Week 4

A-Level Physics

Homework bundle for this week

本周作业合集

exercises.lol

Contents 目录

A-Level Physics Name: ____________ Score: ______

1. The rate of change of velocity with time is called ______.

   ____

2. A car starts at $u = 2\ \frac{\text{m}}{\text{s}}$ and accelerates at $a = 3\ \frac{\text{m}}{\text{s}^2}$ for $t = 4$ s. Find v.

   ____________ m/s

3. A ball thrown horizontally and a ball dropped from the same height hit the ground at the same time (no air resistance).

   ☐ True ☐ False

4. Which quantity is the **rate of change of displacement**?

   ☐ speed

   ☐ velocity

   ☐ acceleration

   ☐ distance

5. Which equation is just the **gradient** of a velocity–time graph?

   ☐ $v = u + at$

   ☐ $s = ut + \frac{1}{2}at^2$

   ☐ $s = \frac{1}{2}(u + v)t$

   ☐ $v^2 = u^2 + 2as$

6. A projectile is launched at $20\ \frac{\text{m}}{\text{s}}$, 30° above the horizontal. What is the **vertical** part of the launch velocity?

   ____________ m/s

7. Deceleration is a completely separate quantity from acceleration.

   ☐ True ☐ False

8. With no air resistance, a heavy ball falls faster than a light one.

   ☐ True ☐ False

9. Select **all** the statements that are true for a projectile (ignore air).

   ☐ The horizontal velocity stays constant

   ☐ The vertical velocity is zero at the highest point

☐ The whole velocity is zero at the highest point

☐ The path is a parabola

☐ A heavier projectile falls faster

Tick every correct option.

10. On a displacement–time graph, a flat (horizontal) line means the object is at rest.

☐ True ☐ False

A-Level Physics

1. **acceleration**

   Acceleration is how fast the velocity changes — a vector, in $\frac{\text{m}}{\text{s}^2}$.

2. **14 m/s**

   Use $v = u + at = 2 + 3 \times 4 = 14\ \frac{\text{m}}{\text{s}}$.

3. **True**

   Yes — the vertical motion is the same free fall for both, and the horizontal speed does not change the fall time.

4. **velocity**

   Velocity is the rate of change of *displacement* (a vector). Speed is the rate of change of *distance* (a scalar).

5. $v = u + at$

   The gradient is $a = \frac{v-u}{t}$, which rearranges to $v = u + at$.

6. **10 m/s**

   Vertical part $= u \sin\theta = 20 \times \sin 30° = 20 \times 0.5 = 10\ \frac{\text{m}}{\text{s}}$.

7. **False**

   No — deceleration is just acceleration in the opposite direction to the motion (a negative acceleration).

8. **False**

   No — free fall has the same acceleration g for every mass. Air resistance is what makes a feather seem to fall slower.

9. **The horizontal velocity stays constant; The vertical velocity is zero at the highest point; The path is a parabola**

   At the top only the *vertical* velocity is zero — the horizontal velocity $u\cos\theta$ carries on, so the ball keeps moving. Mass does not change free fall.

10. **True**

    A flat line has zero gradient, and the gradient is the velocity — so the velocity is zero (at rest).

A-LEVEL PHYSICS • EXERCISE SHEET

2.1 Equations of motion

Name: ______________ Class: __________ Date: ____________ **Total: 49 marks**

KEY WORDS velocity 速度 • acceleration 加速度 • air resistance 空气阻力 • speed 速率 • distance 距离

Objective

Build the skills to answer exam questions on **uniformly accelerated motion 匀加速运动** — choosing and using the SUVAT equations, reading motion graphs, and solving free-fall and projectile problems.

You must be able to:

- find velocity from a displacement–time gradient, and acceleration + displacement from a velocity–time graph
- choose and use the four SUVAT equations for straight-line motion
- solve free-fall problems ($g = 9.81$ m s^{-2}, no air resistance)
- treat the horizontal and vertical motion of a projectile independently
- **describe** the experiment that measures the acceleration of free fall
- **sketch** a motion graph with both axes drawn and labelled

1 Worked examples

Study these first. Each one shows the **method 方法** for a question type used later — examiners give marks for showing the working, not only the final number.

■ Choosing a SUVAT equation

The five symbols are u (start velocity), v (final velocity), a (acceleration), s (displacement) and t (time). Each equation uses **four** of them and leaves one out:

equation	leaves out
$v = u + at$	s
$s = \frac{1}{2}(u + v)t$	a
$s = ut + \frac{1}{2}at^2$	v
$v^2 = u^2 + 2as$	t

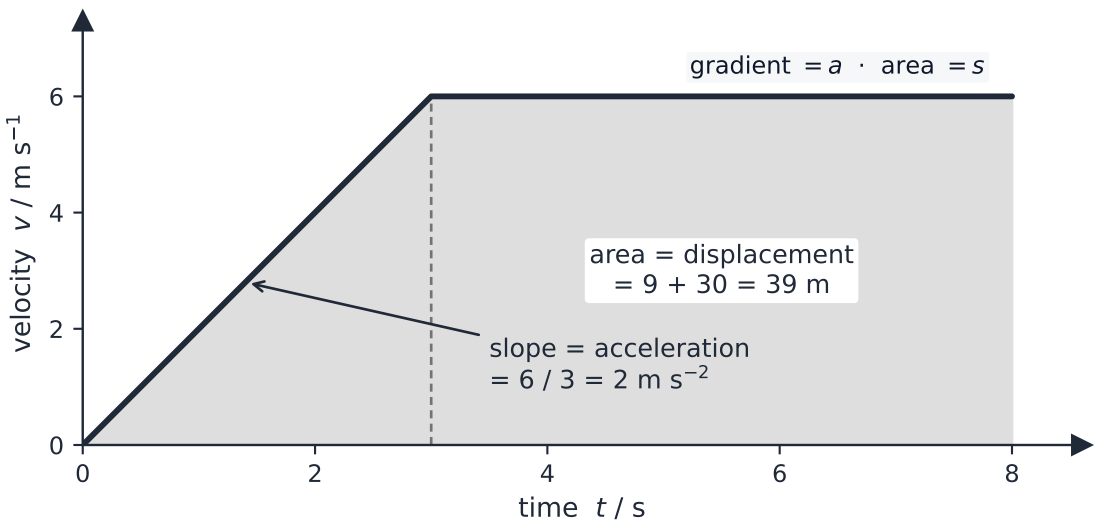
Method: list what you know and what you want, then pick the row that leaves out the symbol you don't have.

Example. A cyclist speeds up uniformly from 4.0 to 13 m s^{-1} in 6.0 s: so $u = 4.0$, $v = 13$, $t = 6.0$; find a, then s.

- For a (no s): $v = u + at \Rightarrow a = \dfrac{v-u}{t} = \dfrac{13-4.0}{6.0} = 1.5$ m s^{-2}.
- For s (no a): $s = \frac{1}{2}(u+v)t = \frac{1}{2}(4.0+13)(6.0) = 51$ m.

Reading a velocity–time graph

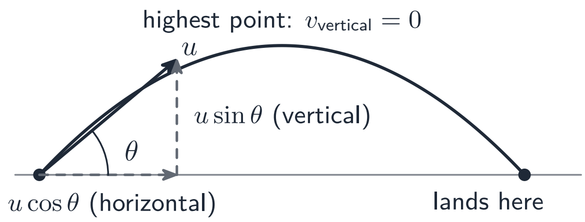
On a velocity–time graph the **gradient** 斜率 (steepness) is the acceleration, and the **area** under the line is the displacement.



(For an *acceleration*–time graph, the area under the line is instead the *change in velocity.*)

A projectile

Horizontal and vertical motion are **independent** — they share only the time t, so solve each as its own SUVAT problem. For a launch at angle θ, first **resolve** the speed: horizontal $u\cos\theta$ (stays constant) and vertical $u\sin\theta$ (changes).



Worked case — a ball thrown **horizontally** at 12 m s^{-1} from a cliff 25 m high ($g = 9.81$ m s^{-2}):

- Vertical (start 0): $25 = \frac{1}{2}g\,t^2 \Rightarrow t = \sqrt{2 \times 25/9.81} = 2.3$ s.
- Horizontal: $x = 12 \times 2.3 = 27$ m.

Measuring the acceleration of free fall

The syllabus asks you to **describe** this experiment, so learn it as five steps:

1. A steel ball is held by an **electromagnet** above a **trapdoor** switch, a measured height h above it.
2. Switching the magnet off starts an electronic **timer** and releases the ball at the same instant.
3. The ball opens the trapdoor on landing, which **stops** the timer, giving the fall time t.
4. The ball falls from rest, so $h = \frac{1}{2}gt^2$. Repeat for **several heights**, plot h against t^2, and the **gradient** is $\frac{1}{2}g$.
5. Measure h from the **bottom** of the ball to the trapdoor, and repeat each timing — the graph, not a single pair of readings, is what removes the random error.

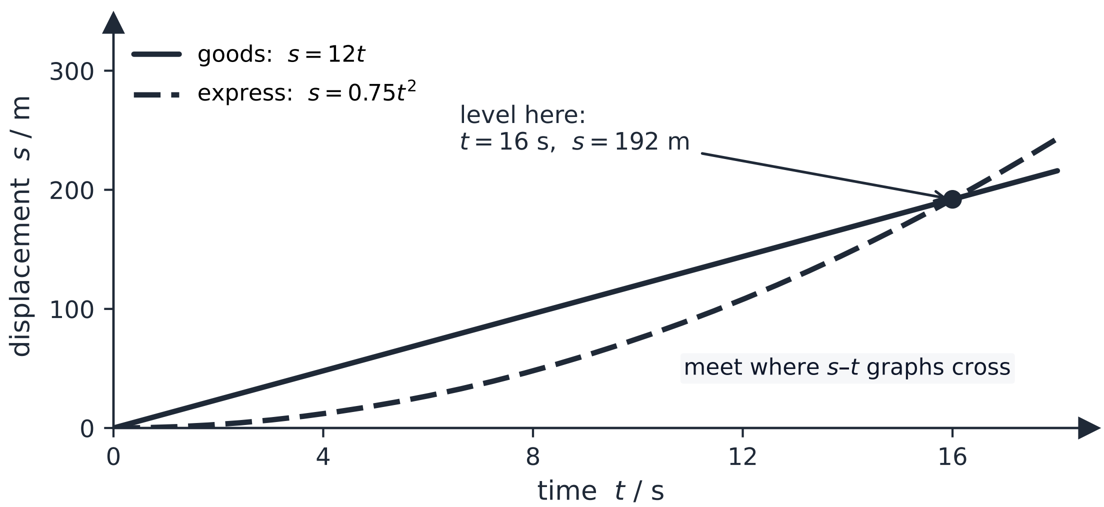
A steel ball is used because **air resistance** on it is negligible; the graph is a straight line **through the origin** only if there is no systematic timing delay.

Two objects meeting

Write a displacement equation for each object using the same start time and positive direction, then set the displacements equal.

A goods train moves at a constant 12 m s^{-1}. As it passes a signal, an express train starts from rest there with acceleration 1.5 m s^{-2}.

- Goods: $s = 12t$. Express: $s = \frac{1}{2}(1.5)t^2 = 0.75t^2$.
- Level when $12t = 0.75t^2 \Rightarrow t = \dfrac{12}{0.75} = 16$ s ($s = 12 \times 16 = 192$ m).



2 Practice

Now apply the methods above.

2.1 For each quantity, write **scalar** 标量 or **vector** 矢量, and state its SI unit: (a) velocity (b) acceleration. [2]

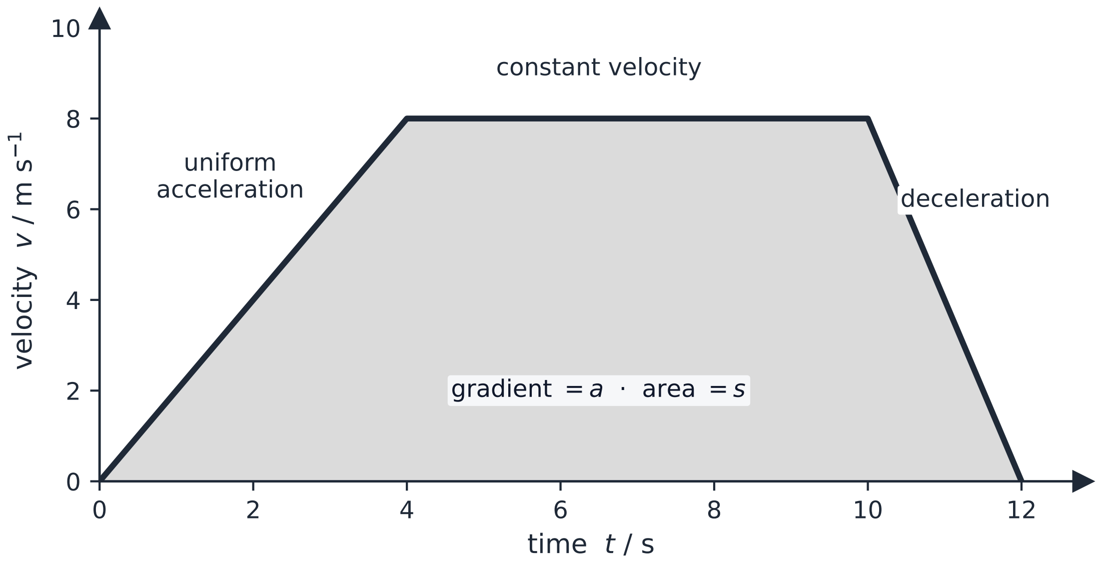
quantity	scalar or vector?	SI unit
velocity		
acceleration		

2.2 A car travelling at 24 m s^{-1} brakes uniformly at 3.0 m s^{-2} until it stops. Find the braking distance. *(Hint: which SUVAT equation links u, v, a and s?)* [3]

2.3 The displacement–time graph of a cyclist is a straight line passing through (2.0 s, 12 m) and (8.0 s, 42 m). **Determine** her velocity, and state how you know her acceleration is zero. [3]

2.4 **Describe** an experiment to determine the acceleration of free fall using a falling object. State the measurements you would take, how you would use them, and one way to reduce the uncertainty. [4]

2.5 The velocity–time graph shows a tram's journey.



Velocity–time graph for the tram's three-phase journey

(a) Find the acceleration during the first 4 s. [1]

(b) Find the total displacement of the tram. *(Hint: split the area into a triangle, a rectangle and a triangle.)* [3]

3 Exam-style questions

3.1 A stone is thrown vertically upwards at 15 m s^{-1}. Take $g = 9.81$ m s^{-2} and ignore air resistance. Its height above the launch point after 2.0 s is closest to: [1]

- **A** 10 m
- **B** 20 m
- **C** 30 m
- **D** 50 m

3.2 The area under an **acceleration–time graph** gives which quantity? [1]

- **A** displacement

- **B** change in velocity
- **C** distance
- **D** force

3.3 A train starts from rest and accelerates uniformly at 0.50 m s^{-2} for 40 s.

(a) Calculate the speed it reaches. [2]

(b) Calculate the distance travelled during these 40 s. [2]

(c) State one assumption you have made in your calculation. [1]

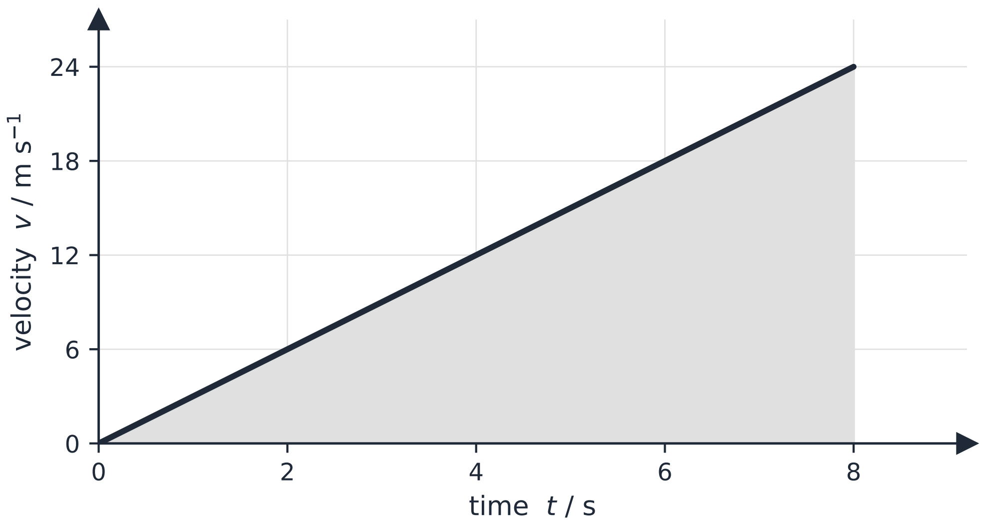
3.4 A ball is kicked from level ground at 20 m s^{-1}, at 30° above the horizontal. Take $g = 9.81$ m s^{-2} and ignore air resistance.

(a) Show that the vertical **component** 分量 of the initial velocity is about 10 m s^{-1}. [1]

(b) Calculate the time the ball is in the air before it lands. [2]

(c) Calculate the horizontal distance it travels (its range). [2]

3.6 A drone of mass 1.8 kg takes off from the ground and rises vertically. The graph shows its velocity for the first 8.0 s of the flight.



(a) **Define** acceleration. [1]

(b) **Determine** the acceleration of the drone. [2]

(c) **Show that** the drone rises 96 m in these 8.0 s. [2]

(d) Calculate the gain in **gravitational potential energy** of the drone. [2]

(e) Calculate the gain in **kinetic energy** of the drone. [2]

(f) **Determine** the average useful power output of the drone's motors during these 8.0 s. [2]

(g) In the space below, **sketch** the variation with time of the **displacement** of the drone over the same 8.0 s. **Draw** and **label** both axes. [3]

(h) A second drone of mass 2.7 kg takes off and follows exactly the same velocity–time graph. **State and explain** whether the average useful power output of its motors is less than, the same as, or greater than your answer to **(f)**. [2]

3.5 A car passes a stationary motorcyclist at a constant 18 m s^{-1}. At that instant the motorcyclist sets off from rest with a uniform acceleration of 3.0 m s^{-2}.

(a) Calculate the time the motorcyclist takes to catch up with the car. [3]

(b) Calculate how far each has travelled at that moment. [1]

(c) Calculate the motorcyclist's speed when she catches the car. [1]

Solutions

2.1 velocity — vector, m s^{-1}; acceleration — vector, m s^{-2}.

2.2 Use $v^2 = u^2 + 2as$ with $v = 0$: $0 = 24^2 + 2(-3.0)s \Rightarrow s = 576/6.0 = 96$ m.

2.3 velocity = gradient $= \dfrac{42-12}{8.0-2.0} = \dfrac{30}{6.0} = 5.0$ m s^{-1}; the graph is a **straight** line, so the gradient — and therefore the velocity — never changes, and acceleration is the rate of change of velocity, so it is zero.

2.4 Release a steel ball from an electromagnet a measured height h above a trapdoor switch; switching the magnet off starts an electronic timer and releases the ball, and the ball opens the trapdoor to stop it, giving t; use $h = \frac{1}{2}gt^2$, or better plot h against t^2 and take $g = 2\times$ gradient; reduce uncertainty by repeating each timing and by using several heights so a graph averages the readings.

2.5 (a) gradient $= 8/4 = 2.0$ m s^{-2}.
(b) triangle $\frac{1}{2}(4)(8) = 16$; rectangle $(6)(8) = 48$; triangle $\frac{1}{2}(2)(8) = 8$; total $= 16+48+8 = 72$ m.

3.1 **A**. $s = (15)(2.0) - \frac{1}{2}(9.81)(2.0)^2 = 30 - 19.6 = 10.4$ m, closest to 10 m.

3.2 **B**. The area under an acceleration–time graph is the change in velocity.

3.3 (a) $v = u + at = 0 + (0.50)(40) = 20$ m s^{-1}.
(b) $s = \frac{1}{2}at^2 = \frac{1}{2}(0.50)(40)^2 = 400$ m. [or $s = \frac{1}{2}(0 + 20)(40)$]
(c) e.g. the acceleration stays constant / the track is straight.

3.4 (a) $u_V = 20 \sin 30° = (20)(0.50) = 10$ m s^{-1}.
(b) time to the top $= u_V/g = 10/9.81 = 1.02$ s; total time $= 2 \times 1.02 = 2.0$ s.
(c) $u_H = 20 \cos 30° = 17.3$ m s^{-1}; range $= u_H \times t = 17.3 \times 2.04 = 35$ m.

3.6 (a) Acceleration is the **rate of change of velocity**.
(b) gradient $= \dfrac{24-0}{8.0-0} = 3.0$ m s^{-2}.
(c) height = area under the line $= \frac{1}{2}(8.0)(24) = 96$ m. [or $s = \frac{1}{2}at^2 = \frac{1}{2}(3.0)(8.0)^2$]
(d) $\Delta E_P = mgh = 1.8 \times 9.81 \times 96 = 1.7 \times 10^3$ J.
(e) $\Delta E_K = \frac{1}{2}mv^2 = \frac{1}{2}(1.8)(24)^2 = 5.2 \times 10^2$ J.
(f) $P = \dfrac{\text{total energy gained}}{t} = \dfrac{1.7 \times 10^3 + 5.2 \times 10^2}{8.0} = 2.8 \times 10^2$ W.
(g) Axes drawn and labelled *displacement* / *m* (vertical) and *time* / *s* (horizontal); a curve starting at the origin; getting **steeper** with time (a parabola, since $s \propto t^2$), reaching 96 m at 8.0 s.
(h) **Greater**. The graph is the same, so it gains the same height and the same speed, but both $\Delta E_P = mgh$ and $\Delta E_K = \frac{1}{2}mv^2$ are **proportional to the mass**, so a heavier drone gains more energy in the same 8.0 s.

3.5 (a) car: $s = 18t$; motorcyclist: $s = \frac{1}{2}(3.0)t^2 = 1.5t^2$. They are level when $18t = 1.5t^2$ $\Rightarrow t = 18/1.5 = 12$ s.
(b) $s = (18)(12) = 216$ m.
(c) $v = at = (3.0)(12) = 36$ m s^{-1}.

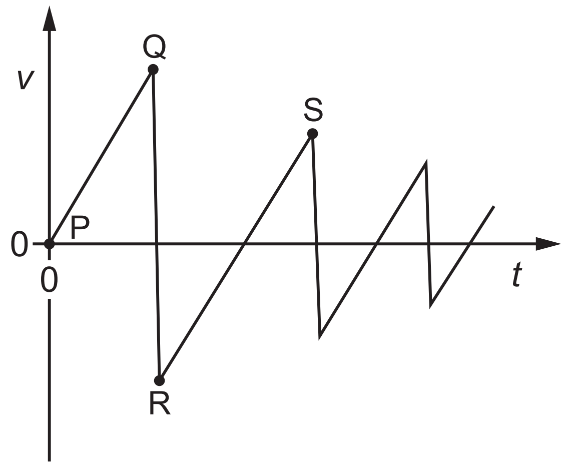
5 A goods train passes through a station at a constant speed of $10\,m\,s^{-1}$ at time $t = 0$. An express train is at rest at the station. The express train leaves the station with a uniform acceleration of $0.5\,m\,s^{-2}$ just as the goods train goes past. Both trains move in the same direction on straight, parallel tracks.

At which time t does the express train overtake the goods train?

A 6 s **B** 10 s **C** 20 s **D** 40 s

6 A ball is held above the ground and released. It falls to the ground and bounces several times.

The graph shows the variation with time t of the velocity v of the ball.



Four points on the graph are labelled P, Q, R and S.

Which statement is **not** correct?

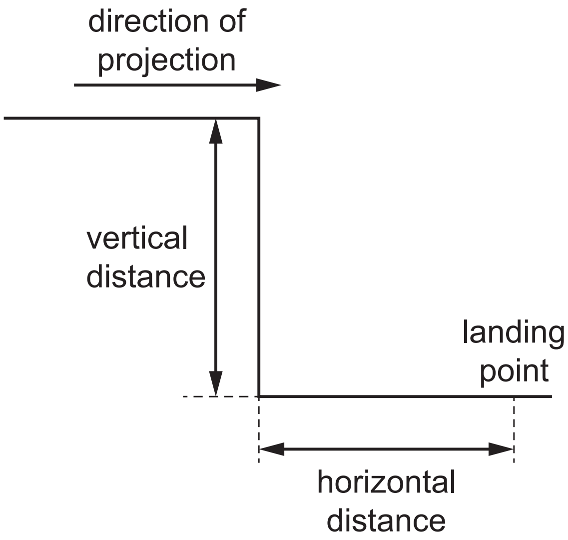
A The area under line PQ represents the initial height of the ball.

B The collisions of the ball with the ground are inelastic.

C The gradient of the line RS represents the acceleration due to free fall.

D The maximum upwards velocity of the ball is reached at point P.

7 An object is projected horizontally. The object falls a vertical distance y and travels a horizontal distance x before landing on the ground.



A second object is projected horizontally with the same initial velocity and falls a vertical distance $4y$ before landing on the ground.

Assume that air resistance is negligible.

Which horizontal distance does the second object travel?

A x **B** $2x$ **C** $4x$ **D** $16x$

A-Level Physics: **w25 12**

5 A car has an initial velocity u. The car then moves with constant acceleration a in a straight line through a displacement d. The car reaches a final velocity v.

Which expression gives the initial velocity u of the car?

A $v - ad$ **B** $\sqrt{v^2 - 2ad}$ **C** $v + ad$ **D** $v - \frac{1}{2}ad^2$

6 A bicycle brakes so that it undergoes uniform deceleration from a speed of $8\,\text{m}\,\text{s}^{-1}$ to $6\,\text{m}\,\text{s}^{-1}$ over a distance of 7 m.

The deceleration of the bicycle remains constant.

Which further distance will the bicycle travel before coming to rest?

A 7 m **B** 9 m **C** 16 m **D** 21 m

1 **(a)** Define acceleration.

....

.... [1]

(b) A rocket is launched vertically from the surface of the Earth.

Fig. 1.1 shows the variation of the velocity of the rocket with time for the first 20 s after its launch.

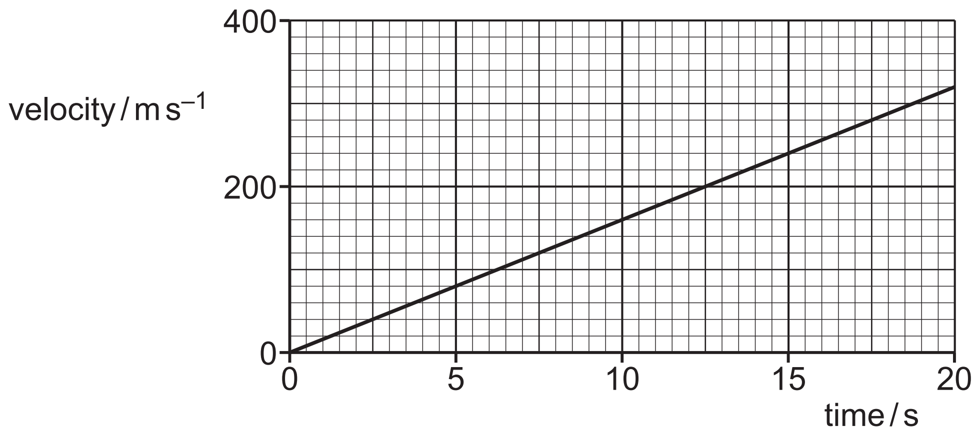


Fig. 1.1

(i) Determine the acceleration of the rocket.

acceleration = ... $m\,s^{-2}$ [1]

(ii) Show that the height of the rocket above the surface of the Earth at a time of 20 s after launch is 3.2 km.

[2]

(c) The mass of the rocket in **(b)** is 2.9×10^6 kg. Assume that this mass remains constant.

For this rocket, from launch to its height at a time of 20 s after launch:

(i) calculate the gain in gravitational potential energy ΔE_P

ΔE_P = ... J [2]

(ii) calculate the gain in kinetic energy ΔE_K

ΔE_K = ... J [2]

(iii) determine the average power output of the rocket engines. Assume that resistive forces are negligible.

power = ... W [2]

[Total: 10]

1 A child kicks a ball so that it leaves horizontal ground with a velocity of $28\,m\,s^{-1}$ at an angle of 34° to the horizontal, as shown in Fig. 1.1.

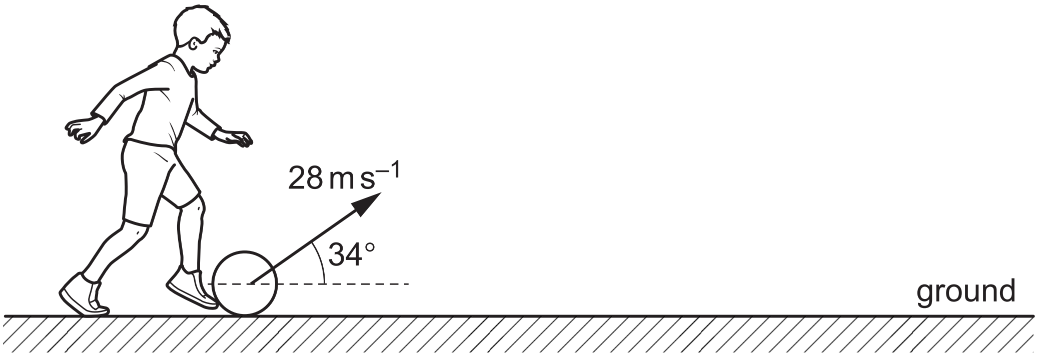


Fig. 1.1

Air resistance is negligible. The ball leaves the ground at time $t = 0$.

(a) (i) Calculate the horizontal component v_H and the vertical component v_V of the velocity of the ball immediately after it has left the ground.

v_H = ... $m\,s^{-1}$

v_V = ... $m\,s^{-1}$
[2]

(ii) Show that the ball reaches its maximum height at time $t = 1.6\,s$.

[1]

(iii) On Fig. 1.2, sketch the variation of v_H with time t between t = 0 and t = 3.2 s. Label your line H.

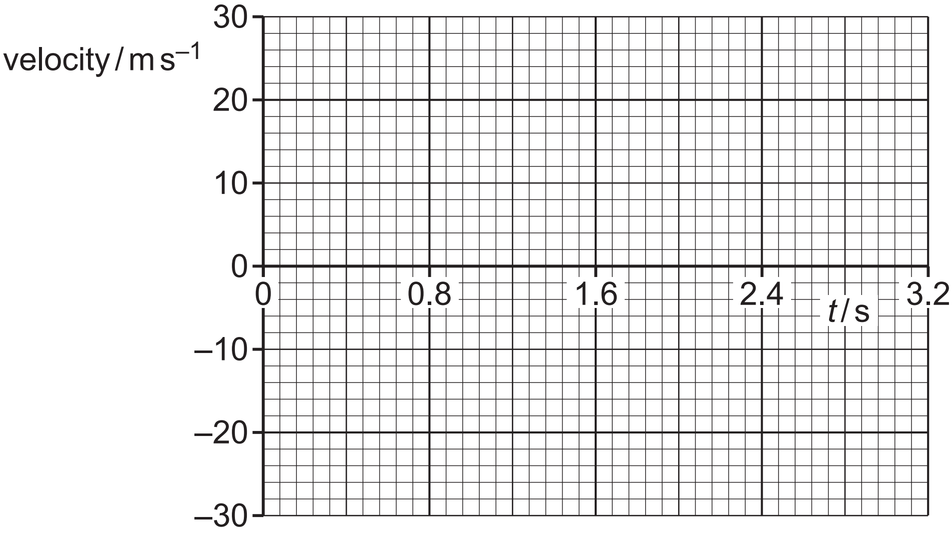


Fig. 1.2

[1]

(iv) On Fig. 1.2, sketch the variation of v_V with time t between t = 0 and t = 3.2 s. Assume that velocity in the upward direction is positive. Label your line V. [3]

(b) The total change in momentum of the ball between leaving the ground at t = 0 and landing on the ground at t = 3.2 s is 13 kg m s^{-1}.

(i) Define momentum.

....

.... [1]

(ii) Calculate the force that acts on the ball while it is in the air.

force = ... N [2]

(iii) Determine the mass of the ball.

mass = ... kg [1]

[Total: 11]

7 Which equation of uniformly accelerated motion can be derived using only the gradient of a velocity–time graph?

A $s = \frac{1}{2}(u + v)t$

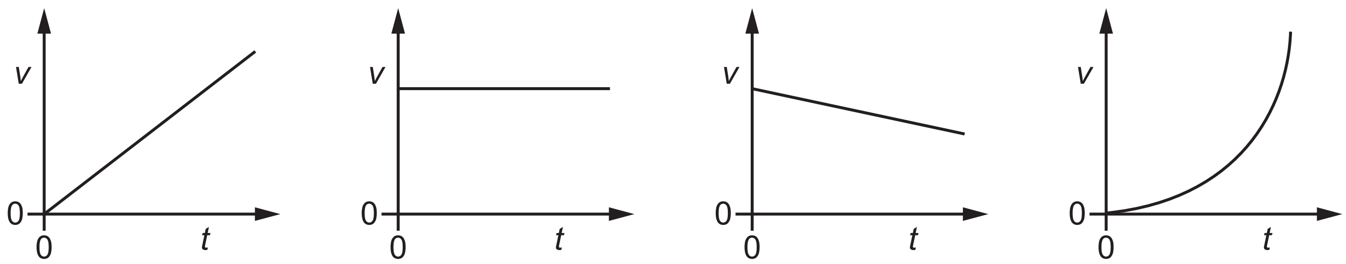
B $s = ut + \frac{1}{2}at^2$

C $v = u + at$

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

8 An object is projected horizontally from a table at time t = 0. The object falls in a uniform gravitational field. Air resistance is negligible.

Graphs P, Q, R and S are velocity–time graphs.



P Q R S

Which graphs represent the horizontal and vertical components of the velocity of the object?

	horizontal	vertical
A	Q	P
B	Q	S
C	R	P
D	R	S

1 **(a)** Define acceleration.

....

.... [1]

(b) In an experiment, two objects A and B are released from the side of a building, as shown in Fig. 1.1.

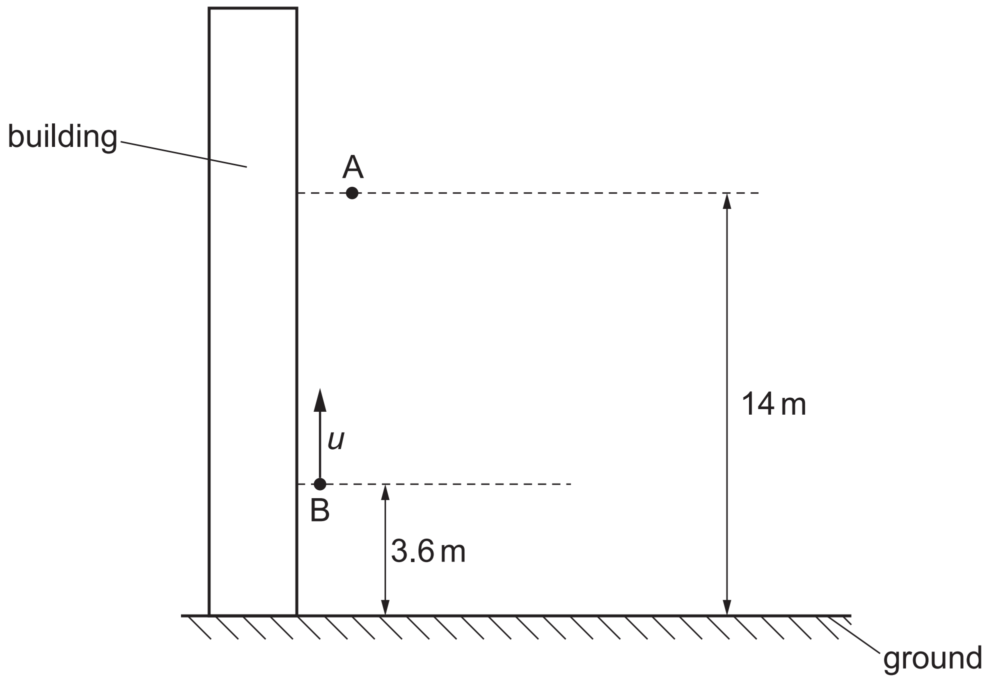


Fig. 1.1 (not to scale)

Object A is released from rest at a height of 14 m above the horizontal ground.
Object B is released with an initial upwards vertical velocity u at a height of 3.6 m above the ground.
Both objects take the same time to reach the ground and they do not collide with each other.
Air resistance is negligible.

(i) Calculate the time taken for object A to reach the ground.

time = ... s [2]

(ii) Use your answer in **(b)(i)** to calculate u.

u = ... $m\,s^{-1}$ [2]

(c) In a second experiment, object B is released from the same height and given the same initial speed as in **(b)** but at a release angle θ to the vertical, as shown in Fig. 1.2.

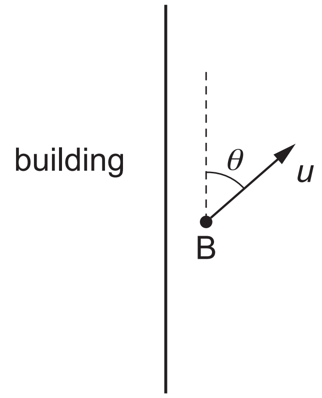


Fig. 1.2

(i) State and explain whether the time taken for object B to reach the ground is less than, the same as or greater than the time in **(b)(i)**.

....

....

.... [2]

(ii) By considering energy, state and explain the effect of the change in release angle on the speed at which B reaches the ground.

....

....

.... [2]

[Total: 9]

4 An aircraft, initially stationary on a runway, takes off with a speed of $85\,\mathrm{km\,h^{-1}}$ in a distance of no more than 1.20 km.

What is the minimum constant acceleration necessary for the aircraft?

A $0.23\,\mathrm{m\,s^{-2}}$ **B** $0.46\,\mathrm{m\,s^{-2}}$ **C** $3.0\,\mathrm{m\,s^{-2}}$ **D** $6.0\,\mathrm{m\,s^{-2}}$

3 **(a)** A truck R of mass 9400 kg moves with constant acceleration in a straight line down a slope, as illustrated in Fig. 3.1.

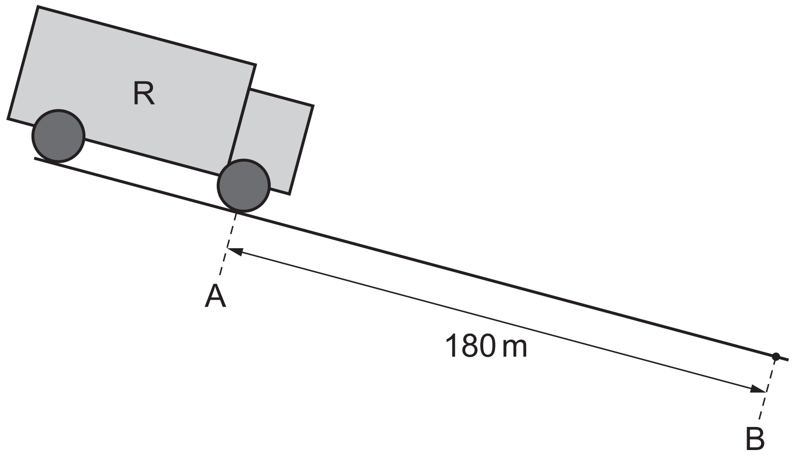


Fig. 3.1

At point A the speed of the truck is 13 m s^{-1} and at point B the speed of the truck is 22 m s^{-1}. A and B are a distance of 180 m apart.

(i) Calculate the acceleration of the truck between A and B.

acceleration = ... m s^{-2} [2]

(ii) Determine the gain in kinetic energy of the truck between A and B.

gain in kinetic energy = ... J [3]

(b) A short time after passing point B truck R moves in a straight line on horizontal ground. The driver of the truck applies the brakes. Fig. 3.2 shows the variation with time of the momentum of the truck.

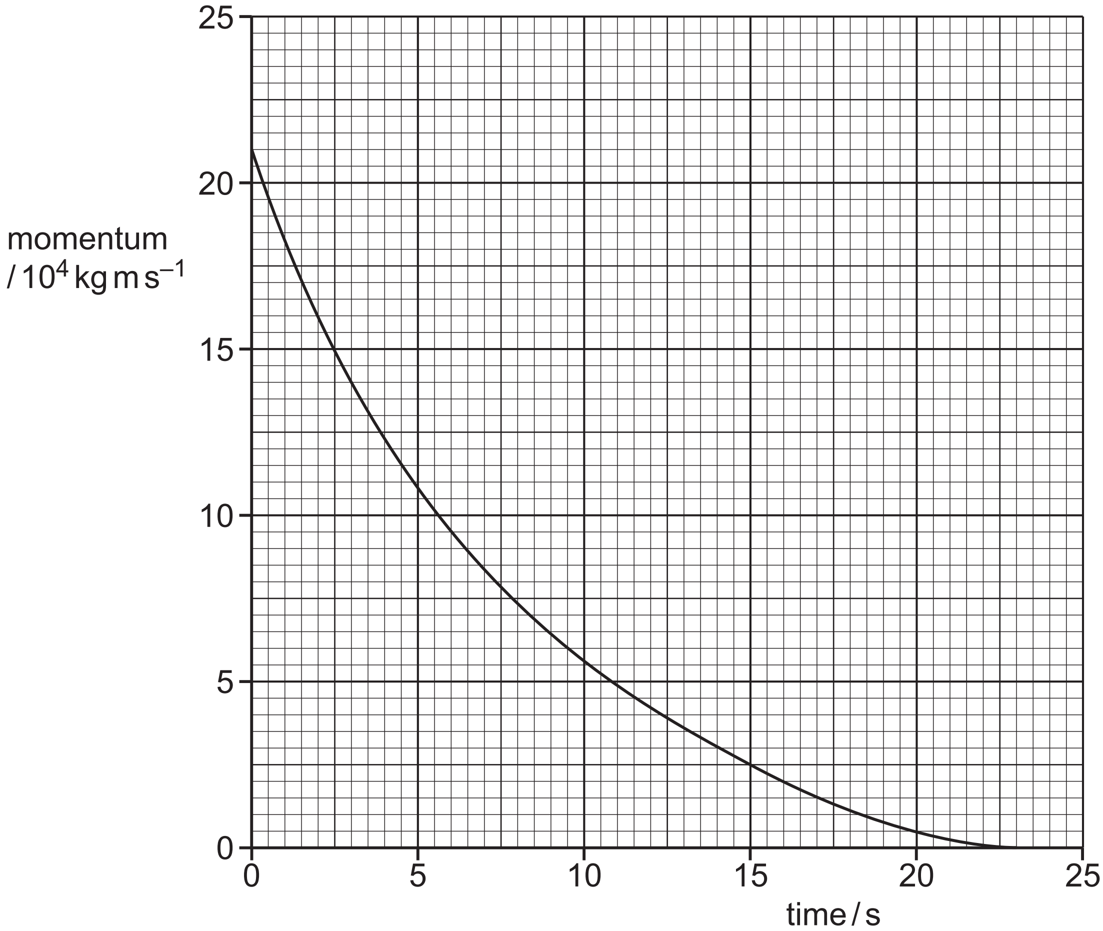


Fig. 3.2

(i) Define force.

....

.... [1]

(ii) Show that the average resultant force F acting on truck R between time t = 0 and t = 15 s is -1.2×10^4 N.

[1]

(iii) An identical truck S has the same initial momentum as truck R. Truck S experiences a constant force equal to the force *F* in **(b)(ii)**.

State and explain whether truck S will take more, less or the same amount of time to come to rest as truck R.

....

....

....

....

....

....

.... [3]

[Total: 10]