

**Q1.** An apple and a leaf fall from a tree at the same instant. Both apple and leaf start at the same height above the ground but the apple hits the ground first.

You may be awarded marks for the quality of written communication in your answer.

Use Newton's laws of motion to explain why

(i) the leaf accelerates at first then reaches a terminal velocity,

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(ii) the apple hits the ground first.

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**(Total 5 marks)**

**Q2.** A supertanker of mass  $4.0 \times 10^8$  kg, cruising at an initial speed of  $4.5 \text{ m s}^{-1}$ , takes one hour to come to rest.

(a) Assuming that the force slowing the tanker down is constant, calculate

(i) the deceleration of the tanker,

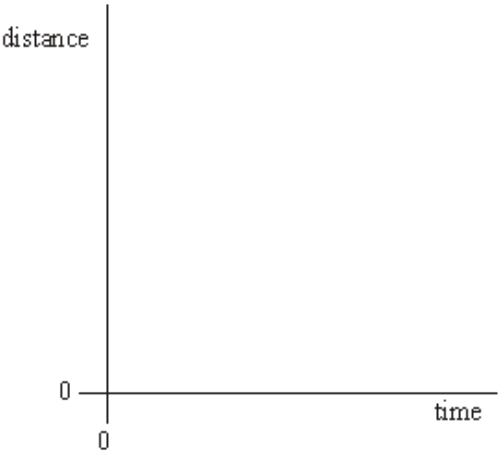
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(ii) the distance travelled by the tanker while slowing to a stop.

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**(4)**

(b) Sketch, using the axes below, a distance-time graph representing the motion of the tanker until it stops.



(2)

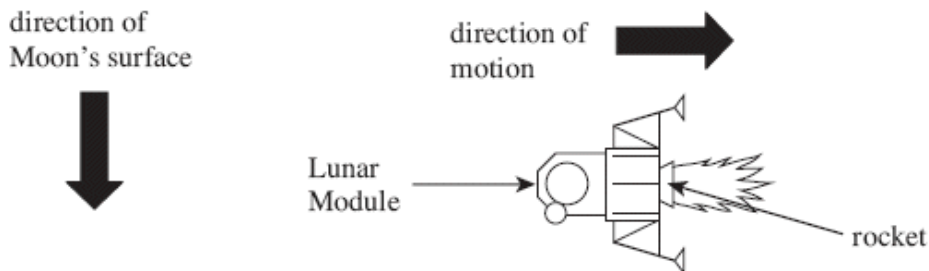
(c) Explain the shape of the graph you have sketched in part (b).

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(2)  
(Total 8 marks)

- Q3.** In the 1969 Moon landing, the Lunar Module separated from the Command Module above the surface of the Moon when it was travelling at a horizontal speed of  $2040 \text{ m s}^{-1}$ . In order to descend to the Moon's surface the Lunar Module needed to reduce its speed using its rocket as shown in **Figure 1**.

**Figure 1**



- (a) (i) The average thrust from the rocket was  $30 \text{ kN}$  and the mass of the Lunar Module was  $15100 \text{ kg}$ . Calculate the horizontal deceleration of the Lunar Module.

answer = .....  $\text{m s}^{-2}$

(2)

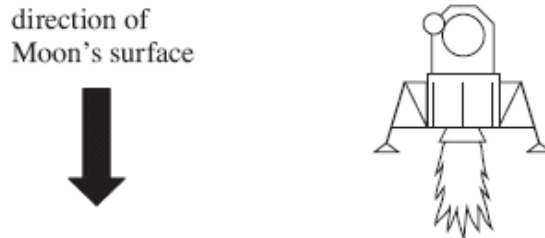
- (ii) Calculate the time for the Lunar Module to slow to the required horizontal velocity of  $150 \text{ m s}^{-1}$ . Assume the mass remained constant.

answer = ..... s

(2)

- (b) The rocket was then used to control the velocity of descent so that the Lunar Module descended vertically with a constant velocity as shown in **Figure 2**. Due to the use of fuel during the previous deceleration, the mass of the Lunar Module had fallen by 53%.

**Figure 2**



acceleration due to gravity near the Moon's surface =  $1.61 \text{ m s}^{-2}$

- (i) Draw force vectors on **Figure 2** to show the forces acting on the Lunar Module at this time. Label the vectors.

(2)

- (ii) Calculate the thrust force needed to maintain a constant vertical downwards velocity.

answer = ..... N

(2)

- (c) When the Lunar Module was 1.2 m from the lunar surface, the rocket was switched off. At this point the vertical velocity was  $0.80 \text{ m s}^{-1}$ . Calculate the vertical velocity at which the Lunar Module reached the lunar surface.

answer = .....  $\text{m s}^{-1}$

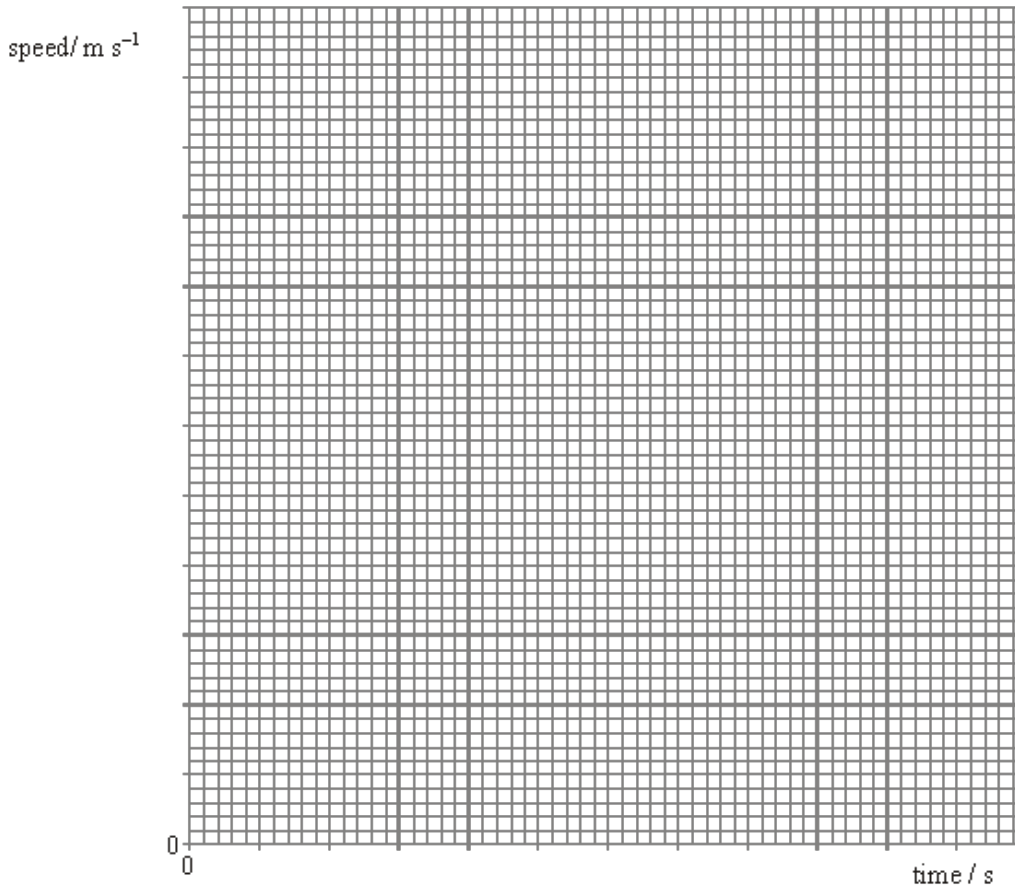
(2)

**(Total 10 marks)**

**Q4.** A car accelerates from rest to a speed of  $26 \text{ m s}^{-1}$ . The table shows how the speed of the car varies over the first 30 seconds of motion.

<b>time/ s</b>	0	5.0	10.0	15.0	20.0	25.0	30.0
<b>speed/ <math>\text{m s}^{-1}</math></b>	0	16.5	22.5	24.5	25.5	26.0	26.0

(a) Draw a graph of speed against time on the grid provided.



(3)

(b) Calculate the average acceleration of the car over the first 25 s.

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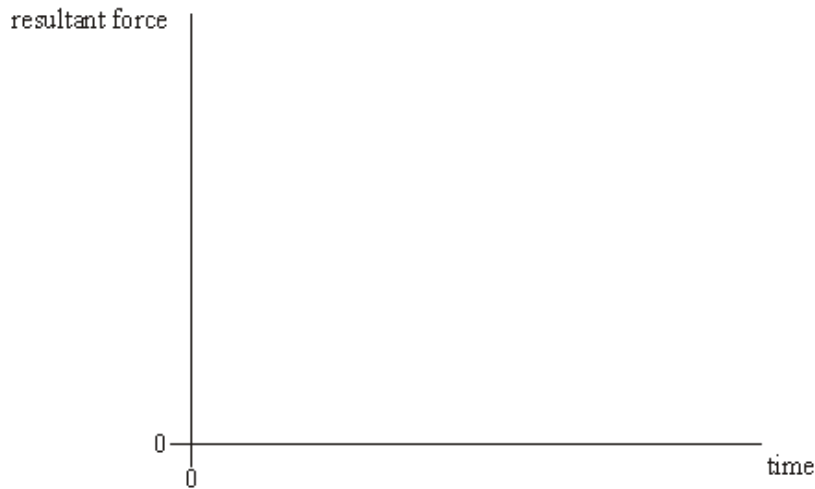
(2)

(c) Use your graph to estimate the distance travelled by the car in the first 25 s.

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(2)

- (d) Using the axes below, sketch a graph to show how the resultant force acting on the car varies over the first 30 s of motion.



(2)

- (e) Explain the shape of the graph you have sketched in part (d), with reference to the graph you plotted in part (a).

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(2)

(Total 11 marks)

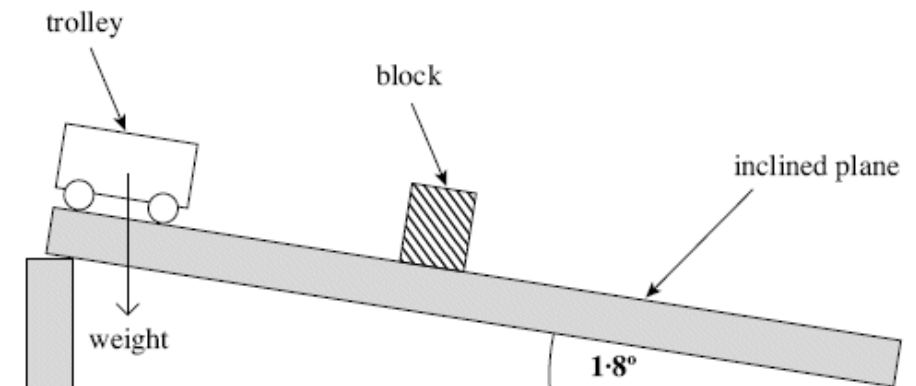
**Q5.** Galileo used an inclined plane, similar to the one shown in the figure below, to investigate the motion of falling objects.

- (a) Explain why using an inclined plane rather than free fall would produce data which is valid when investigating the motion of a falling object.

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(2)

- (b) In a demonstration of Galileo's investigation, the number of swings of a pendulum was used to time a trolley after it was released from rest. A block was positioned to mark the distance that the trolley had travelled after a chosen whole number of swings. See the figure below.



The mass of the trolley in the figure above is 0.20 kg and the slope is at an angle of  $1.8^\circ$  to the horizontal.

- (i) Show that the component of the weight acting along the slope is about 0.06 N.

(2)

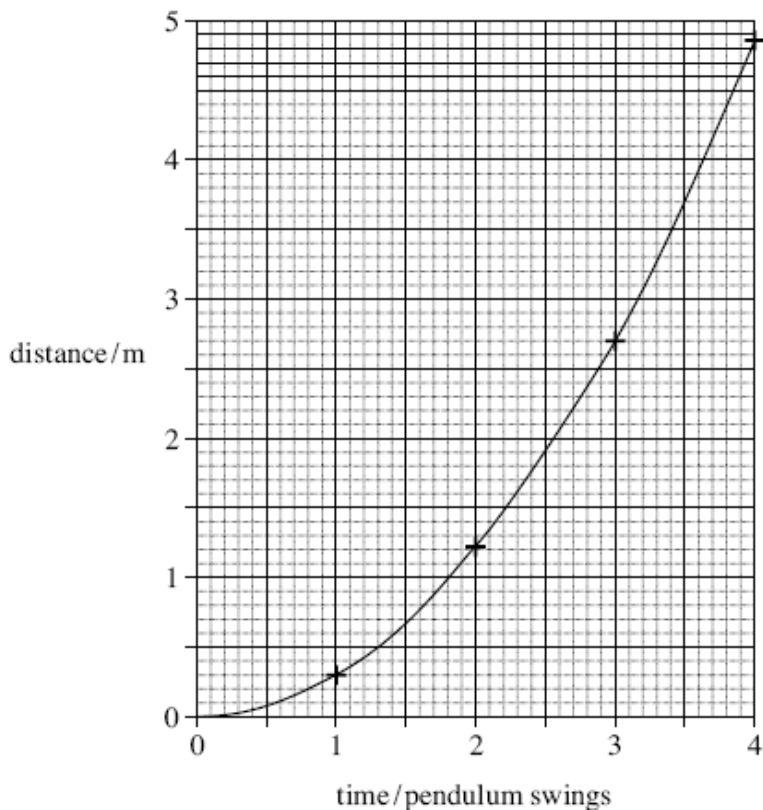
- (ii) Calculate the initial acceleration down the slope.

answer = .....  $\text{m s}^{-2}$

(2)

(c) In this experiment, the following data was obtained. A graph of the data is shown below it.

time / pendulum swings	distance travelled /m
1	0.29
2	1.22
3	2.70
4	4.85



From the graph above, state what you would conclude about the motion of the trolley?  
Give a reason for your answer.

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(2)



- (d) Each complete pendulum swing had a period of 1.4 s. Use the graph above to find the speed of the trolley after it had travelled 3.0 m.

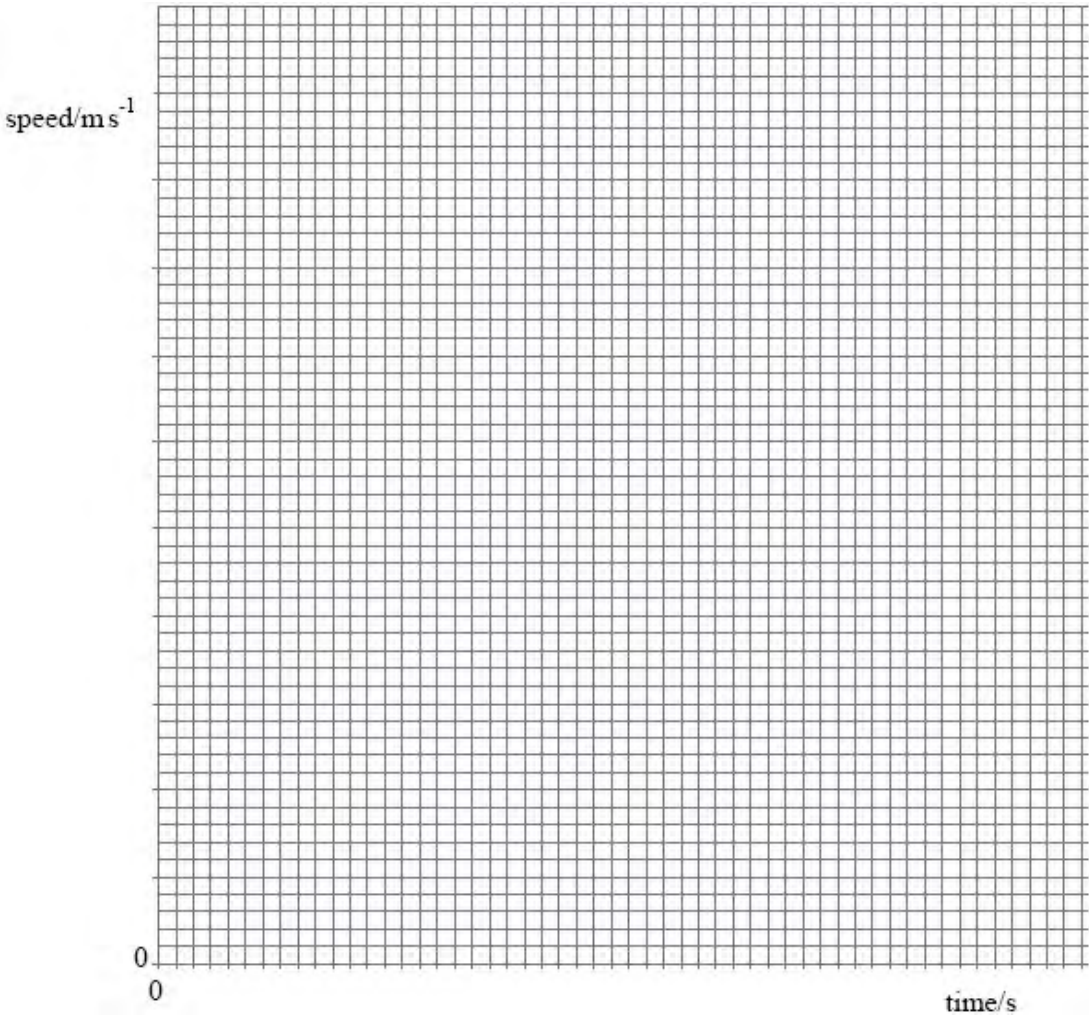
answer = ..... m s<sup>-1</sup>

(3)  
(Total 11 marks)

- Q6.** A car accelerates from rest to a speed of 26 m s<sup>-1</sup>. The table shows how the speed of the car varies over the first 30 seconds of motion.

time/s	0	5.0	10.0	15.0	20.0	25.0	30.0
speed/m s <sup>-1</sup>	0	16.5	22.5	24.5	25.5	26.0	26.0

(a) Draw a graph of speed against time on the grid below.



(5)

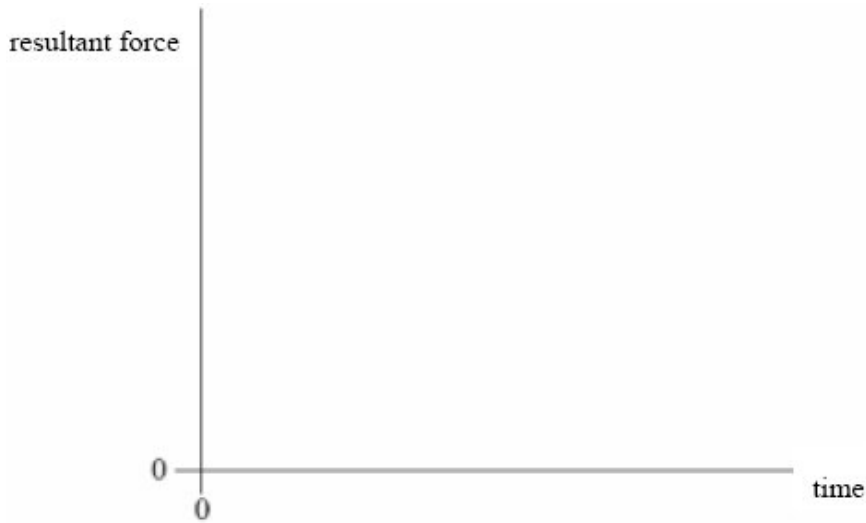
(b) Calculate the average acceleration of the car over the first 25 s.

(2)

(c) Use your graph to estimate the distance travelled by the car in the first 25 s.

(2)

- (d) Using the axes below, sketch a graph to show how the resultant force acting on the car varies over the first 30 s of motion.



(3)

- (e) Explain the shape of the graph you have sketched in part (d), with reference to the graph you plotted in part (a).

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(2)

(Total 14 marks)

- M1.** (i) weight greater than air resistance  
 [or (initially only) weight/gravity acting] (1)  
 hence resultant force downwards or therefore acceleration (2nd law) (1)  
 air resistance or upward force increases with speed (1)  
 until air resistance equals weight or resultant force is zero (1)  
 leaf moves at constant velocity (1st law)  
 [or 1st law applied correctly] (1)
- (ii) air resistance depends on shape  
 [or other correct statement about air resistance] (1)  
 air resistance less significant (1)  
 air resistance less, therefore greater velocity  
 [or average velocity greater or accelerates for longer] (1)

max 5  
 QWC 2

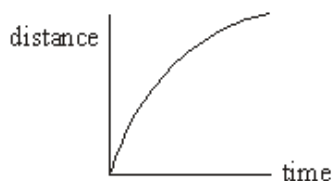
[5]

- M2.** (a) (i) (use of  $a = \frac{\Delta v}{\Delta t}$  gives)  $a = \frac{4.5}{3600}$  (1)  
 $= 1.25 \times 10^{-3} \text{ms}^{-2}$  (1)
- (ii) (use of  $v^2 = u^2 + 2as$  gives)  $0 = 4.5^2 - 2 \times 1.25 \times 10^{-3} \times s$  (1)

$$s \left( = \frac{20.25}{2.5 \times 10^{-3}} \right) = 8.1 \times 10^3 \text{m} \text{ (1)}$$

4

- (b) increasing curve (1)  
 correct curve (1)



1

- (c) gradient (slope) of graph represents speed (1)  
 hence graph has decreasing gradient (1)

2

[8]

**M3.** (a) (i)  $\left(\alpha = \frac{F}{m}\right) = \frac{(-)30(000)}{15100}$  **(1)** = (-)2.0 (= 1.99 m s<sup>-2</sup>) **(1)**

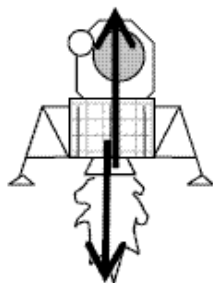
2

(ii)  $(v = u + at) t = \frac{v-u}{a}$  or substitution **(1)**

=  $\left(\frac{150 - 20401}{-1.99}\right) = 950$  (s) **(1)** ecf from (i)

2

(b) (i)



opposing vertical arrows of roughly equal length **or** labelled weight/mg/gravity/W **and** thrust/reaction/R/F/TF/engine force/rocket force/motor force/motive force/driving force **(1)**

correctly labelled

+ arrows vertical

+ not more than 2 mm apart

+ roughly central

+ weight arrow originates within rectangular section and thrust originates within rectangular section or on jet outlet **(1)**

2

(ii) new mass = 15100 × 0.47 = 7097 (kg) **(1)**

(F = mg = 7097 × 16(1)) = 11000 (= 11426 N) **(1)**

2

(c)  $(v^2 = u^2 + 2as \ v = \sqrt{0.80^2 + 2 \times 1.61 \times 1.2})$  correct  $u$ ,  $a$  and  $s$  clearly identified **(1)**

= 2.1 (= 2.122 m s<sup>-1</sup>) **(1)**

2

[10]

**M4.** (a) scales **(1)**

six points correctly plotted **(1)**

trendline **(1)**

3

- (b) average acceleration =  $\frac{26}{25}$  (1)  
 = 1.0(4) ms<sup>-2</sup> (1)  
 (allow C.E. for incorrect values used in acceleration calculation) 2
- (c) area under graph (1)  
 = 510 ± 30 m (1) 2
- (d) (graph to show force starting from y-axis)  
 decreasing (not a straight line) (1)  
 to zero (at end of graph) (1) 2
- (e) (since) gradient of a velocity-time graph gives acceleration (1)  
 first graph shows acceleration is decreasing (1) 2

[11]

- M5.** (a) any **two** from  
 freefall is too quick (any indication of slower motion) (1)  
 (Galileo had) no (accurate) method to **time** freefall (or valid  
 comment regarding timing of freefall or inclined plane) (1)  
 correct reference to **air** resistance or **drag** (not 'wind') (1) max 2
- (b) (i)  $0.20 \times 9.81 = 1.962$  (N) (1)  
 (1.962 sin 1.8 =) 0.0616 or 0.062 seen (1) (allow 0.061)  
 (0.0628 for use of g = 10 gets 1 mark) 2

(ii)  $0.06(16)/0.20$

**or** use of  $a = F/m$  with a clearly identified force but not the weight

**or**  $g \sin \theta = g \sin 1.8^\circ$  **(1)**

$0.31 \text{ (m s}^{-2}\text{)} \text{ (1) (0.308)}$

*accept 0.3 or 0.30 correct answer only for second mark*

**or**  $(a = 2s/l^2)$

$= 2 \times 0.29/1.4^2 \text{ (1)} = 0.31 \text{ (1)}$  or use of other values from table

2

- (c) accelerating
- (1)**
- (accept increasing speed, etc but not increasing acceleration/quicker motion, etc)

greater distance for each additional swing ('per unit time' must be implied)  
or gradient/ steepness/ slope increasing **(1)** (accept curves upwards)

2

- (d)
- tangent used:**

tangent drawn at  $3.0 \text{ m} \pm 0.3$  on graph **(1)**their time from graph  $\times 1.4$  **(1)**

$= 1.28 \text{ to } 1.44 \text{ (m s}^{-1}\text{)} \text{ (1)}$

**or suvat used:**

use of  $v = \frac{2s}{t}$  or  $v = (u) + at$  with  $a$  from (b) (ii) **(1)**

$(t =) 4.4 \text{ to } 4.5 \text{ (s)} \text{ (1)}$

$(\text{speed} =) 1.3 \text{ to } 1.4 \text{ (m s}^{-1}\text{)} \text{ (1)}$

3

**[11]**

- M6.**
- (a) scales
- (1)(1)**
- (one mark for each scale)

six points correctly plotted **(1)(1)**  
(ignore 0,0 and lose one mark for each error)trend line **(1)** (if misses more than two points then lose mark)

5

- (b) average acceleration =  $26/25$  **(1)**  
=  $1.0(4) \text{ m s}^{-2}$  **(1)** e.c.f. from correct values used 2
- (c) area under graph **(1)** =  $510 \pm 30\text{m}$  **(1)** 2
- (d) curve decreasing **(1)**  
to zero at end of graph **(1)** and starting from vertical axis within 1mm **(1)** 3
- (e) (since) gradient of a velocity-time graph gives acceleration **(1)**  
(first graph shows) acceleration is decreasing **(1)**  
**or** resistive force increases (with speed) **(1)**  
so resultant force (or acceleration) decreases **(1)** 2

[14]



