Access Tuition

A-Level Physics

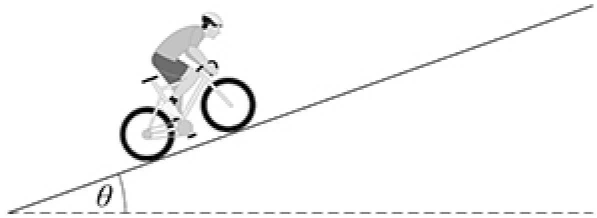
Motion Along a Straight Line

Question Paper

Time available: 65 minutes
Marks available: 47 marks

1. (a) **Figure 1** shows a cyclist going up a hill.

Figure 1



not to scale

The angle θ of the slope of the hill is constant.
The total mass m of the cyclist and bicycle is $65\ \mathrm{kg}$.

Write an expression for the component of the total weight parallel to the slope.

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(1)

(b) The useful power output of the cyclist is $310\ \mathrm{W}$.
The cyclist has a steady speed of $1.63\ \mathrm{m\ s^{-1}}$.

Assume that air resistance is negligible at this speed.

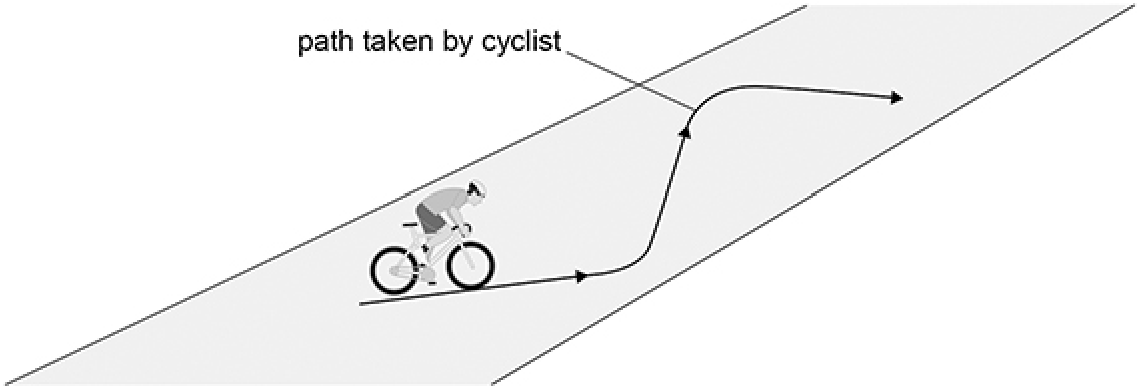
Calculate θ.

θ = ____________________ °

(2)

Figure 2 shows an alternative 'zig-zag' path taken by the cyclist up the same hill. She maintains a steady speed of $1.63\ \mathrm{m\ s^{-1}}$.

Figure 2



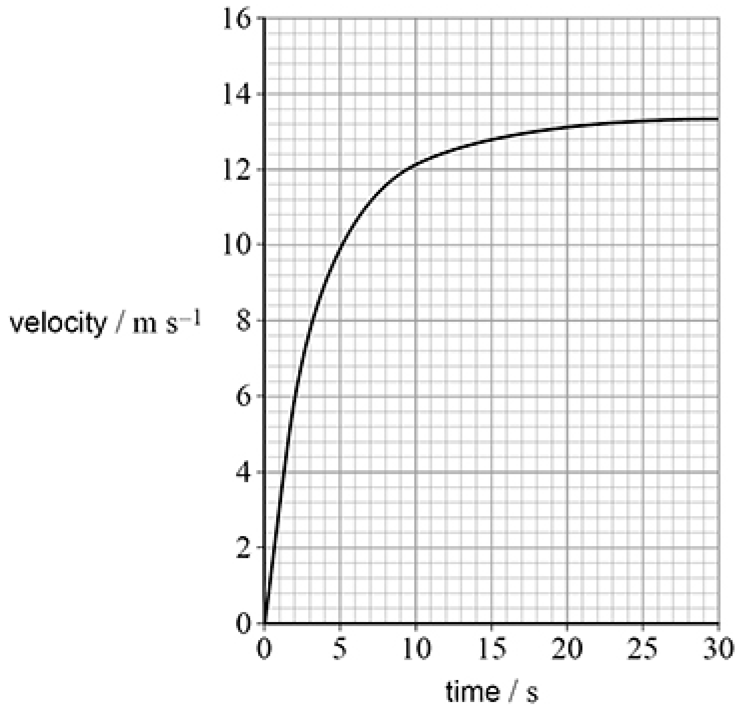
(c) Discuss how her useful power output when taking the path in **Figure 2** compares with her useful power output in part (b).

(3)

The cyclist reaches the top of the hill. She then travels back down the hill in a straight line. The bicycle rolls freely without the cyclist pushing the pedals or applying the brakes.

Figure 3 shows the variation of her velocity with time as she goes down the hill.

Figure 3



(d) Determine the acceleration of the cyclist 10.0 s after she begins to go down the hill.

acceleration = _______________ $m\ s^{-2}$

(3)

(e) Energy transfers occur as the cyclist travels down the hill.

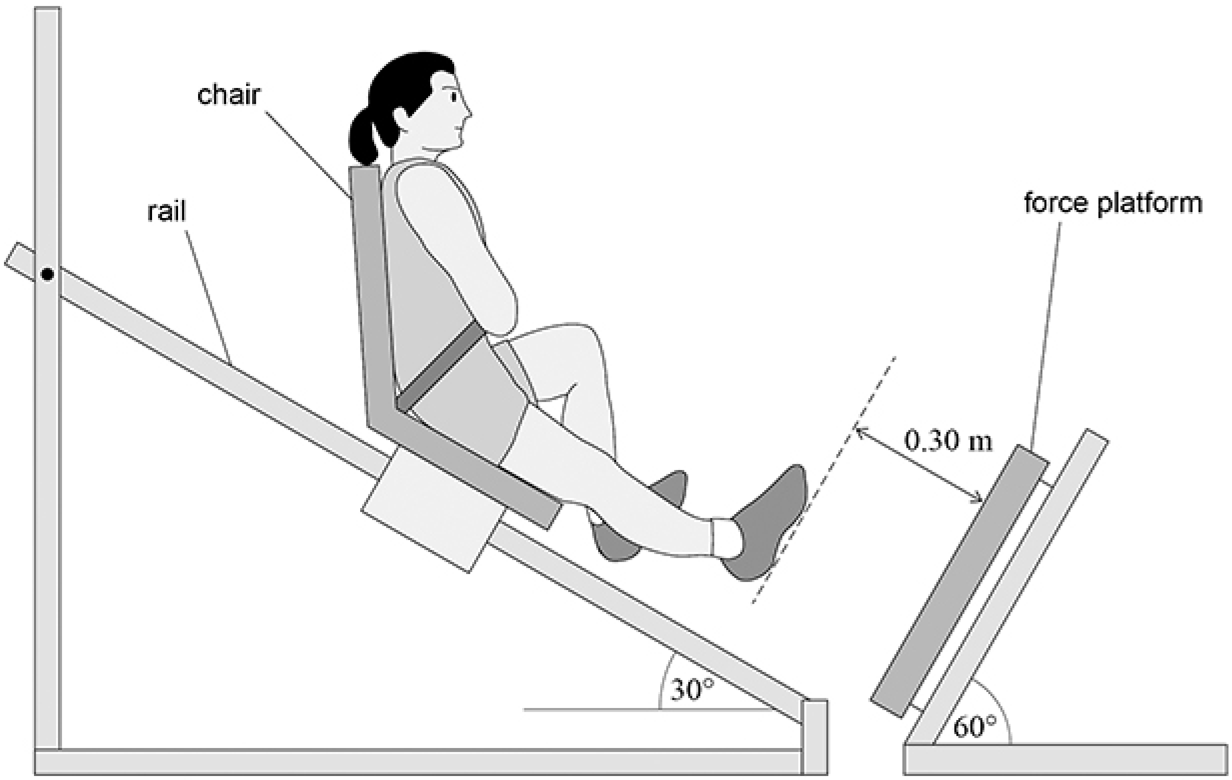
Outline how these energy transfers explain the shape of the graph in **Figure 3**.

(4)

(Total 13 marks)

2. **Figure 1** shows apparatus used to measure the force exerted by an athlete during a single-leg jump.

Figure 1



In **Figure 1**, the athlete is strapped into a chair and held at rest halfway along a rail. The chair is then released to slide down the rail. The athlete keeps her right leg extended until her right foot makes contact with a force platform.
Friction between the rail and the chair is negligible.

initial distance between right foot and platform = 0.30 m
angle between rail and floor = $30°$
angle between platform and floor = $60°$

(a) Show that the athlete and chair accelerate towards the platform at approximately 5 m s^{-2}.

(1)

(b) Calculate the speed of the athlete when her right foot makes initial contact with the platform.

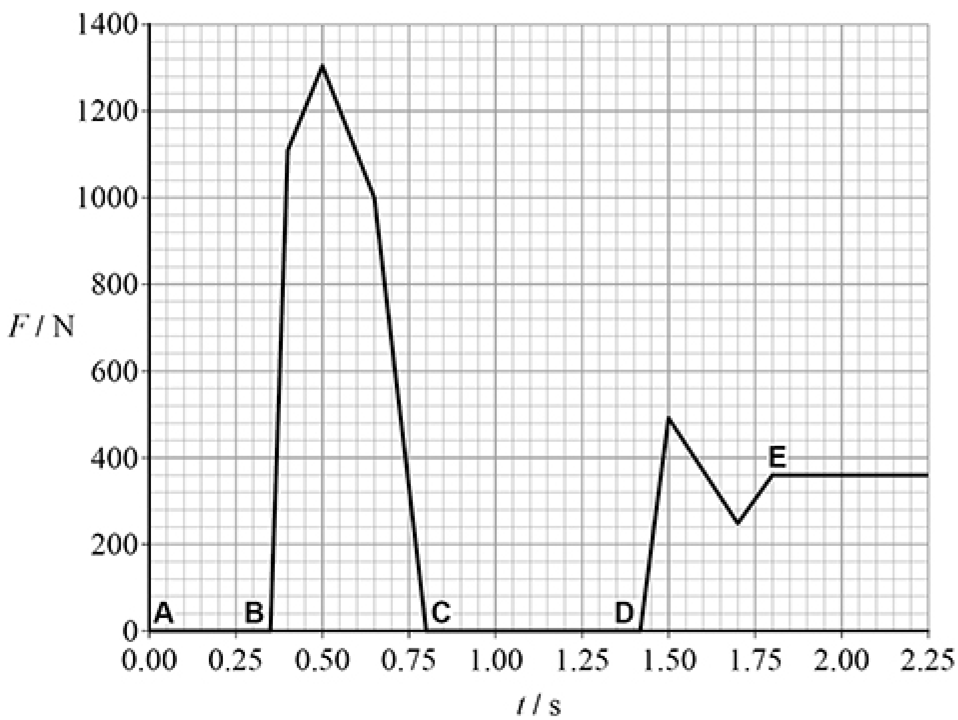
speed = _______________ $m\ s^{-1}$

(2)

After her right foot makes contact with the platform, she uses her right leg to stop moving and then push herself back up the rail. She slides down the rail again, lands on the platform with both feet and comes to rest.

Figure 2 shows the variation of force *F* on the platform with time *t* during the full motion.

Figure 2



The sequence below describes what happens at the five instances **A**, **B**, **C**, **D** and **E** shown in **Figure 2**.

A: athlete and chair are released at t = 0.00 s
B: right foot of athlete contacts the platform with leg fully extended
C: right foot loses contact with the platform
D: athlete lands on the platform with both feet
E: athlete and chair come to rest

(c) Determine the impulse provided by the force platform between **B** and **C**.

impulse = _______________ N s

(2)

(d) Determine the distance travelled by the athlete between **C** and **D**.

distance travelled = _______________ m

(3)

(e) Determine, using **Figure 2**, the combined mass of the athlete and chair.

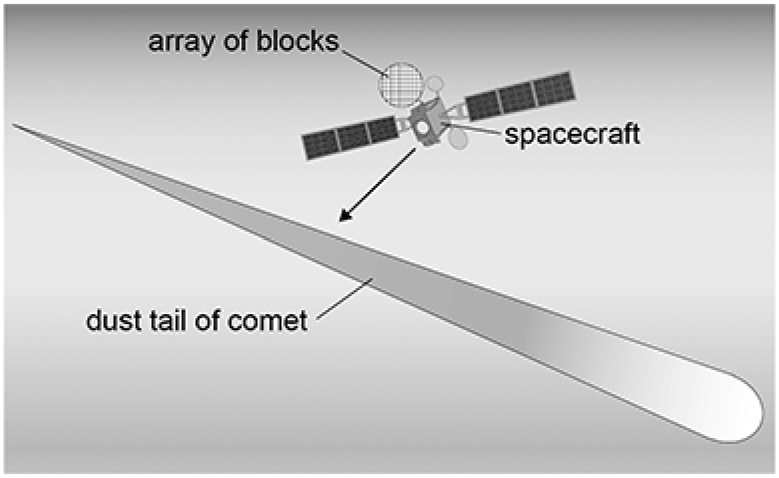
mass = _______________ kg

(2)

(Total 10 marks)

3. **Figure 1** shows a spacecraft travelling towards a comet.
The spacecraft has an array of blocks designed to capture small dust particles from the comet's tail.

Figure 1



To test the blocks before launch, a spherical dust particle **P** is fired at a right angle to the surface of a fixed, stationary block.

P has a mass of 1.1×10^{-9} kg. It has a speed of 5.9×10^{3} m s^{-1} when it hits the surface of the block.

P comes to rest inside the block.

(a) Calculate the work done in bringing **P** to rest.

work done = _______________ J

(1)

(b) **P** travels a distance of 2.9 cm in a straight line inside the block before coming to rest. The resultant force on **P** varies as it penetrates the block.

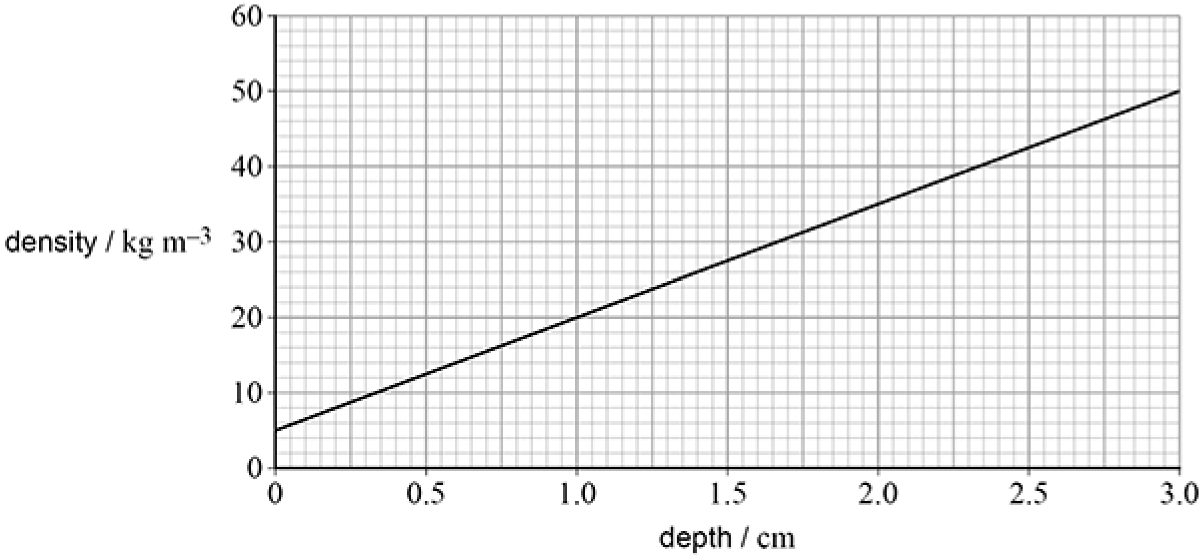
Calculate the average force acting on **P** as it is brought to rest.

average force = _______________ N

(2)

(c) The block is rectangular with an area of cross-section of 8.0 cm^2 and a thickness of 3.0 cm. **Figure 2** shows how the density of the block varies with depth up to its maximum thickness.

Figure 2



Calculate the mass of the block.

mass = ________________ kg

(4)

(d) In another test, a spherical particle **Q** is fired at a right angle to the surface of an identical block.

Q has the same mass as **P** and is travelling at the same speed as **P** when it strikes the surface of the block.
Q is made from a less dense material than **P**.

Compare the distance travelled by **Q** with that travelled by **P** as they are brought to rest.

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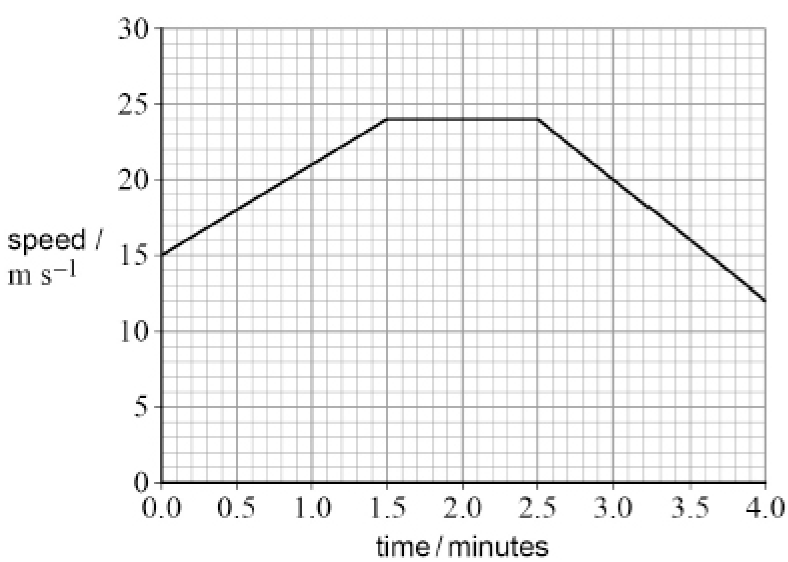
(3)
(Total 10 marks)

4. A pair of cameras is used on a motorway to help determine the average speed of vehicles travelling between the two cameras.

Figure 1 shows the speed–time graph for a car moving between the two cameras.

Figure 1



(a) The speed limit for the motorway between the two cameras is 22 m s^{-1}.

Determine whether the average speed of the car exceeded this speed limit.

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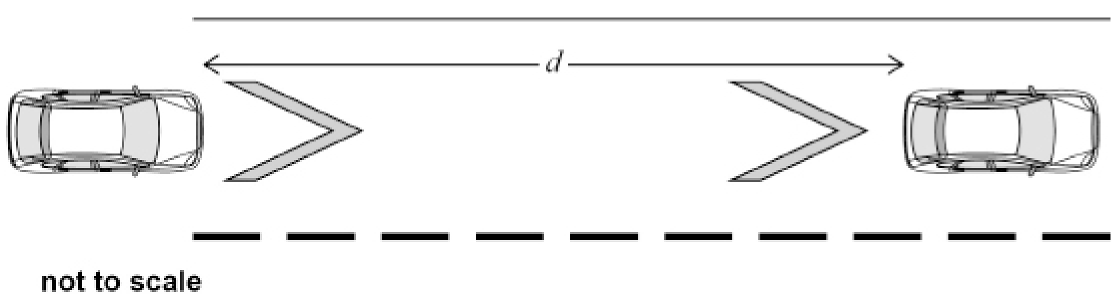
(3)

(b) Markings called chevrons are used on motorways.

The chevron separation is designed to give a driver time to respond to any change in speed of the car in front. The driver is advised to keep a minimum distance d behind the car in front, as shown in **Figure 2**.

Figure 2



Government research suggests that the typical time for a driver to respond is between 1.6 s and 2.0 s.

Suggest a value for d where the speed limit is 31 m s^{-1}.

d = _______________ m

(2)

(c) The chevron separation is based on the response time, not on the time taken for a car to stop.

The brakes of a car are applied when its speed is 31 m s^{-1} and the car comes to rest. The total mass of the car is 1200 kg.

The average braking force acting on the car is 6.8 kN.

Calculate the time taken for the braking force to stop the car **and** the distance travelled by the car in this time.

time = _______________ s

distance = _______________ m

(4)

(d) Suggest why the chevron separation on motorways does not take into account the distance travelled as a car comes to rest after the brakes are applied.

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(1)

(e) At bends on motorways the road is sloped so that a car is less likely to slide out of its lane when travelling at a high speed.

Figure 3 shows a car of mass 1200 kg travelling around a curve of radius 200 m. The motorway is sloped at an angle of 5.0°.

Figure 4 shows the weight W and reaction force N acting on the car. The advisory speed for the bend is chosen so that the friction force down the slope is zero.

Figure 3

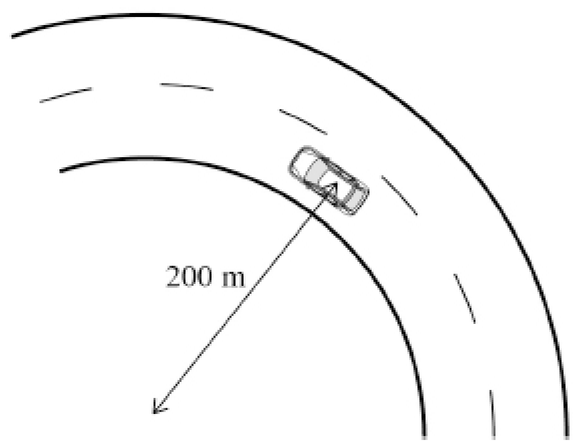
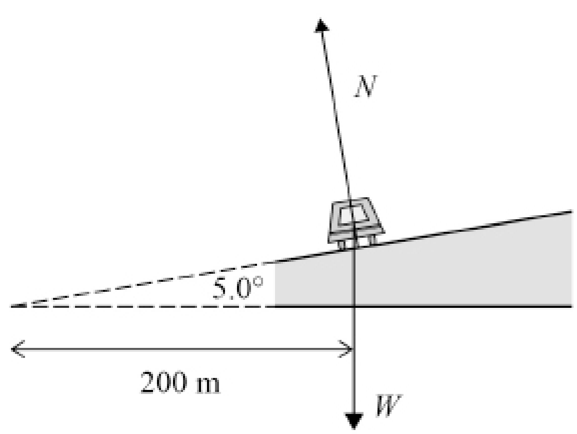


Figure 4



Suggest an appropriate advisory speed for this section of the motorway.

advisory speed = ________________ m s^{-1}

(4)

(Total 14 marks)