Past-paper walk-through

Gravitational potential energy and kinetic energy ▪ 5.2

eXercise

Questions in this set

- 9702/11 N25 Q17 ▪ 1 mark
- 9702/11 N25 Q18 ▪ 1 mark
- 9702/12 N25 Q17 ▪ 1 mark
- 9702/12 N25 Q18 ▪ 1 mark
- 9702/14 N25 Q17 ▪ 1 mark
- 9702/14 N25 Q19 ▪ 1 mark
- 9702/11 J25 Q17 ▪ 1 mark
- 9702/12 J25 Q18 ▪ 1 mark
- 9702/13 J25 Q18 ▪ 1 mark
- 9702/13 J25 Q19 ▪ 1 mark

Questions in this set

- 9702/24 J25 Q3 ▪ 11 marks
- 9702/12 M25 Q15 ▪ 1 mark

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = “or words to that effect” – the wording need not match.

Question 17

9702/11 N25 ▪ Q17 ▪ 1 mark

An object with a mass of 100 g falls a vertical distance of 10 m.

What is the change in the gravitational potential energy of the object? **[1]**

A 1 J

B 10 J

C 100 J

D $10\,000$ J

Solution 17

- **A** 1 J
- **B** 10 J ✓
- **C** 100 J
- **D** $10\,000$ J

Why

- Convert the mass first: 100 g $= 0.100$ kg.
- $\Delta E_p = mgh = 0.100 \times 9.81 \times 10 = 9.81$ J.
- That is about 10 J; D comes from leaving the mass in grams.

Question 18

9702/11 N25 ▪ Q18 ▪ 1 mark

A bungee jumper jumps from a platform and is decelerated by an elastic bungee cord, as shown.

When the jumper makes the jump, his initial gravitational potential energy relative to the ground is converted into his kinetic energy and into elastic potential energy in the cord.

At which part of the jump are all three types of energy non-zero? **[1]**

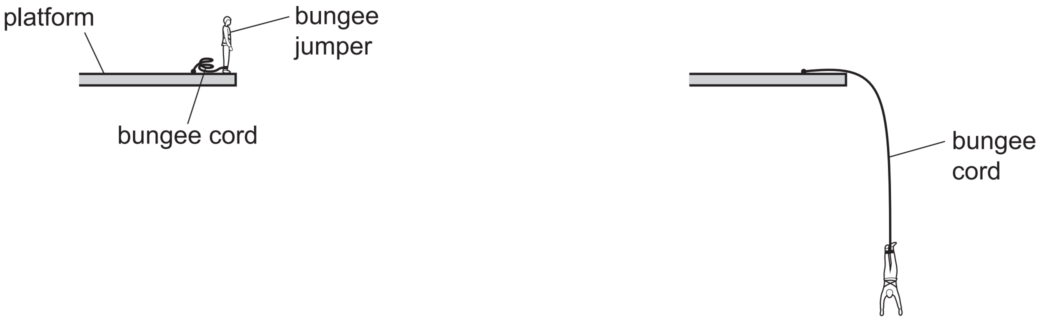
A on the platform before the jump

B on the way down before the cord has started to extend

C on the way down as he decelerates

D at the bottom of the jump when he is stationary

Question 18



Solution 18

A on the platform before the jump

B on the way down before the cord has started to extend

C on the way down as he decelerates ✓

D at the bottom of the jump when he is stationary

Why

- Gravitational potential energy is non-zero while he is above the ground.
- Elastic potential energy is non-zero only once the cord has gone taut and begun to stretch.
- Kinetic energy is non-zero only while he is moving, so all three overlap only on the way down as he decelerates – at the bottom he is stationary.

Question 17

9702/12 N25 ▪ Q17 ▪ 1 mark

A student attempts to derive the formula for kinetic energy E_K. She begins by considering an object of mass m that is initially at rest. A constant force F applied to the object causes it to accelerate to final velocity v in displacement s. The kinetic energy gained by the object is equal to the work done on the object by the force F.

Which equation does the student **not** need in order to derive the formula for E_K? **[1]**

A $F = ma$

B $W = Fs$

C $E = \frac{1}{2}Fs$

D $v^2 = u^2 + 2as$

Solution 17

A $F = ma$

B $W = Fs$

C $E = \frac{1}{2}Fs$ ✓

D $v^2 = u^2 + 2as$

Why

- The derivation uses $W = Fs$, then $F = ma$, then $v^2 = u^2 + 2as$ to replace s.
- Substituting $s = v^2/2a$ into $W = mas$ gives $W = \frac{1}{2}mv^2$ directly.
- $E = \frac{1}{2}Fs$ is not a standard equation and plays no part in it.

Question 18

9702/12 N25 ▪ Q18 ▪ 1 mark

A ball falls towards the ground from point X. Point X is 2.4 m above the ground. The ball rebounds from the ground and rises to point Y. Point Y is 1.8 m above the ground.

A single value of the change in height Δh is used to calculate the change in gravitational potential energy of the ball from X to Y.

What is the magnitude of Δh? **[1]**

A 0.6 m

B 1.8 m

C 2.4 m

D 4.2 m

Solution 18

A 0.6 m ✓

B 1.8 m

C 2.4 m

D 4.2 m

Why

- Gravitational potential energy depends only on the start and end heights, not on the path.
- X is at 2.4 m and Y at 1.8 m, so the change in height is $2.4 - 1.8 = 0.6$ m.
- D adds the descent and the rise together, but they partly cancel.

Question 17

9702/14 N25 ▪ Q17 ▪ 1 mark

A toy car travels around a vertical loop track.

The toy car is released from rest at a height of 58 cm above the bottom of the vertical loop.

The car is at a height of 32 cm when it is at the top of the vertical loop.

Assume that no resistive forces act on the car.

What is the speed of the car at the top of the vertical loop? **[1]**

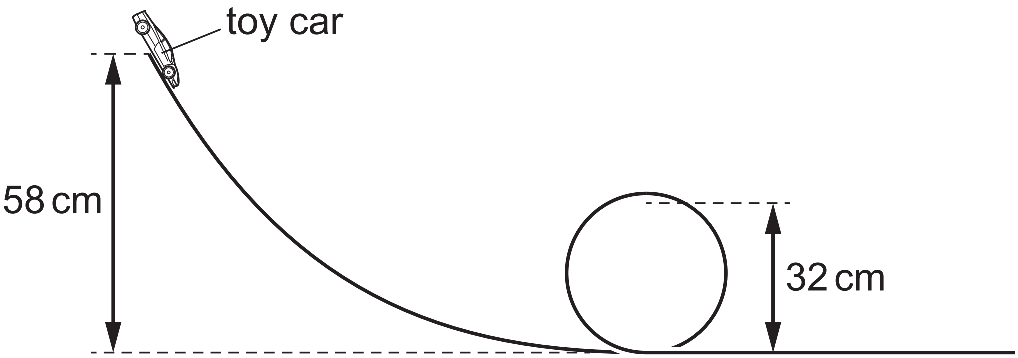
A $0.87\ \mathrm{m\,s^{-1}}$

B $2.3\ \mathrm{m\,s^{-1}}$

C $2.5\ \mathrm{m\,s^{-1}}$

D $3.4\ \mathrm{m\,s^{-1}}$

Question 17



Solution 17

A $0.87\ \mathrm{m\,s^{-1}}$

B $2.3\ \mathrm{m\,s^{-1}}$ ✓

C $2.5\ \mathrm{m\,s^{-1}}$

D $3.4\ \mathrm{m\,s^{-1}}$

Why

- Only the *difference* in height matters: $58 - 32 = 26$ cm $= 0.26$ m.
- Energy conservation gives $\frac{1}{2}mv^2 = mg(0.26)$.
- $v = \sqrt{2 \times 9.81 \times 0.26} = 2.3$ m s^{-1}.

Question 19

9702/14 N25 ▪ Q19 ▪ 1 mark

An object travels between two points. The change in gravitational potential energy ΔE_p of the object is given by

$$\Delta E_p = mg\Delta h$$

where m is the mass of the object, Δh is its change in height and g is the acceleration of free fall.

What is a necessary condition in order for the above equation to be valid? **[1]**

A The object must have a constant acceleration of $9.81\ \text{m s}^{-2}$.

B The object must be travelling in a uniform gravitational field.

C The object must be travelling only in a vertical direction.

Question 19

D The resultant force on the object must be equal to its weight.

Solution 19

A The object must have a constant acceleration of 9.81 m s^{-2}.

B The object must be travelling in a uniform gravitational field. ✓

C The object must be travelling only in a vertical direction.

D The resultant force on the object must be equal to its weight.

Why

- A constant *g* is what lets the simple product *mgh* replace a more general calculation.
- That is precisely what a uniform gravitational field means.
- The object's own acceleration is irrelevant – it may be lifted slowly or dropped.

Question 17

9702/11 J25 ▪ Q17 ▪ 1 mark

An object is falling in a uniform gravitational field.

Which two quantities are sufficient to calculate the change in gravitational potential energy? **[1]**

- **A** mass and acceleration of free fall
- **B** mass and change in vertical displacement
- **C** weight and acceleration of free fall
- **D** weight and change in vertical displacement

Solution 17

A mass and acceleration of free fall

B mass and change in vertical displacement

C weight and acceleration of free fall

D weight and change in vertical displacement ✓

Why

- $\Delta E_p = mg\Delta h$, and mg is exactly the weight.
- So the weight together with the change in height is enough.
- B gives mass and height but no g; A and C have no height at all.

Question 18

9702/12 J25 ▪ Q18 ▪ 1 mark

A ball of mass 1.2 kg travels horizontally at a speed of $3.0\ \mathrm{m\,s^{-1}}$.

The ball hits a cushion and comes to rest over a horizontal distance of 0.020 m.

What is the work done by the cushion on the ball to bring the ball to rest? **[1]**

A 0.24 J

B 1.8 J

C 5.4 J

D 11 J

Solution 18

A 0.24 J

B 1.8 J

C 5.4 J ✓

D 11 J

Why

- The work done by the cushion equals the kinetic energy it removes.
- $E_k = \frac{1}{2}mv^2 = \frac{1}{2}(1.2)(3.0)^2 = 5.4$ J.
- The 0.020 m is not needed for the energy – it would give the average force instead.

Question 18

9702/13 J25 ▪ Q18 ▪ 1 mark

18 A ball is released from rest and falls vertically to the ground.

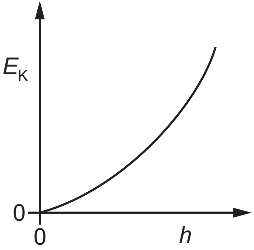
The kinetic energy E_K of the ball varies as the height h of the ball above the ground changes.

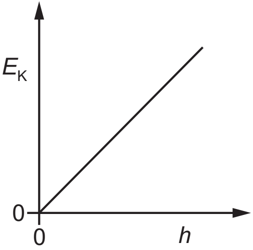
Air resistance is negligible.

Which graph shows the variation of E_K with h?

A **B**

Question 18





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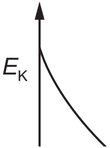

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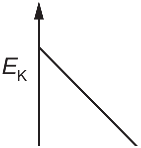
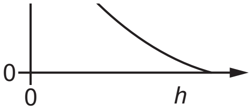
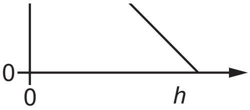


Question 18





Solution 18

Answer: **D**

Why

- With no air resistance the total energy is constant, so $E_k = mg(H - h)$.
- That is a straight line falling as h rises, reaching zero at the release height.
- So the graph is linear with a negative gradient, not a curve.

Question 19

9702/13 J25 ▪ Q19 ▪ 1 mark

19 An object travelling with a speed of $10\,\mathrm{m\,s^{-1}}$ has kinetic energy of 1500 J.

The speed of the object is increased to $40\,\mathrm{m\,s^{-1}}$.

What is the new kinetic energy of the object?

A 4500 J **B** 6000 J **C** 24 000 J **D** 1 350 000 J

Solution 19

Answer: **C**

Why

- Kinetic energy goes as v^2, so quadrupling the speed multiplies it by 16.
- $1500 \times 16 = 24\,000$ J.
- B assumes it scales with v and gives only four times as much.

Question 3

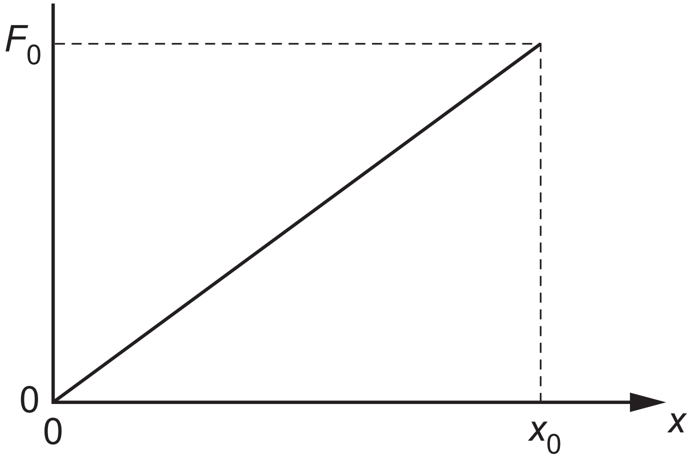
9702/24 J25 ▪ Q3 ▪ 11 marks

The lower end of a vertical spring is fixed to a horizontal surface, as shown in Fig. 3.1. The mass of the spring is negligible. A block of mass 5.5 kg drops vertically onto the spring and is brought to rest as the spring is compressed.

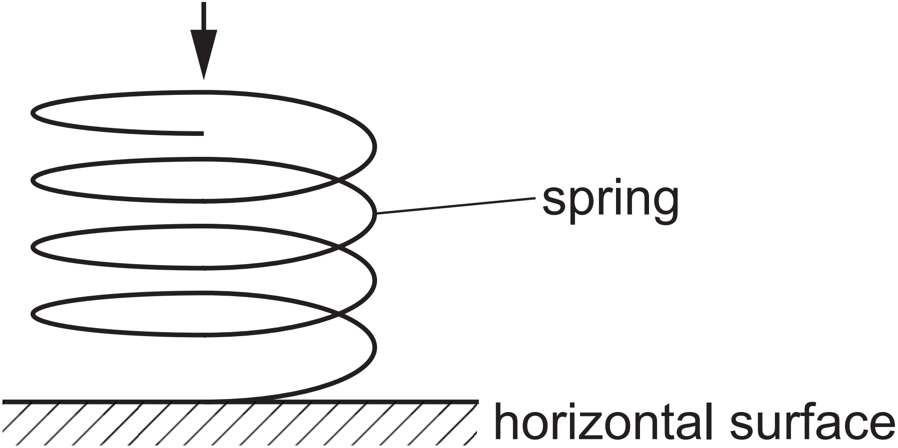
(a) The block has kinetic energy 110 J as it makes contact with the spring.

Calculate the speed of the block as it makes contact with the spring. **[2]**

Question 3



Question 3



Question 3

9702/24 J25 ▪ Q3 ▪ 11 marks

The lower end of a vertical spring is fixed to a horizontal surface, as shown in Fig. 3.1. The mass of the spring is negligible. A block of mass 5.5 kg drops vertically onto the spring and is brought to rest as the spring is compressed.

(b) The gravitational potential energy of the block decreases by 20 J as the spring is compressed to its maximum compression x_0.

Show that x_0 is 0.37 m. **[2]**

Question 3

9702/24 J25 ▪ Q3 ▪ 11 marks

The lower end of a vertical spring is fixed to a horizontal surface, as shown in Fig. 3.1. The mass of the spring is negligible. A block of mass 5.5 kg drops vertically onto the spring and is brought to rest as the spring is compressed.

(c) Assume that, as the spring compresses, all of the energy lost by the block is converted into the elastic potential energy of the spring.

Use the data from **(a)** and **(b)** to determine the maximum elastic potential energy of the spring.

Show your working. **[1]**

Question 3

9702/24 J25 ▪ Q3 ▪ 11 marks

The lower end of a vertical spring is fixed to a horizontal surface, as shown in Fig. 3.1. The mass of the spring is negligible. A block of mass 5.5 kg drops vertically onto the spring and is brought to rest as the spring is compressed.

(d) The variation of the force F acting on the spring with the compression x of the spring is shown in Fig. 3.2.

Use the information in (b) and your answer in (c) to show that the maximum force F_0 exerted on the spring by the block is 700 N. **[2]**

Question 3

9702/24 J25 ▪ Q3 ▪ 11 marks

The lower end of a vertical spring is fixed to a horizontal surface, as shown in Fig. 3.1. The mass of the spring is negligible. A block of mass 5.5 kg drops vertically onto the spring and is brought to rest as the spring is compressed.

(e)(i) the resultant force acting on the block **[2]**

(e)(ii) the acceleration of the block. **[2]**

Solution 3

(a) Worked steps

- $E_K = \frac{1}{2}mv^2$, so $v = \sqrt{\dfrac{2E_K}{m}}$
- $v = \sqrt{\dfrac{2 \times 110}{5.5}} = \sqrt{40}$
- $v = 6.3$ m s^{-1}

Solution 3

Mark scheme

- $E_{(K)} = \frac{1}{2}mv^2$
- $110 = \frac{1}{2} \times 5.5 \times v^2$
- $v = 6.3$ m s^{-1}

Solution 3

(b) Worked steps

While the spring compresses, the block falls a further distance equal to the compression itself.

- $\Delta E_P = mg\Delta h$, with $\Delta h = x_0$.
- $x_0 = \dfrac{\Delta E_P}{mg} = \dfrac{20}{5.5 \times 9.81}$
- $x_0 = 0.37$ m, as required.

Solution 3

Mark scheme

- $(\Delta)E_{(P)}/20 = mg(\Delta)h$ OR $(\Delta)E_{(P)}/20 = mgx_0$
- $(x_0 =)20/5.5 \times 9.81 = 0.37$ (m)
- Allow $(\Delta)h$ for x_0

Solution 3

(c)

Worked steps

All the energy the block loses goes into the spring — and it loses **both** kinds.

- Kinetic energy lost: 110 J (it comes to rest).
- Gravitational potential energy lost: 20 J.
- Maximum elastic potential energy $= 110 + 20 = 130$ J

Mark scheme

- $[\max\ (E_{(P)})] = 110 + 20 = 130$ J

Solution 3

(d) Worked steps

The graph is a straight line through the origin, so the work stored is the **area of the triangle** under it.

- $E_{\mathrm{P}} = \frac{1}{2}F_0 x_0$
- $F_0 = \dfrac{2E_{\mathrm{P}}}{x_0} = \dfrac{2 \times 130}{0.37}$
- $F_0 = 700$ N, as required.

Mark scheme

- (max) $E_{(P)}/130 = \frac{1}{2}F_{(0)}x_{(0)}$ **C1**

Solution 3

- $(F_0 =) 2 \times 130/0.37 = 700$ (N) **A1**
- **or** (max) $E_{(P)}/130 = 1/2kx^2_{(0)}$
- $(F_0 =) kx_{(0)}$
- (C1)
- $(F_0 =) 2 \times 130 \times 0.37/(0.37)^2 = 700$ (N)
- (A1)

Solution 3

(e)(i)

Worked steps

At maximum compression two forces act on the block, and they act in opposite directions.

- Weight (down) $= 5.5 \times 9.81 = 54$ N
- Spring push (up) $= 700$ N
- Resultant $= 700 - 54 = 650$ N, directed **upwards**.

Mark scheme

- (weight) $= 5.5 \times 9.81$ **C1**
- resultant force $= 700 - (5.5 \times 9.81)$
- $= 650$ N **A1**

Solution 3

(e)(ii)

Worked steps

- $F = ma$, so $a = \dfrac{F}{m} = \dfrac{650}{5.5}$
- $a = 120$ m s^{-2}, upwards.

That is about 12 g — which is why the block stops so abruptly.

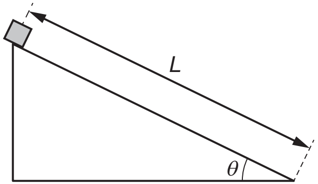
Mark scheme

- $F = ma$ **C1**
- $a = 650/5.5$ **or** $(700/5.5) - 9.81$
- $a = 120$ m s^{-2} **A1**

Question 15

9702/12 M25 ▪ Q15 ▪ 1 mark

15 A block is released from rest at the top of a slope inclined at an angle to the horizontal. The slope has length L as shown in the diagram.



There are no resistive forces acting on the block.

What is the speed of the block at the bottom of the slope?

Question 15

A $4.43\sqrt{L\cos\theta}$ **B** $4.43\sqrt{L\sin\theta}$ **C** $19.6L\cos\theta$ **D** $19.6L\sin\theta$

Solution 15

Answer: **B**

Why

- The vertical drop is $L \sin \theta$, not L itself.
- Energy conservation: $\frac{1}{2}mv^2 = mgL \sin \theta$, so $v = \sqrt{2gL \sin \theta}$.
- $\sqrt{2g} = \sqrt{19.6} = 4.43$, giving $v = 4.43\sqrt{L \sin \theta}$.