) the proportion of initial GPE transforming into KE would be less, due to increased amount of possible rotational, thermal and sound energy conversions (It is impossible to measure those stores of energy (thermal, rotational, sound) under school laboratory conditions. The card is more likely to wobble, snag the light gates, or miss them entirely).

6. (Almost equal, but) increase in KE is always slightly less than decrease in GPE.

7. The difference between the decrease in GPE and increase in KE is very small. Additionally, the gradient of the best fit line is very close to one with a y-intercept, which is very close to zero. This shows that total energy of the card at the beginning is same as the total energy of the card at the end.

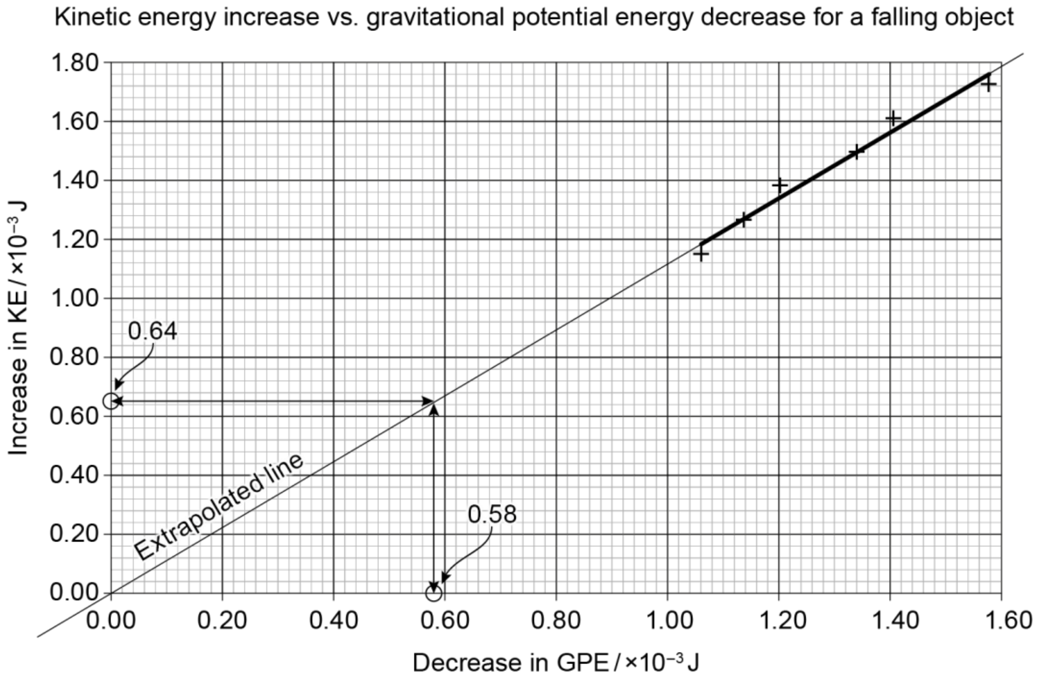
8. Some masses could be attached to the bottom sides of the card symmetrically to minimise the rotation. Or another midline could be drawn to identify where the fingers will be holding the card at the beginning.

Worksheet L: Suggested answers, continued

9. (a) $v = \sqrt{2 \times 10\,\frac{N}{kg} \times 0.05\ m} = 1\ m/s$

(b) $1.15 \times 10^{-3}\ kg \times 10\frac{N}{kg} \times 0.05\ m = 0.58 \times 10^{-3}\ J$

To find the corresponding increase in KE, we first need to extrapolate the best fit line.



Then use this value in KE equation:

$\frac{1}{2}mv^2 = 0.64 \times 10^{-3}\ J \rightarrow v = 1.1\ m/s$

10. Several photogates could be used to measure the speeds at different heights in a single drop and total mechanical energy is found.

A cart is released from the top of an inclined track and its speed is found at the bottom.

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