1. A car travels at a constant speed of $40\,\text{m s}^{-1}$ in a straight line along a horizontal racetrack. At time $t = 0$, the car passes a motorcyclist who is at rest. The motorcyclist immediately sets off to catch up with the car.

The motorcyclist accelerates at $4\,\text{m s}^{-2}$ for 15 s and then accelerates at $1\,\text{m s}^{-2}$ for a further T seconds until he catches up with the car.

(a) Sketch, on the same axes, the speed-time graph for the motion of the car and the speed-time graph for the motion of the motorcyclist, from time $t = 0$ to the instant when the motorcyclist catches up with the car.

(2)

At the instant when $t = t_1$ seconds, the car and the motorcyclist are moving at the same speed.

(b) Find the value of t_1

(2)

(c) Show that $T^2 + kT - 300 = 0$, where k is a constant to be found.

(6)

January 2020/Q5

2. A helicopter is hovering at rest above horizontal ground at the point H. A parachutist steps out of the helicopter and immediately falls vertically and freely under gravity from rest for 2.5 s. His parachute then opens and causes him to immediately decelerate at a constant rate of $3.9\,\text{m s}^{-2}$ for T seconds ($T < 6$), until his speed is reduced to $V\,\text{m s}^{-1}$. He then moves with this constant speed $V\,\text{m s}^{-1}$ until he hits the ground. While he is decelerating, he falls a distance of 73.75 m. The total time between the instant when he leaves H and the instant when he hits the ground is 20 s.

The parachutist is modelled as a particle.

(a) Find the speed of the parachutist at the instant when his parachute opens.

(1)

(b) Sketch a speed-time graph for the motion of the parachutist from the instant when he leaves H to the instant when he hits the ground.

(2)

(c) Find the value of T.

(5)

(d) Find, to the nearest metre, the height of the point H above the ground.

(4)

January 2021/Q7

3. Two trams, tram A and tram B, run on parallel straight horizontal tracks. Initially the two trams are at rest in the depot and level with each other.

At time $t = 0$, tram A starts to move. Tram A moves with constant acceleration $2\,\text{m s}^{-2}$ for 5 seconds and then continues to move along the track at constant speed.

At time $t = 20$ seconds, tram B starts from rest and moves in the same direction as tram A. Tram B moves with constant acceleration $3\,\text{m s}^{-2}$ for 4 seconds and then continues to move along the track at constant speed.

The trams are modelled as particles.

(a) Sketch, on the same axes, a speed-time graph for the motion of tram A and a speed-time graph for the motion of tram B, from $t = 0$ to the instant when tram B overtakes tram A.

(3)

At the instant when the two trams are moving with the same speed, tram A is d metres in front of tram B.

(b) Find the value of d.

(5)

(c) Find the distance of the trams from the depot at the instant when tram B overtakes tram A.

(5)

June2021/Q8

4. At time $t = 0$, a small ball is projected vertically upwards from a point A which is 24.5 m above the ground. The ball first comes to instantaneous rest at the point B, where $AB = 19.6\,\text{m}$ and first hits the ground at time $t = T$ seconds.

The ball is modelled as a particle moving freely under gravity.

(a) Find the value of T.

(6)

(b) Sketch a speed-time graph for the motion of the ball from $t = 0$ to $t = T$ seconds.

(No further calculations are needed in order to draw this sketch.)

(2)

January 2022/Q4

5.

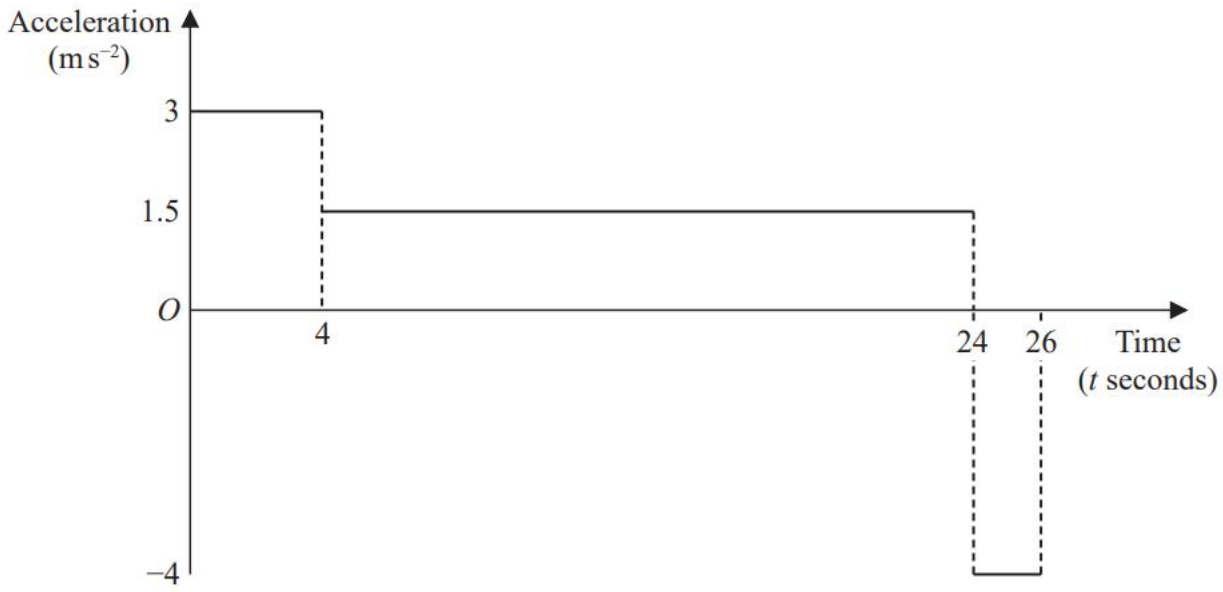

Figure 5

The acceleration-time graph shown in Figure 5 represents part of a journey made by a car along a straight horizontal road. The car accelerated from rest at time $t = 0$

(a) Find the distance travelled by the car during the first 4 s of its journey.

(2)

(b) Find the total distance travelled by the car during the first 26 s of its journey.

(6)

October 2021/Q8

6. A motorbike is moving with constant acceleration along a straight horizontal road.

The motorbike passes a point P and 10 seconds later passes a point Q.

The speed of the motorbike as it passes Q is $28\,\text{m s}^{-1}$

Given that $PQ = 220\,\text{m}$,

(a) find the acceleration of the motorbike,

(3)

(b) find the distance travelled by the motorbike during the fifth second after passing P

(4)

June2022/Q2

7. A car is moving at a constant speed of $25\,\text{m s}^{-1}$ along a straight horizontal road.

The car is modelled as a particle.

At time $t = 0$, the car is at the point A and the driver sees a road sign 48 m ahead.

Let t seconds be the time that elapses after the car passes A.

In a **first** model, the car is assumed to decelerate uniformly at $6\,\text{m s}^{-2}$ from A until the car reaches the road sign.

(a) Use this first model to find the speed of the car as it reaches the sign.

(2)

The road sign indicates that the speed limit immediately after the sign is $13\,\text{m s}^{-1}$.

In a **second** model, the car is assumed to decelerate uniformly at $6\,\text{m s}^{-2}$ from A until it reaches a speed of $13\,\text{m s}^{-1}$. The car then maintains this speed until it reaches the road sign.

(b) Use this second model to find the value of t at which the car reaches the sign.

(4)

In a **third** model, the car is assumed to move with constant speed $25\,\text{m s}^{-1}$ from A until time $t = 0.2$, the car then decelerates uniformly at $6\,\text{m s}^{-2}$ until it reaches a speed of $13\,\text{m s}^{-1}$. The car then maintains this speed until it reaches the road sign.

(c) Use this third model to find the value of t at which the car reaches the sign.

(4)

October 2021/Q3

8. A small ball is projected vertically upwards with speed $29.4\,\text{m s}^{-1}$ from a point A which is 19.6 m above horizontal ground.

The ball is modelled as a particle moving freely under gravity until it hits the ground. It is assumed that the ball does not rebound.

(a) Find the distance travelled by the ball while its speed is less than $14.7\,\text{m s}^{-1}$

(3)

(b) Find the time for which the ball is moving with a speed of more than $29.4\,\text{m s}^{-1}$

(3)

(c) Sketch a speed-time graph for the motion of the ball from the instant when it is projected from A to the instant when it hits the ground. Show clearly where your graph meets the axes.

(3)

October 2022/Q5

9. A train travels along a straight horizontal track between two stations A and B.

The train starts from rest at station A and accelerates uniformly for T seconds until it reaches a speed of $20\,\text{m s}^{-1}$

The train then travels at a constant speed of $20\,\text{m s}^{-1}$ for 3 minutes before decelerating uniformly until it comes to rest at station B.

The magnitude of the acceleration of the train is twice the magnitude of the deceleration.

(a) On the axes below, sketch a speed–time graph to illustrate the motion of the train as it moves from station A to station B.

If you need to redraw your graph, use the axes on page 3

(3)

Stations A and B are 4.8 km apart.

(b) Find the value of T

(5)

(c) Find the acceleration of the train during the first T seconds of its motion.

(2)

January 2023/Q1

10.

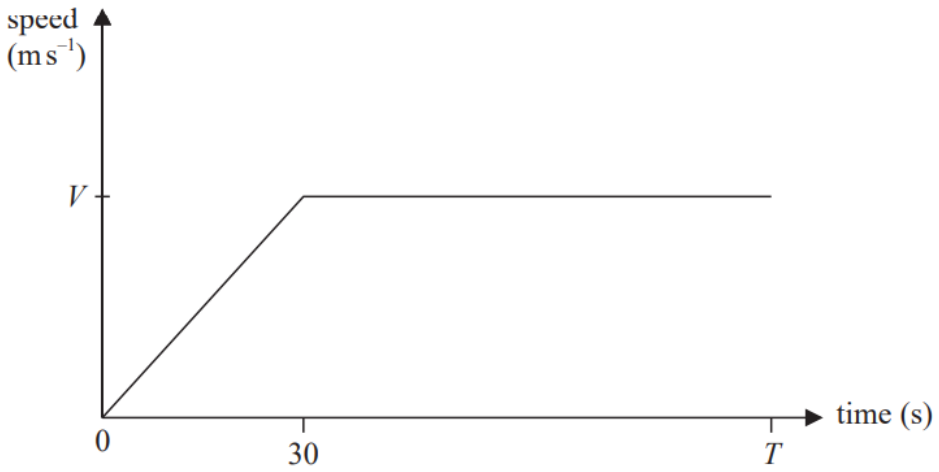

Figure 2

The speed-time graph in Figure 2 illustrates the motion of a car travelling along a straight horizontal road.
At time $t = 0$, the car starts from rest and accelerates uniformly for 30 s until it reaches a speed of $V\,\text{m s}^{-1}$
The car then travels at a constant speed of $V\,\text{m s}^{-1}$ until time $t = T$ seconds.

(a) Show that the distance travelled by the car between $t = 0$ and $t = T$ seconds is $V(T - 15)$ metres.

(2)

A motorbike also travels along the same road.

- The motorbike starts from rest at time $\boldsymbol{t = 10\,s}$ and accelerates uniformly for 40 s
- The acceleration of the motorbike is the **same** as the acceleration of the car
- The motorbike then travels at a constant speed for a further 10 s before decelerating uniformly until it reaches a speed of $V\,\text{m s}^{-1}$ at time T seconds

(b) On Figure 2, sketch a speed-time graph for the motion of the motorbike.

[*If you need to redraw your sketch, there is a copy of Figure 2 on page 15.*]

(2)

(c) Show that the constant speed of the motorbike is $\frac{4V}{3}\,\text{m s}^{-1}$

(2)

At time $t = T$ seconds, the distance travelled by each vehicle is the same.

(d) Find the value of T

(5)

June2023/Q5

11.

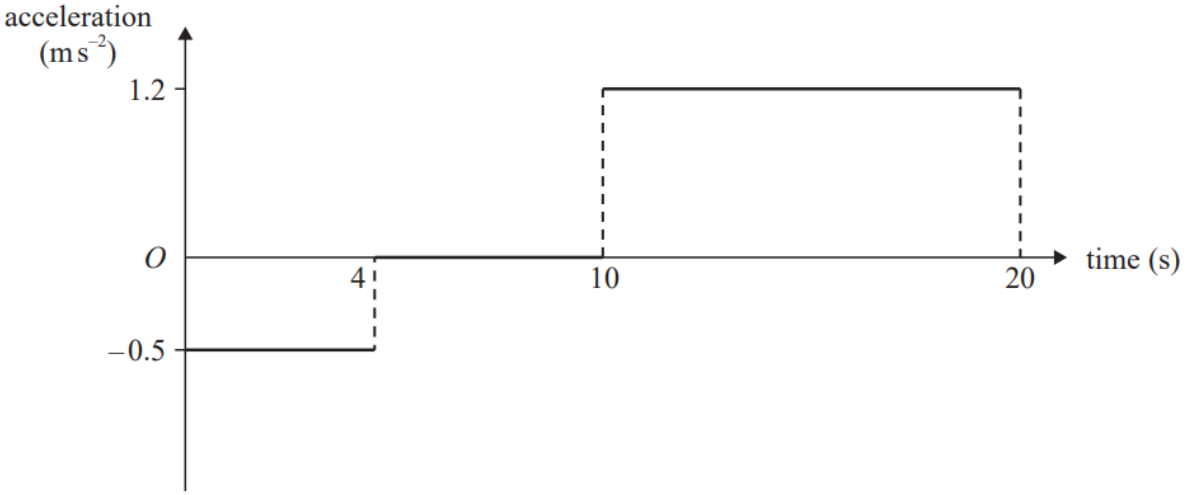

Figure 2

Two fixed points, A and B, are on a straight horizontal road.

The **acceleration-time** graph in Figure 2 represents the motion of a car travelling along the road as it moves from A to B.

At time $t = 0$, the car passes through A with speed $8\,\text{m s}^{-1}$

At time $t = 20\,\text{s}$, the car passes through B with speed $v\,\text{m s}^{-1}$

(a) Show that $v = 18$

(3)

(b) Sketch a speed-time graph for the motion of the car from A to B.

(3)

(c) Find the distance AB.

(4)

October 2023/Q2

12. A van travels with constant acceleration along a straight horizontal road.

The van passes a point A with speed $u\,\text{m s}^{-1}$ and 20 seconds later passes a point B with speed $28\,\text{m s}^{-1}$

The distance AB is 400 m.

(a) Show that $u = 12$

(2)

(b) Find the time taken for the van to travel from A to the midpoint of AB.

(5)

The van has mass 1200 kg.

During its motion the van experiences a constant resistive force of magnitude 260 N

(c) Find the magnitude of the driving force exerted by the engine of the van as it travels from A to B.

(3)

January 2024/Q3

13. A parachute is used to deliver a box of supplies. The parachute is attached to the box.

- the parachute and box are dropped from rest from a helicopter that is hovering at a height of 520 m above the ground
- the parachute and box fall vertically and freely under gravity for 5 seconds, then the parachute opens
- from the instant the parachute opens, it provides a resistance to motion of magnitude 3200 N
- the parachute and box continue to fall vertically downwards after the parachute opens
- the parachute and box are modelled throughout the motion as a particle P of mass 250 kg

(a) Find the distance fallen by P in the first 5 seconds.

(2)

(b) Find the speed with which P lands on the ground.

(7)

(c) Find the total time from the instant when P is dropped from the helicopter to the instant when P lands on the ground.

(3)

(d) Sketch a speed-time graph for the motion of P from the instant when P is dropped from the helicopter to the instant when P lands on the ground.

(2)

June2024/Q5

14. A particle is projected vertically upwards with speed $U\,\text{m s}^{-1}$ from a point A.

The point A is 12 m vertically above the point B.

Point B is on horizontal ground.

The particle moves freely under gravity until it hits the ground at B.

The time taken for the particle to travel from A to B is 4 seconds.

(a) Find the value of U.

(3)

(b) Find the speed of the particle as it hits the ground at B.

(3)

(c) Sketch a speed-time graph for the motion of the particle from the instant it leaves A to the instant it reaches B. (No further calculations are required.)

(2)

June2025/Q3

15. The points A and B lie on the same straight horizontal road.

Figure 2, on page 11, shows the speed-time graph of a cyclist P, for his journey from A to B.
At time $t = 0$, P starts from rest at A and accelerates uniformly for 9 seconds until his speed is $V\,\text{m s}^{-1}$

He then travels at constant speed $V\,\text{m s}^{-1}$

When $t = 42$, cyclist P passes B.

Given that the distance AB is 120 m,

(a) show that $V = 3.2$

(3)

(b) Find the acceleration of cyclist P between $t = 0$ and $t = 9$

(2)

16. Cyclist P continues to cycle along the road in the same direction at the same constant speed, $V\,\text{m s}^{-1}$

When $t = 6$, a second cyclist Q sets off from A and travels in the same direction as P along the same road. She accelerates for T seconds until her speed is $3.6\,\text{m s}^{-1}$

She then travels at constant speed $3.6\,\text{m s}^{-1}$

Cyclist Q catches up with P when $t = 54$

(c) On Figure 2, on page 11, sketch a speed-time graph showing the journeys of **both** cyclists, for the interval $0 \leqslant t \leqslant 54$

(3)

(d) Find the value of T

(5)

October 2024/Q4

17. The fixed points A, B and C lie in a straight line on a horizontal road.

- At time $t = 0$, a motorbike passes through A with speed $5\,\text{m s}^{-1}$
- From A, the motorbike accelerates uniformly until it reaches B with a speed of $V\,\text{m s}^{-1}$
- The motorbike takes T_1 seconds to travel from A to B
- From B, the motorbike decelerates uniformly until it comes to rest at C
- The motorbike takes T_2 seconds to travel from B to C

(a) Sketch a speed-time graph for the motion of the motorbike as it moves from A to C.

(3)

The distance AB is 132 m and the distance BC is 136 m.

(b) Find, in terms of V, an expression for

(i) T_1

(ii) T_2

(4)

Given that the motorbike takes 28 s to travel from A to C,

(c) find the value of V,

(2)

(d) find the deceleration of the motorbike.

(2)

January2025/Q2