1. Which of the following quantities is a vector?

A density

B mass

C strain

D weight

(Total 1 mark)

2. Newton's third law tells us that

A actions usually have a reaction

B weight and normal contact force are always equal and opposite

C moving with constant velocity is the same as being at rest

D forces always arise in pairs

(Total 1 mark)

3. An athlete throws a javelin. Just as it hits the ground the javelin has a horizontal velocity component of 20 m s^{-1} and a vertical velocity component of 10 m s^{-1}. The magnitude of the javelin's velocity as it hits the ground is

A 10 m s^{-1}

B 15 m s^{-1}

C 22 m s^{-1}

D 30 m s^{-1}

(Total 1 mark)

4. If air resistance is neglected, the horizontal velocity component of an arrow fired from a bow .... with distance travelled

A decreases linearly from zero

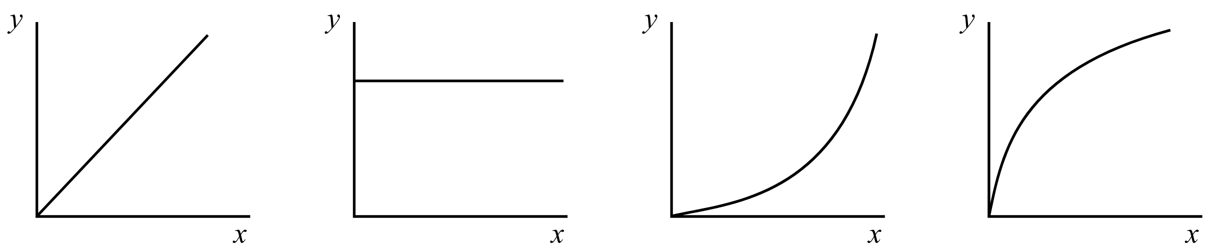
B increases from zero to a maximum

C increases linearly from zero

D stays constant at a non-zero value

(Total 1 mark)

5.

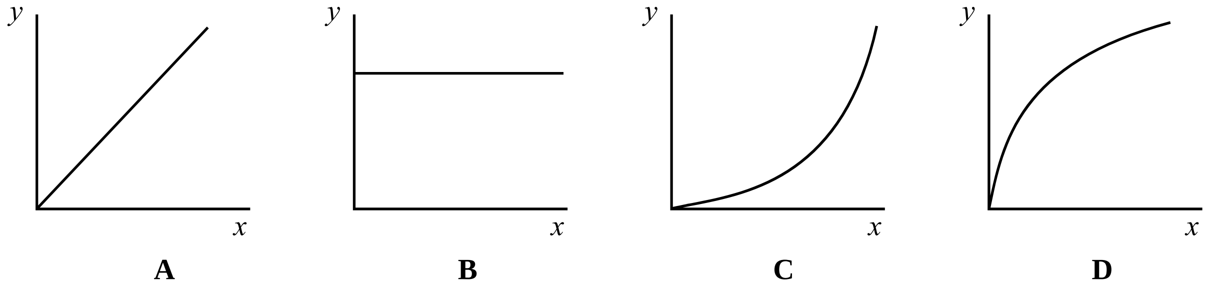


A **B** **C** **D**

Variable on *y*-axis	**Variable on *x*-axis**
The kinetic energy of a car accelerating uniformly from rest	Displacement from starting position

(Total 1 mark)

6.



Variable on *y*-axis	**Variable on *x*-axis**
The acceleration of a feather falling near to the Moon’s surface	Height above the Moon’s surface

(Total 1 mark)

7. A shot putter launches the shot at an angle of 30o to the horizontal. The throw is repeated with the same launch speed, but this time at an angle of 40o to the horizontal. Which of the following is **not** correct?

A The horizontal range is greater

B The horizontal velocity component is increased

C The maximum height reached is greater

D The shot is in the air for longer

(Total 1 mark)

8. (a) Near schools the speed limit is 20 mph. It is claimed that reducing the speed limit from 30 mph (13.3 m s^{-1}) to 20 mph (8.9 m s^{-1}) halves the risk of serious injury in a car accident.

When a car is involved in a crash, the collision energy depends upon the car's speed just before impact.

(i) Determine $\dfrac{\text{kinetic energy of car travelling at 20 mph}}{\text{kinetic energy of car travelling at 30 mph}}$.

$\dfrac{\text{kinetic energy of car travelling at 20 mph}}{\text{kinetic energy of car travelling at 30 mph}}$ = ...

(1)

(ii) To what extent does your answer support the claim?

....

....

(2)

(b) A car of mass 1200 kg is in a crash. The front bumper of the car deforms, and the car is brought to rest from an initial speed of 10 m s^{-1} in a distance of 0.12 m.

By considering the work done on the car as it is brought to rest, calculate the average impact force that acts.

Average impact force = ...

(3)

(c) Modern cars include crumple zones to reduce the size of the impact force. Suggest how the crumple zones do this.

....

....

....

(1)
(Total 7 marks)

9. A skydiver accelerates towards the ground at 9.81 m s–2 at the instant that he leaves the aeroplane.

(a) Explain why his acceleration will decrease as he continues to fall.

....

....

....

....

(2)

(b) The skydiver opens his parachute. Explain why he reaches a terminal velocity shortly afterwards.

....

....

....

....

(2)

(c) The velocity at which he then hits the ground is similar to that achieved when falling freely from a height of 3 m. Calculate this velocity.

Velocity = ...

(2)
(Total 6 marks)

10. A raindrop has a radius of 0.70 mm. It is falling at terminal velocity through air.

(a) Show that the mass of the raindrop is approximately 1×10^{-6} kg.
Density of water = 1000 kg m^{-3}.

....

....

....

(2)

(b) Ignoring any upthrust on the raindrop, calculate its terminal velocity.
Viscosity of air = 8.90×10^{-4} kg m^{-1} s^{-1}.

Terminal velocity = ...

(2)
(Total 4 marks)

11. A student was asked the following question: "Describe the variation in energy of a bungee jumper from the moment that the jumper is released to the lowest point that the jumper reaches." As an answer the student wrote the following:

"Initially the jumper has gravitational potential energy, which is converted into elastic potential energy as the cord stretches. At the lowest point in the jump, all of the gravitational potential energy has been converted to elastic potential energy."

(a) Discuss the student's answer, highlighting any incorrect or missing physics.

....

....

....

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....

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....

....

(4)

(b) The bungee jumper has a mass of 80 kg and is in free fall through the air. At a particular instant the force of the air resistance acting on the bungee jumper is 285 N.
Calculate the acceleration of the jumper.

Acceleration = ...

(2)
(Total 6 marks)

12. An astronaut on the moon drops a hammer. The gravitational acceleration is 1.6 m s–2.

(a) How long does the hammer take to fall 1.0 m from rest?

Time = ...

(2)

(b) Calculate the velocity of the hammer just before it hits the ground.

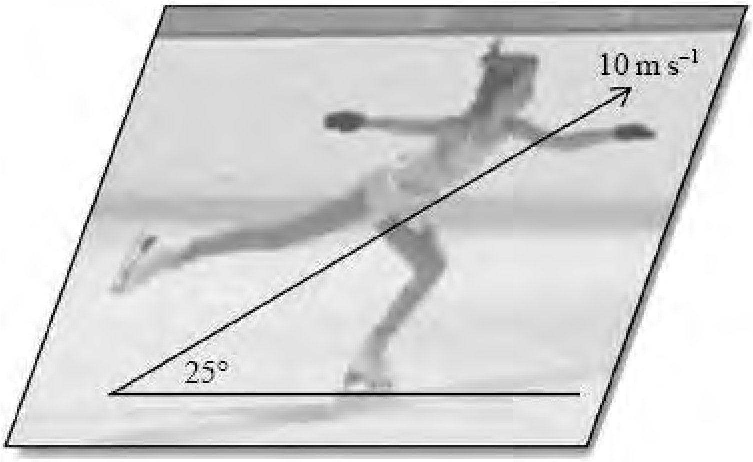
Velocity = ...

(2)

(Total 4 marks)

13. Performing complex jumps is an important aspect of a figure skater's program. Jumps with great heights and jump distances tend to leave a better impression with the judges, resulting in better marks for the skater.

A skater of mass 60 kg leaves the ice with a velocity of 10 m s–1 at an angle of 25° to the horizontal.



(a) Show that the vertical component of the skater's velocity is approximately 4 m s^{-1}.

....

....

(2)

(b) Calculate the time taken to reach the top of the jump.

Time taken = ...

(2)

(c) Calculate the maximum height reached.

Maximum height = ...

(2)

(Total 6 marks)

14. The photograph shows a climber abseiling down a rock face. At the instant shown the climber is in equilibrium.

(a) Explain what is meant by equilibrium in this context.

....

....

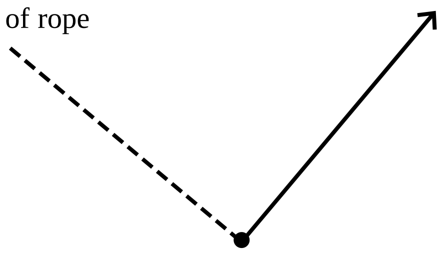
(1)

(b) The climber's mass is 65 kg. Calculate his weight.

Weight = ...

(2)

(c) (i) Below is an incomplete free-body force diagram for the climber.



One of the forces, which is assumed to be acting perpendicular to the rope is already shown. Label this force, and add labelled arrows to the diagram to represent the other two forces acting on the climber. Assume that the rope hanging down from the climber exerts a negligible force on him.

(3)

(ii) The rope is at an angle of 40° to the horizontal. Calculate the tension in the rope.

Tension in rope = ...

(2)

(d) The climber is wearing protective headgear in case of an accident. Describe the properties of a material suitable for the headgear, and explain why these properties are desirable.

....

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....

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....

....

(4)
(Total 12 marks)

15. Three identical resistors are connected across a potential difference V so that one of them is in parallel with the other two which are connected in series. The power dissipated through the first one, compared to the power dissipated by each of the other two, is approximately

A the same

B half as much

C twice as much

D four times as much

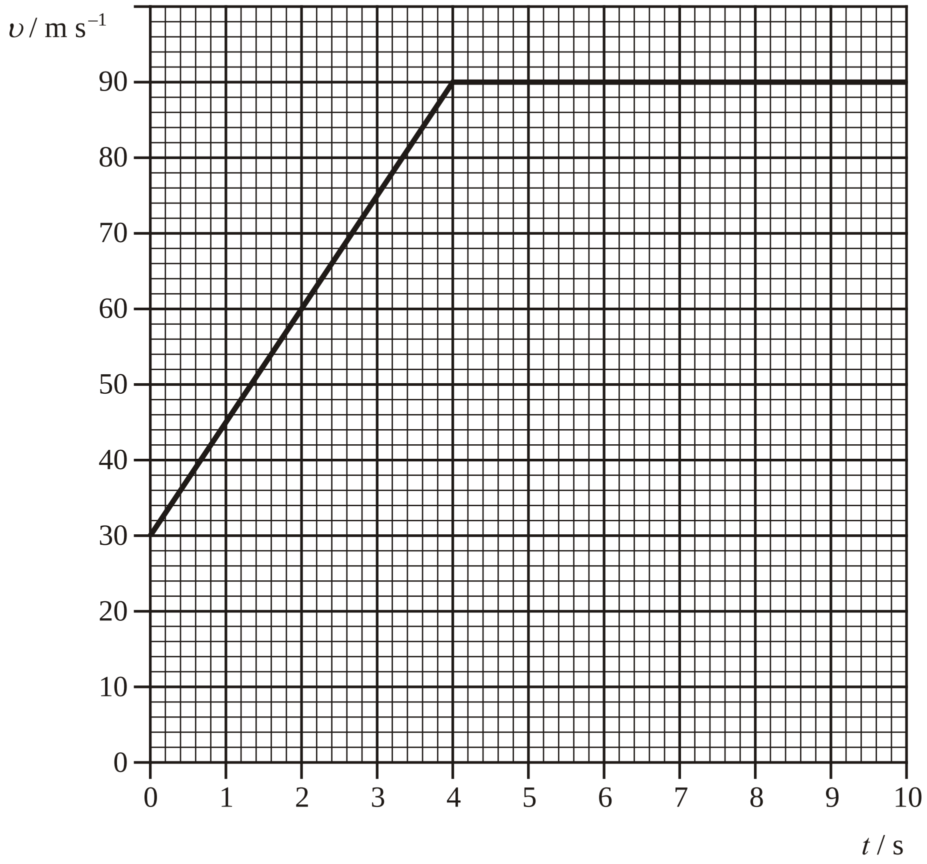
(Total 1 mark)

16. For each of the physical quantities in the table below add the missing information. The first one has been done for you.

Physical quantity	**Base units**	**Vector or scalar**
force	kg m s^{-2}	vector
displacement		
gravitational potential energy		
power		

(Total 3 marks)

17. The graph below shows how the velocity of a motorbike varies with time during the final 10 s of a race.



(a) (i) Describe the motion shown by the graph.

....

.... **(2)**

(ii) Show that during the final 10 s the motorbike travels a distance of approximately 800 m.

....

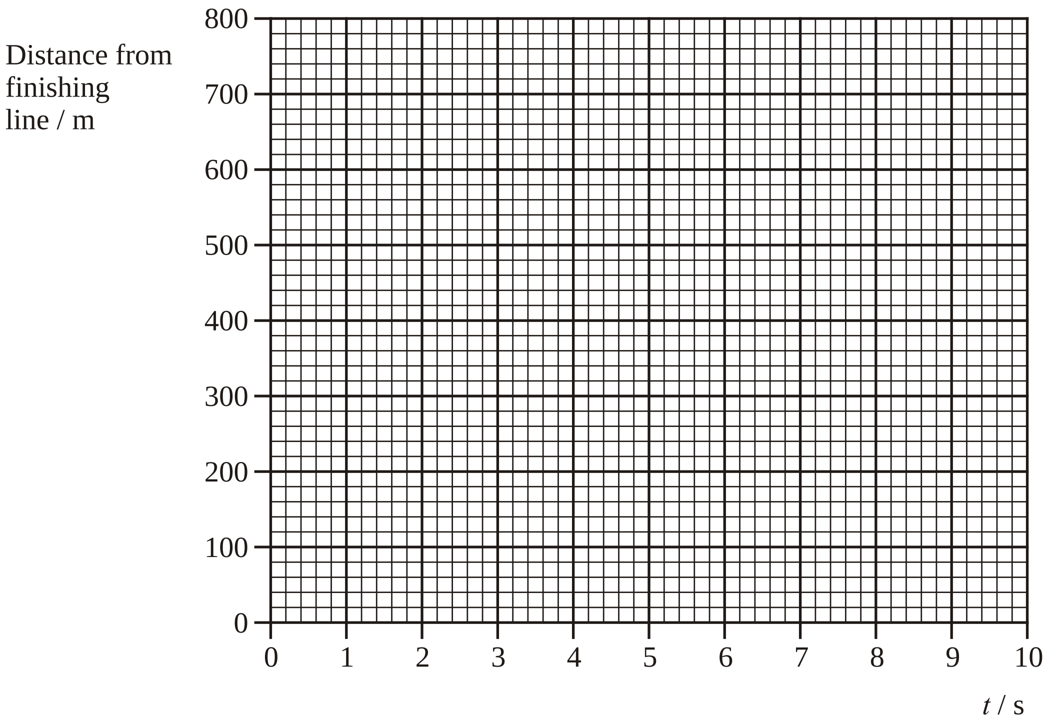
....

....

....

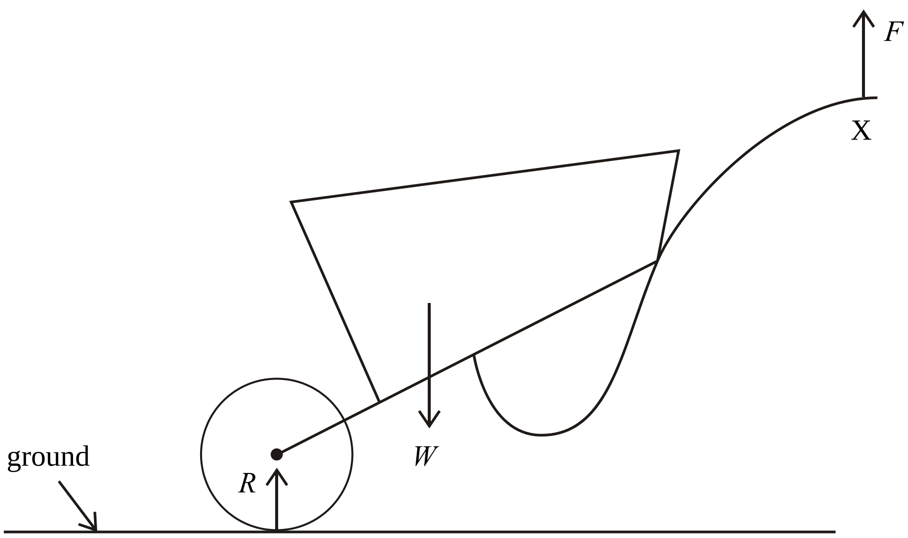
.... **(3)**

(b) Using the axes below, sketch a graph showing how the distance of the motorbike from the finishing line varies with time during the final 10 s of the race.



(3)
(Total 8 marks)

18. A gardener tilts a wheelbarrow of weight *W* by applying a total upward force *F* to its handles. The diagram shows the forces acting on the wheelbarrow. *R* is the normal reaction (contact) force acting on the wheel.



(a) (i) The wheelbarrow is stationary. State an expression that relates *R*, *W* and *F*.

....

(1)

(ii) Each of these three forces is one of a Newton's third law pair of forces.

Complete the following statements.

The force that pairs with *R* acts on ....

The force that pairs with *W* acts on ....

The force that pairs with *F* acts on ....

(3)

(b) The gardener now pushes the wheelbarrow forward. To do this he must change the magnitude and direction of the force *F*.

(i) Add an arrow to the diagram, at X, to show the approximate direction in which this force must act. Label this arrow P.

(1)

(ii) Explain why the magnitude and direction of force F must change when the gardener pushes the wheelbarrow forward.

....

....

....

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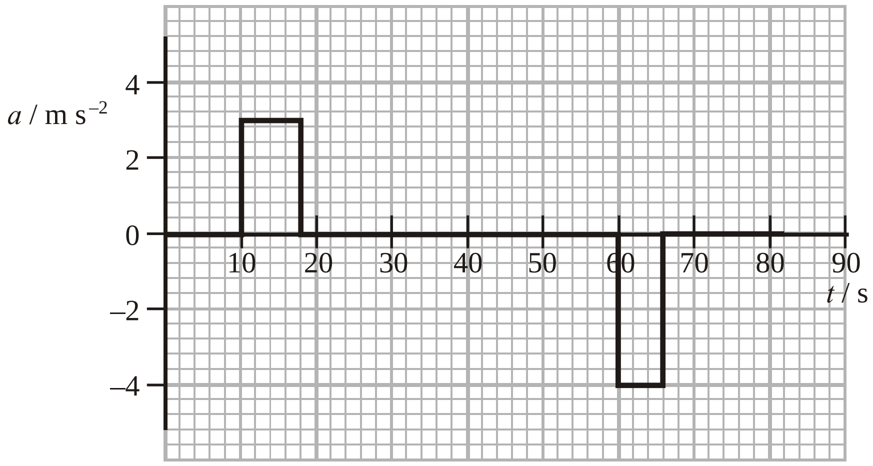
....

(3)
(Total 8 marks)

19. The owner of the case wheels it onto an electric railcar that is powered from a 750 V d.c. supply rail. The railcar makes a short journey from one terminal of an airport to another.

(i) The graph shows the acceleration of the railcar during this journey.



Use the graph to determine the steady speed v of the railcar during the middle section of the journey.

....

....

....

....

....

(ii) Show that the railcar comes to rest at the end of the journey.

....

....

....

....

....

(4)

(iii) When moving at the steady speed v the railcar draws 96 A from the power rail in order to overcome resistive forces that total 3000 N.

Use this data to determine a second value for v.

....

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....

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....

....

(3)
(Total 7 marks)

20. A student reads the following statement in a novel.

"A man weighing 70 kilograms will fall 100 metres in less than 5 seconds."

(a) Comment on the use of the word **weighing**.

....

....

(1)

(b) Make an appropriate calculation to check whether the statement is correct. Assume the man falls from rest.

....

....

....

....

(2)

(c) Calculate the kinetic energy of the man after falling 100 m from rest.

....

....

....

....

....

Kinetic energy = ...

(3)

(Total 6 marks)

21. A student is surprised to read that the optimum angle for a long football throw-in is below 35°, having been taught to assume an angle of 45° for maximum range.

She investigates projectile motion with the following spreadsheet showing the variation of horizontal and vertical components of velocity with time. She has assumed there is no air resistance.

	A	B	C
1	launch speed / m s^{-1}	15.2	
2	launch angle / °	45	
3			
4	time / s	horizontal component of velocity v_h/ m s^{-1}	vertical component of velocity v_v/ m s^{-1}
5	0.0	10.7	10.7
6	0.2	10.7	8.8
7	0.4	10.7	6.8
8	0.6	10.7	4.9
9	0.8	10.7	2.9
10	1.0	10.7	0.9
11	1.2	10.7	–1.0
12	1.4	10.7	–3.0
13	1.6	10.7	–4.9
14	1.8	10.7	–6.9
15	2.0	10.7	–8.9
16	2.2	10.7	–10.8

(a) Write the formula which is used to calculate cell C6, the vertical component of velocity after 0.2 s.

....

(1)

(b) The vertical component changes with time but the horizontal component is constant. Explain why the values in cells B5 to B16 are all the same.

....

....

(1)

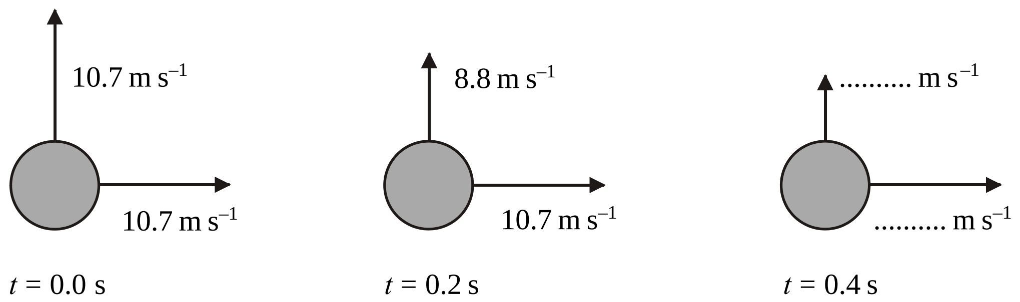
(c) What is the significance of the negative values in column C?

....

....

(1)

(d) The student sketches the components of the ball's velocity for three different times.



(i) Complete the diagram for time $t = 0.4$ s.

(1)

(ii) Calculate the ball's velocity at time $t = 0.4$ s.
(Give its direction as the angle to the horizontal.)

....

....

....

....

....

Magnitude = ...

Direction = ...

(4)

(e) (i) The launch angle is changed to 35°. Calculate the initial vertical and horizontal velocity components. The launch speed remains at 15.2 m s^{-1}.

....

....

....

....

....

Vertical component of velocity = ...

Horizontal component of velocity = ...

(2)

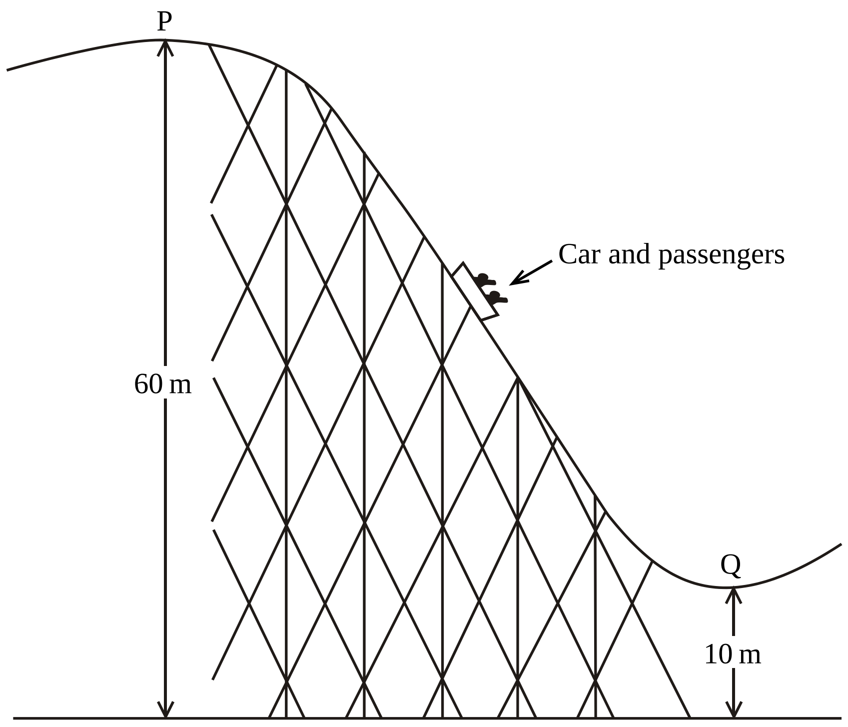
(ii) Suggest a reason why a football thrown at 35° to the horizontal travels a greater distance than one thrown at 45°.

....

....

(1)
(Total 11 marks)

22. The diagram shows part of a rollercoaster ride. The car begins its descent at P where it has negligible speed. It reaches maximum speed at Q.



(a) If there were no forces opposing its motion, show that the speed of the car at Q would be approximately 30 m s^{-1}.

....

....

....

....

....

(3)

(b) A braking system is used to prevent the car travelling faster than 27 m s^{-1}.

(i) The car and passengers shown in the diagram have a total mass of 750 kg. The length of track from P to Q is 80 m. Calculate the average braking force that would be required if the speed of the car is to be limited to 27 m s^{-1}.

....

....

....

....

....

Braking force = ...

(3)

(ii) In practice, the braking system would not have to produce this magnitude of force. Suggest why.

....

....

(1)

(iii) Explain whether the braking force would have to change if the car was carrying a heavier load of passengers. You may be awarded a mark for the clarity of your answer.

....

....

....

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....

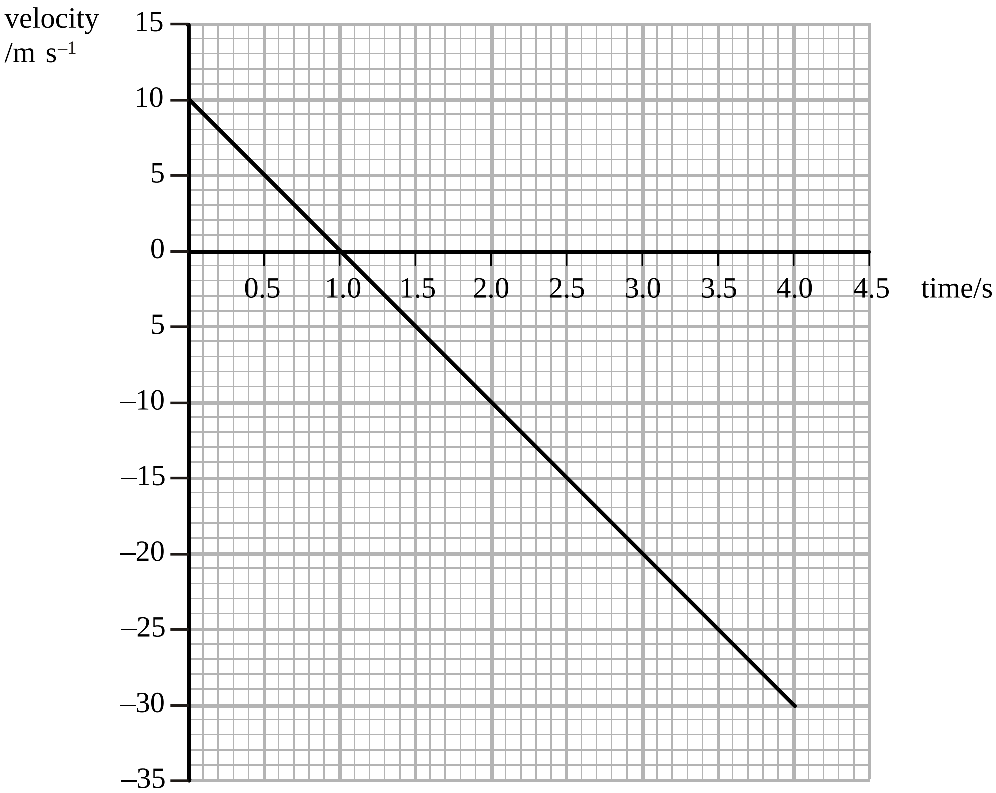
....

....

....

(4)
(Total 11 marks)

23. A hot-air balloon is rising vertically at a speed of 10 m s–1. An object is released from the balloon. The graph shows how the velocity of the object varies with time from when it leaves the balloon to when it reaches the ground four seconds later. It is assumed that the air resistance is negligible.



(a) Use the graph to

(i) show that the object continues to rise for a further 5 m after it is released.

....

....

(1)

(ii) determine the total distance travelled by the object from when it is released from the balloon to when it reaches the ground.

....

....

Total distance = ...

(2)

(b) Hence determine the object's final displacement from its point of release from the balloon.

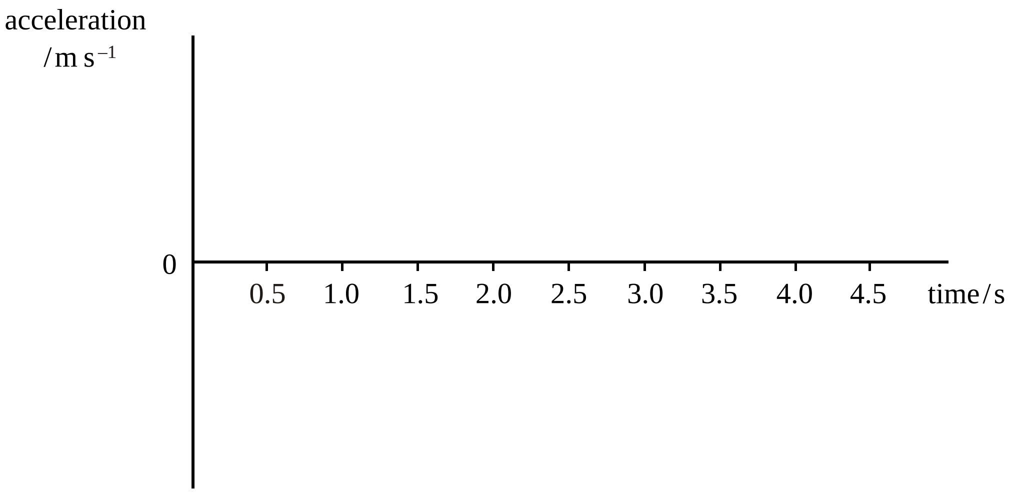
....

....

Displacement = ...

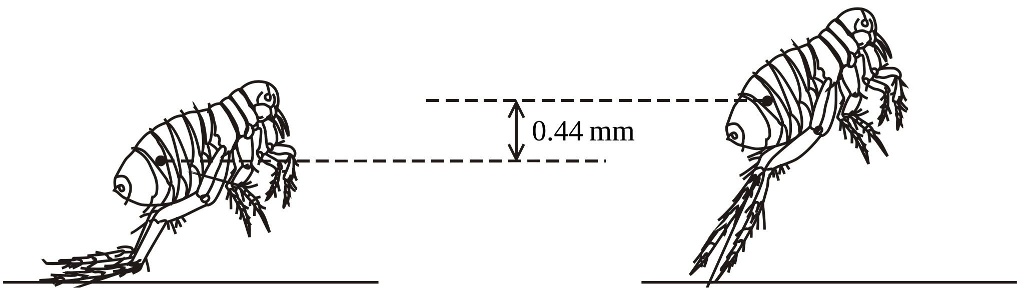
(2)

(c) Using the axes below, sketch a graph showing how the acceleration of the object changes during the time from when it leaves the balloon to when it hits the ground.
Mark any significant values on the axes.



(3)
(Total 8 marks)

24. A flea jumps vertically from a surface. It does this by rapidly extending its legs so that it experiences an upward force. Figure 1 shows the flea before it begins its jump. Figure 2 shows the flea the moment its legs are fully extended and about to leave the surface.



(a) Explain how Newton's third law accounts for the upward force produced.

....

....

....

(2)

(b) (i) At the moment the flea's legs leave the surface its body is raised 0.44 mm and it is moving at a speed of 0.95 m s^{-1}. Show that the average acceleration of the flea during take-off is about 1000 m s^{-2}.

....

....

....

....

....

(3)

(ii) The mass of the flea is 4.0×10^{-7} kg. Calculate the resultant vertical force acting on the flea.

....

Resultant vertical force = ...

(1)

(c) (i) What constant force opposes the upward motion of the flea?

....

....

(1)

(ii) Air resistance also opposes the motion of the flea. At the instant the flea's legs leave the surface it is travelling at 0.95 m s^{-1}. It takes a further 9.3×10^{-2} s to reach its maximum height. Calculate the change in height it achieves during this time. Assume its deceleration is constant.

....

....

....

....

....

Change in height = ...

(3)

(Total 10 marks)

25. A helium-filled balloon on a string is attached to an electric balance. The reading is:

–0.0094kg

(a) (i) Explain how this shows that the force being exerted on the balance by the balloon is about 0.1 N upwards.

....

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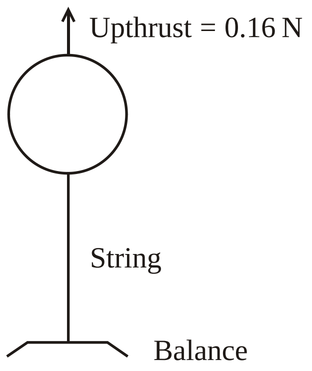
....

....

....

(2)

The force of upthrust on the balloon is 0.16 N.



(ii) Add labelled arrows to identify the other two forces acting on the balloon and show that the value of weight is about 0.07 N.

....

....

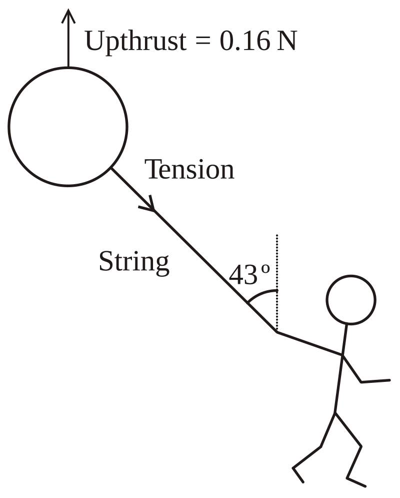
....

....

....

(3)

(b) The balloon is given to a child. The child holds the balloon by the string and walks at a constant speed. The balloon trails at an angle of 43° to the vertical as shown.



(i) Add labelled arrows to identify the other forces acting on the balloon in this situation. Values are not required.

(2)

(ii) Write an expression for the vertical component of the tension in the string.

....

(1)

(iii) By considering the vertical forces acting on the balloon, calculate the tension in the string in this situation.

....

....

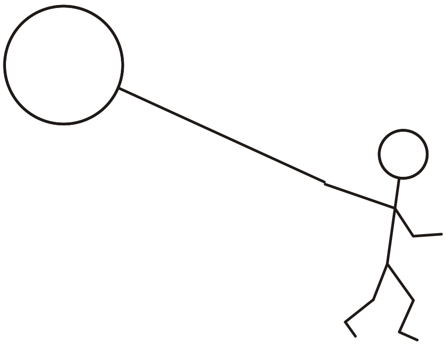
....

....

Tension = ...

(2)

(c) The child walks faster. The new angle of the balloon and string is shown below. Explain the change in angle.



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....

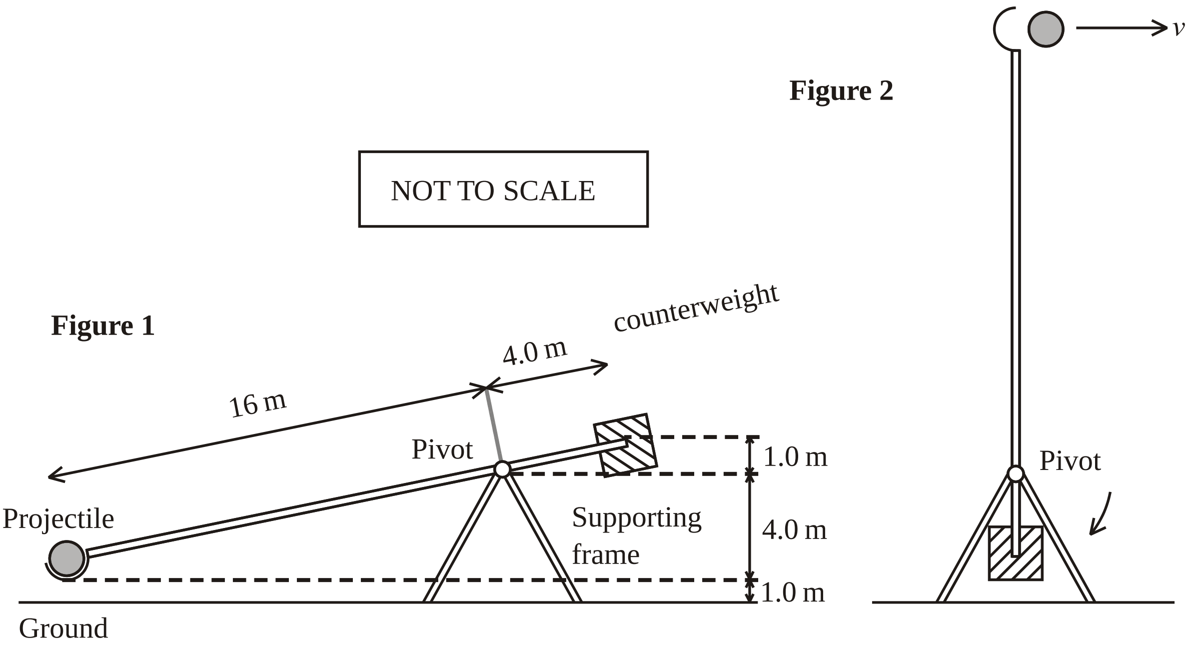
....

....

(2)

(Total 12 marks)

26. A medieval siege engine, called a trebuchet, uses a pivoted lever arm to fire a rock projectile. Figure 1 shows a trebuchet which is ready to fire. The gravitational potential energy (E_{grav}) of the large stone counter weight is converted into E_{grav} and kinetic energy (E_k) of the small projectile and E_k of the counter weight.



(a) The mass of the counter weight is 760 kg. It falls through 5 m. Show that the Eg it loses is about 37 000 J.

....

....

....

(2)

(b) (i) The mass of the projectile is 55 kg. Its height increases by 20 m as the lever arm rotates. Show that the total E_k of the projectile and the counterweight is about 26 000 J.

....

....

....

(2)

(ii) State one assumption you have made in your calculation of the E_k.

....

.... **(1)**

(iii) The equation below can be used to find the speed *v*.

$$26\ 000\ \text{J} = \frac{1}{2} \times 760\ \text{kg} \times \left(\frac{v}{4}\right)^2 + \frac{1}{2} \times 55\ \text{kg} \times v^2$$

Explain the term $\frac{1}{2} \times 760\ \text{kg} \times \left(\frac{v}{4}\right)^2$ in this equation.

....

....

.... **(2)**

(c) Solving this equation gives a speed *v* of 22.5 m s^{-1}.

(i) Assuming the trebuchet launches its projectile horizontally over level ground, calculate the time of flight of the projectile.

....

....

....

Time = ... **(2)**

(ii) Calculate the distance the projectile travels before it hits the ground.

....

....

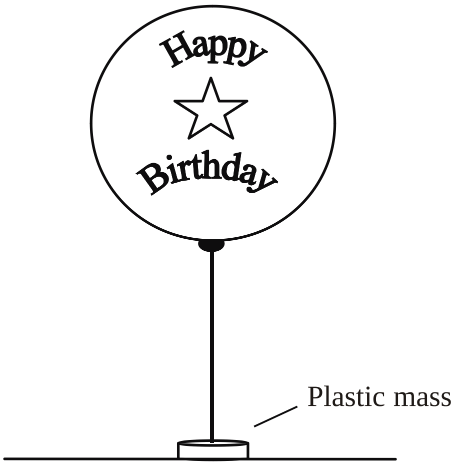
....

Distance = ...

(2)

(Total 11 marks)

27. A child's birthday balloon is filled with helium to make it rise. A ribbon is tied to it, holding a small plastic mass designed to prevent the balloon from floating away.



(a) Add labelled arrows to the diagram of the balloon to show the forces acting on the balloon.

(2)

(b) The balloon is approximately a sphere, of diameter 30 cm. Show that the upthrust on the balloon is about 0.2 N.

The density of the surrounding air $\rho = 1.30 \text{ kg m}^{-3}$

....

....

....

....

(3)

(c) The ribbon is cut and the balloon begins to rise slowly.

(i) Sketch a diagram to show the airflow around the balloon as it rises.

(1)

(ii) What is the name of this type of airflow?

....

(1)

(d) A student suggests that if the balloon reaches terminal velocity, its motion could be described by the relationship

$$mg + 6\pi r\eta v = \frac{4}{3}\pi r^3 \rho g$$

where η = viscosity of air, m = mass of the balloon, r = radius of the balloon and v = the terminal velocity reached.

(i) Write the above relationship as a word equation.

....

(1)

(ii) The balloon has a total weight of 0.17 N. Use the equation given above to calculate the corresponding value for the terminal velocity of the balloon.

Viscosity of air = 1.8×10^{-5} N s m^{-2}

....

....

....

....

Terminal velocity = ...

(3)

(iii) Suggest a reason why the balloon is not likely to reach this calculated velocity.

....

....

(1)
(Total 12 marks)

28. (a) State the difference between distance and displacement.

....

....

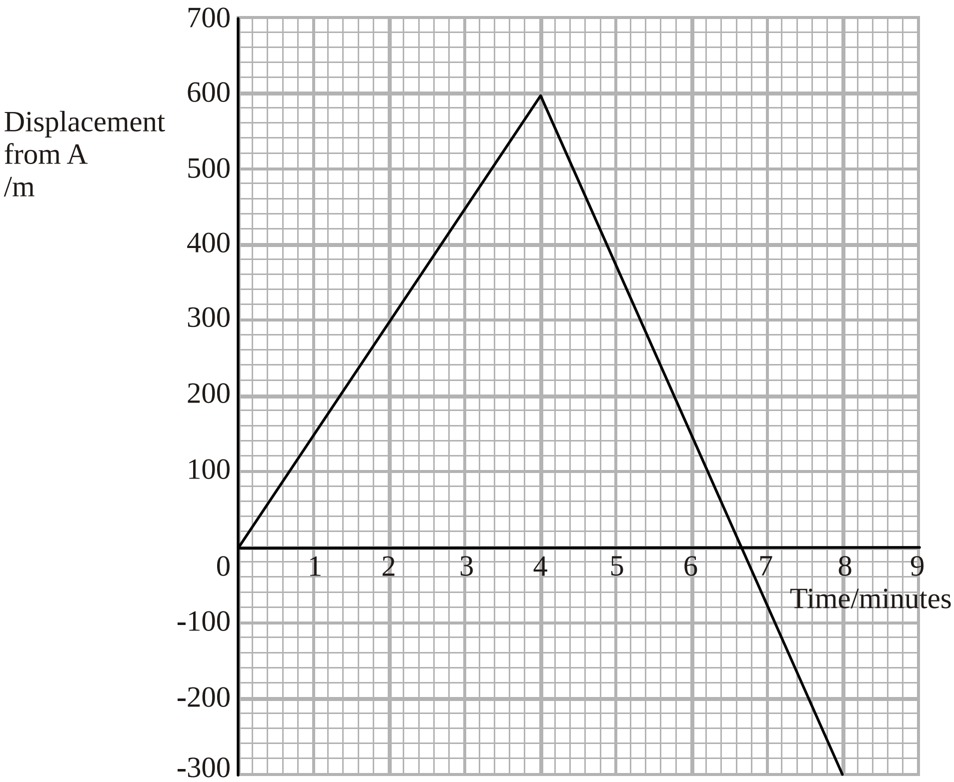
....

....

(1)

(b) Figure 1 shows an idealised displacement-time graph for the journey of a train along a straight horizontal track, from the moment when it passes a point A on the track. Initially the train moves in an easterly direction away from A.

Figure 1



(i) Describe the position of the train relative to A at the end of the 8 minutes covered by the graph.

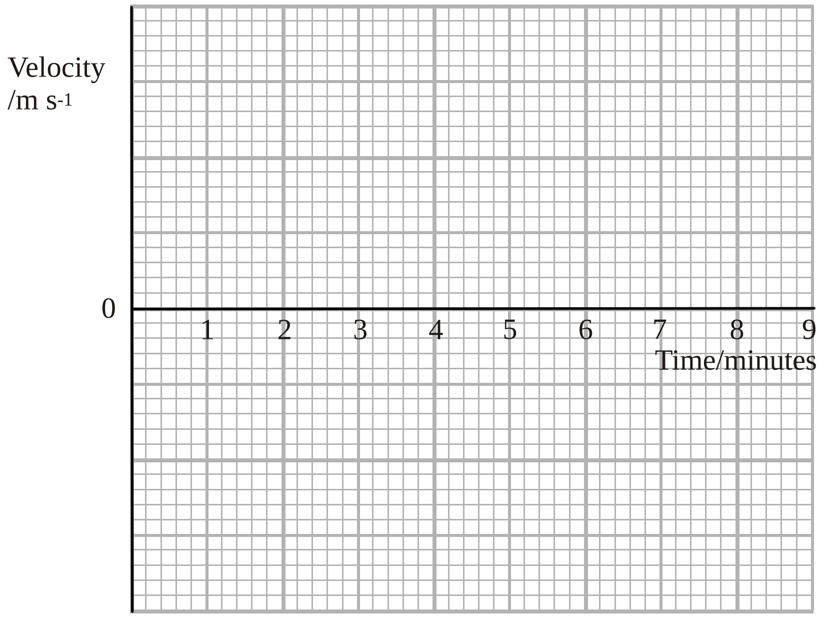
....

....

(2)

(ii) Use the grid, Figure 2, to plot a velocity against time graph of the journey shown in Figure 1. Do the calculations that are required on the lines below the grid.

Figure 2



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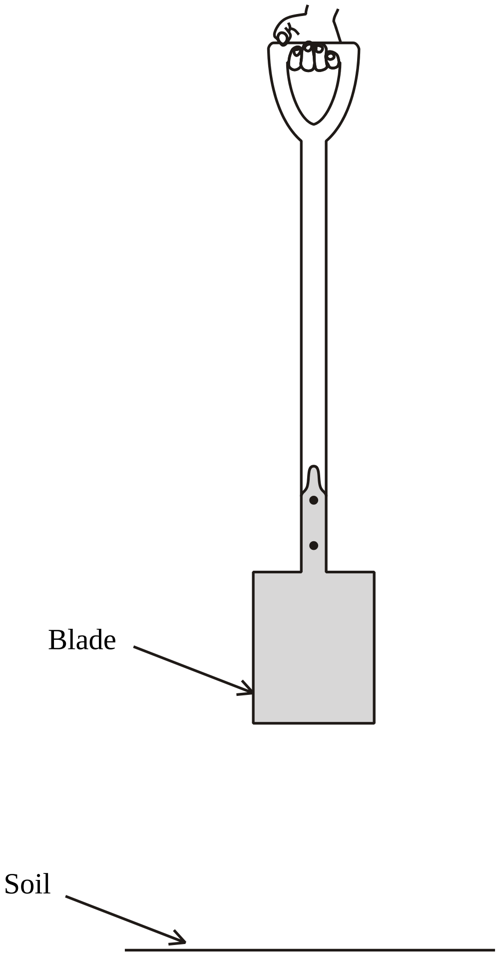
....

(4)
(Total 7 marks)

29. The diagram shows a spade being held above a flat area of soil.



(a) The spade is released and falls vertically. It takes 0.29 s for the blade to reach the soil.

(i) Show that the speed of the spade at this instant is approximately 3 m s^{-1}.

....

....

....

....

....

(3)

(ii) The spade penetrates 50 mm into the soil. Calculate the average acceleration of the spade in the soil.

....

....

....

....

....

Average acceleration = ...

(3)

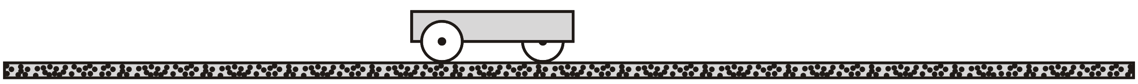
(b) A **heavier** spade of identical shape is now dropped from the same height into the same patch of soil. Underline the correct phrase in the brackets to describe what difference, if any, there would be in the speed at impact and the acceleration in the soil compared to the lighter spade. Assume the resistive forces on both spades are the same.

The heavier spade would have {a higher/a lower/the same} speed at impact as the lighter spade.

The heavier spade would have {a higher/a lower/the same} acceleration in the soil as the lighter spade.

(2)
(Total 8 marks)

30. A student is provided with a trolley and a track as shown in the diagram below. He is required to apply different forces to the trolley, measure the corresponding accelerations and hence demonstrate the relationship between the two. Any additional normal school laboratory equipment is available for him to use.



(a) Describe how he could

(i) apply a constant measurable force;

....

....

....

....

(1)

(ii) measure the velocity of the trolley at a point on the track as the trolley moves under the action of this applied force. List any additional apparatus that would be required. You may add to the diagram above to help your description.

....

....

....

....

....

....

....

....

....

....

....

(3)

(b) Assuming the velocity has been measured at one point, what additional measurements are required to determine the acceleration?

....

....

....

....

....

....

(2)

(c) How could the student demonstrate the expected relationship between the force and the acceleration?

....

....

....

....

....

(2)

(d) In such an experiment, the track is given a slight tilt to compensate for friction. Why is this necessary if the relationship suggested by Newton's second law is to be successfully demonstrated?

....

....

....

....

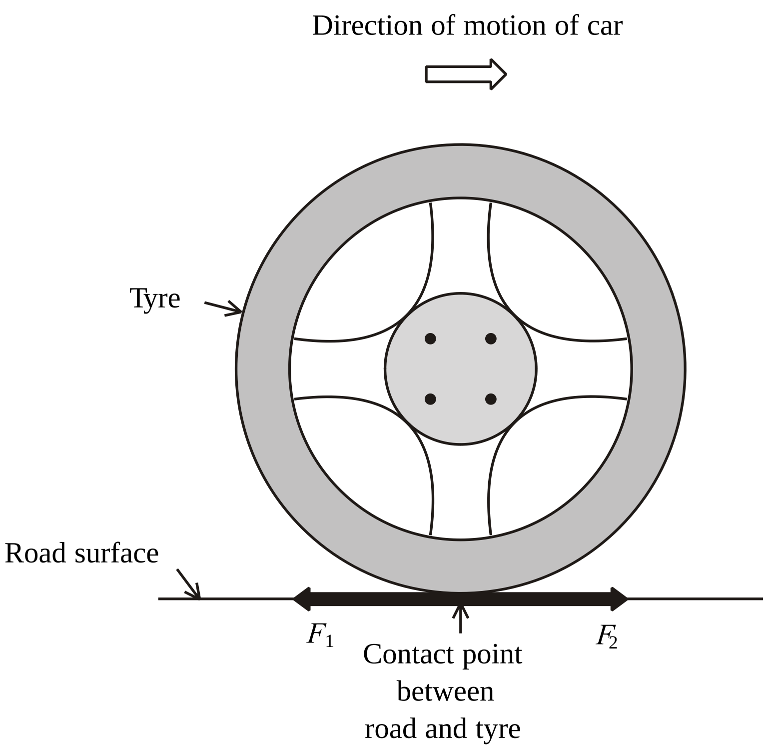
....

....

....

(2)
(Total 10 marks)

31. The force produced by the engine of a car which drives it is ultimately transmitted to the area of contact between the car's tyres and the road surface. The diagram shows a wheel at an instant during the motion of the car when it is being driven forward in the direction indicated.



Two horizontal forces act at the point of contact between the tyre and road due to the transmitted force from the engine. These are shown as F_1 and F_2. Assume that the area of contact between the tyre and road is very small.

(a) Complete the statements

(i) F_1 is the force of the .... on the ....

(ii) F_2 is the force of the .... on the ....

(2)

(b) (i) The total forward force on the car is 400 N when the car is travelling at a constant speed of 10 m s^{-1} along a level road. Calculate the effective power driving the car forward.

....

....

....

Power = ...

(2)

(ii) Hence calculate the total work done by the 400 N force in 5 minutes in maintaining the speed of 10 m s^{-1}.

....

....

Work done =.................................

(1)

(c) Although work is done on the car, it continues to move at a constant speed.

Explain why the car is not gaining kinetic energy.

....

....

....

....

....

....

(2)
(Total 7 marks)

32. (a) On 20 July 1969, Neil Armstrong became the first human to step onto the surface of the moon.

One experiment carried out was to film a hammer and a feather dropped at the same time from rest. They fell side by side all the way to the ground, falling a distance of 1.35 m in a time of 1.25 s.

(i) Show that this gives a value for their acceleration of about 1.7 m s^{-2}.

....

....

....

(2)

(ii) Explain why the acceleration of both the hammer and the feather was constant throughout their fall.

....

....

....

(2)

In the questions that follow, assume that on the Moon

acceleration of free fall $g = 1.7 \text{ m s}^{-2}$

gravitational field strength $g = 1.7 \text{ N kg}^{-1}$.

(b) Neil Armstrong and his space suit had a total mass of 105 kg. Calculate his weight, including the spacesuit, on the Moon.

....

....

Weight = ...

(2)

(c) In 1971 another astronaut, Alan Shepherd, hit a golf ball on the Moon. He later said that it went ‘ ... miles and miles ...’

(i) Suppose that he hit the ball so that it left his club at a speed of 45 m s^{-1}, at an angle of 20° to the horizontal. Calculate the time of flight of the ball.

....

....

....

....

....

....

Time = ...

(3)

(ii) Calculate the horizontal distance travelled by the ball before landing.

....

....

....

Distance = ...

(2)

(iii) Comment on this distance in relation to his statement. 1 mile = 1.6 km

....

....

(1)

(Total 12 marks)

33. A student films a car as it reduces speed by braking. By making measurements against a scale on the road he obtains values for the distance the car travels during each 0.5 s interval after the start of braking.

His measurements and calculations are shown in the spreadsheet.

	A	B	C	D	E	F
1	interval number	interval distance/m	total time/s	average speed during interval/m s^{-1}	distance from start/m	kinetic energy/kJ
2						
3						
4	1	13.2	0.5	26.4	13.2	209
5	2	11.8	1.0	23.6	25.0	167
6	3	10.5	1.5	21.0	35.3	
7	4	9.1	2.0	18.2	44.6	99
8	5	7.6	2.5		52.2	69
9						
10	interval time/s	mass of car/kg				
11	0.5	600				

(a) (i) Calculate the value for average speed missing from cell D8.

....

Speed = ... m s^{-1}

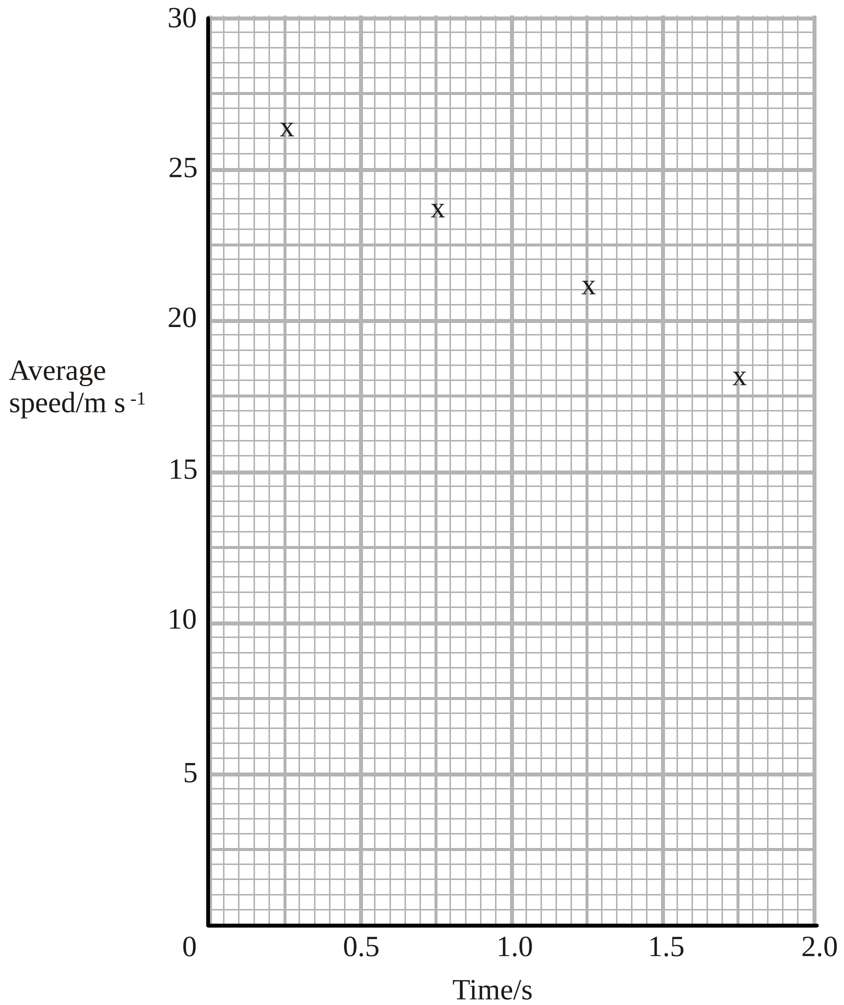
(1)

(ii) Write down a suitable formula for cell E7.

....

(1)

Values of average speed against time for the car are plotted on the grid below.



(iii) Use the graph to find the average deceleration of the car.

....

....

Average deceleration = ...

(3)

(b) (i) Calculate the average braking force on the car.

....

....

Average braking force = ...

(2)

(ii) State the origin of this force on the car.

....

(1)

(c) (i) Calculate the value for kinetic energy missing from cell F6.

....

....

Kinetic energy = ... kJ

(2)

(ii) The student decides to plot a graph of the kinetic energy of the car against the distance it has travelled since the brakes were applied.

Explain why the gradient of this graph is equal to the braking force on the car.

....

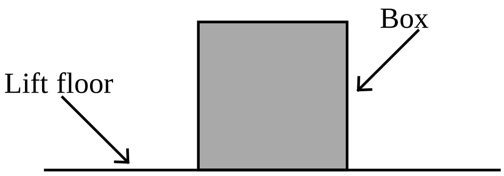
....

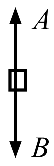
....

....

(2)
(Total 12 marks)

34. Figure 1 shows a box resting on the floor of a stationary lift. Figure 2 is a free-body force diagram showing the forces *A* and *B* that act on the box.



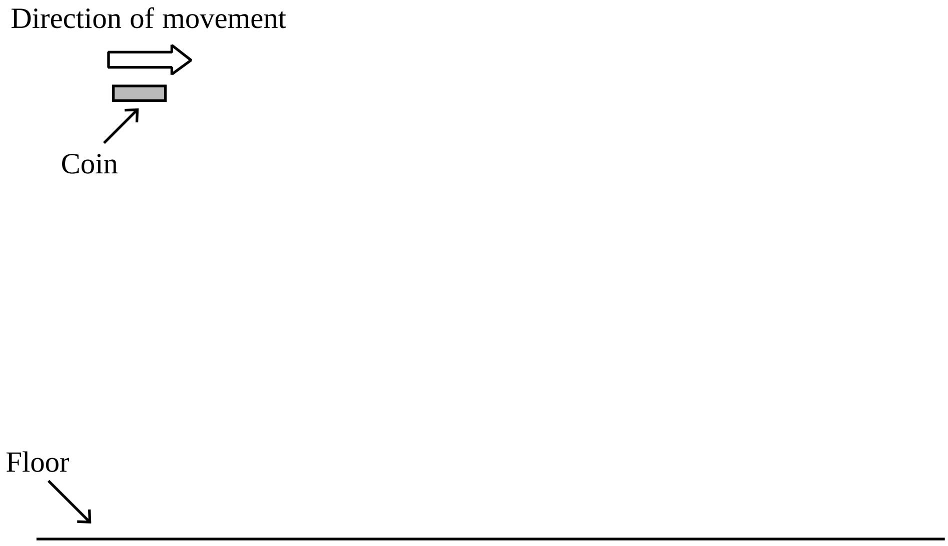


For each of the following situations, **tick** the appropriate boxes to show how the magnitude of the forces *A* and *B* change, if at all, compared with when the lift is stationary.

Situation	Force *A*			Force *B*		
	increases	no change	decreases	increases	no change	decreases
Lift accelerating upwards						
Lift moving with constant speed upwards						
Lift accelerating downwards						
Lift moving with constant speed downwards						

(Total 4 marks)

35. A coin is flicked off a table so that it initially leaves the table travelling in a horizontal direction with a speed of 1.5 m s^{-1}. The diagram shows the coin at the instant it leaves the table. Air resistance can be assumed to have a negligible effect throughout this question.



(a) Add to the diagram the path followed by the coin to the floor.

(1)

(b) (i) The table is 0.70 m high. Show that the coin takes approximately 0.4 s to reach the floor.

....

....

....

....

....

(3)

(ii) Hence calculate the **horizontal** distance the coin travels in the time it takes to fall to the floor.

....

....

....

Horizontal distance = ...

(2)

(c) A coin of greater mass is flicked with the same horizontal speed of 1.5 m s^{-1}. Compare the path of this coin with that of the coin in the first part of the question. Explain your answer. You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

....

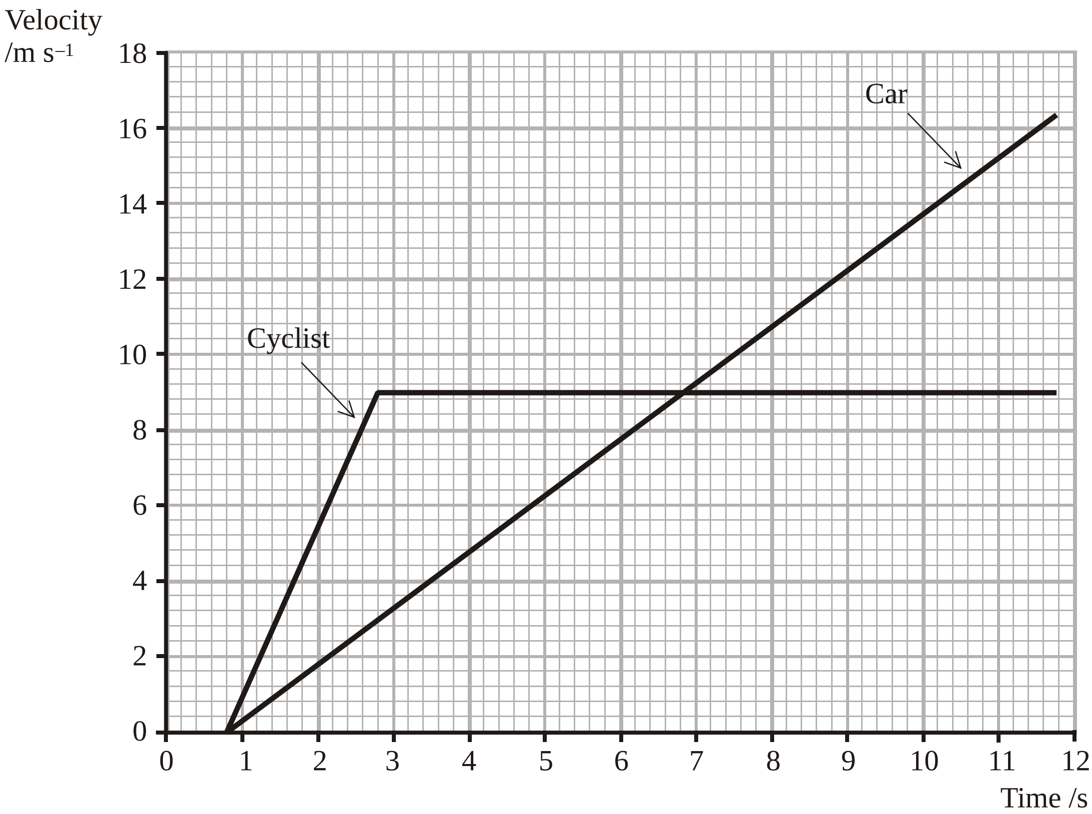
....

....

....

(Total 10 marks)

36. A cyclist and a car are both stationary at traffic lights. They are alongside each other with their front wheels in line. The lights change and they both move forward in the same direction along a straight flat road. The idealised graph shows the variation of velocity against time for both the cyclist and the car from the instant the lights change to green to the instant they are again level.



(a) What does the time interval of 0.8 s at the beginning of the graph represent?

....

.... **(1)**

(b) (i) How long does it take, from the instant the lights change to green, for the car to reach the same velocity as the cyclist?

.... **(1)**

(ii) Determine the distance between the cyclist and the car at this time.

....

....

....

....

....

....

Distance = ...

(3)

(c) What is the relationship between the average velocity of the cyclist and the average velocity of the car for the time interval covered by the graph?

....

(1)
(Total 6 marks)

37. A student is working on a spreadsheet to model the fall of a golf ball from rest from the window of a tall building.

(a) He assumes that the acceleration remains constant at 9.81 m s^{-2} for the first two seconds of the fall. Comment on whether this is a reasonable assumption.

....

....

(1)

	A	B	C	D
1	time from start / s	velocity reached/ m s^{-1}	distance fallen during 0.20 s time interval / m	total distance from the start /m
2				
3	0.00	0.00	0.00	0.00
4	0.20	1.96	0.20	0.20
5	0.40	3.92	0.59	0.78
6	0.60	5.89	0.98	1.77
7	0.80	7.85	1.37	3.14
8	1.00	9.81	1.77	4.91
9	1.20	11.77	2.16	7.06
10	1.40	13.73	2.55	9.61
11	1.60	15.70	2.94	12.56
12	1.80	17.66	3.34	15.89
13	2.00	19.62	3.73	19.62

(b) Cell B6 is calculated using the formula B6 = 9.81*A6. Explain why this is appropriate.

....

....

....

....

(2)

(c) Cell C7 is calculated using the formula C7 = ((B6+B7)/2)*0.20.

(i) Explain what (B6+B7)/2 represents.

....

....

(1)

(ii) Why is this fraction multiplied by 0.20?

....

....

(1)

(d) Give an appropriate spreadsheet formula that uses cell D9 to calculate cell D10.

....

....

(1)

(e) You can check that this spreadsheet model is giving sensible answers for the total distance fallen by calculating the distance using an equation from the list of formulae at the back of the paper. Calculate the answer for cell D11.

....

....

....

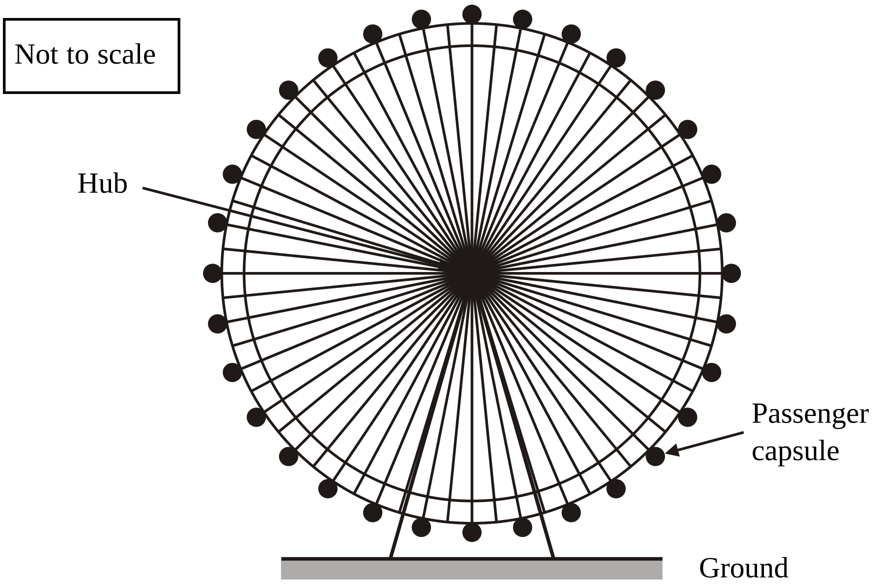
....

(2)

(Total 8 marks)

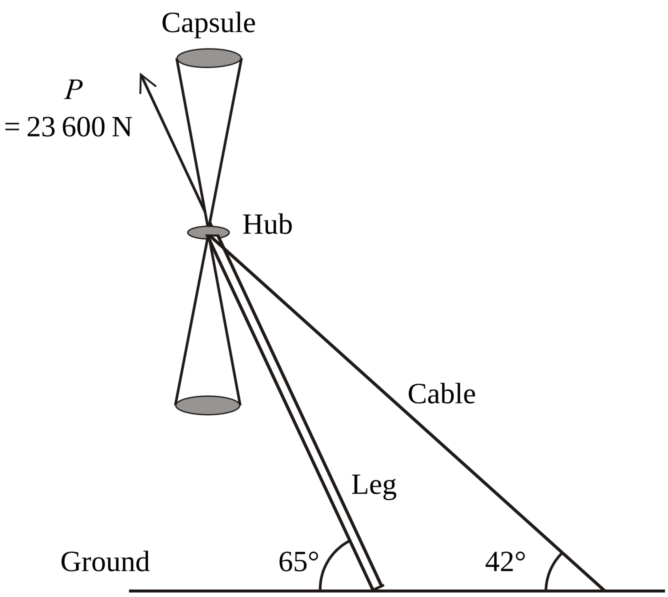
38. The London Eye is like a giant bicycle wheel supported in a vertical position, as shown in Figure 1.

Figure 1



This question is about modelling one way of supporting the wheel. In this model there is just one leg supporting the axle, and one cable exerting enough tension to hold the wheel upright, as shown in Figure 2 below.

Figure 2



The total weight *W* of the wheel and passengers is 12 400 N. Assume that the weights of the leg and cable are negligible.

In this model we will assume that there are only three forces acting on the wheel: its weight *W*, the tension from the cable *T* and the push from the leg *P*.

(a) The direction of *P* is marked on Figure 2. Use labelled arrows to show the direction of *W* and the direction of *T*.

(2)

(b) The magnitude of *P* is 23 600 N. Calculate the horizontal component of *P*.

....

....

Horizontal component of *P* = ...

(2)

(c) (i) State the magnitude of the horizontal component of *T*.

Horizontal component of *T* = ...

(1)

(ii) Calculate the magnitude of *T*.

....

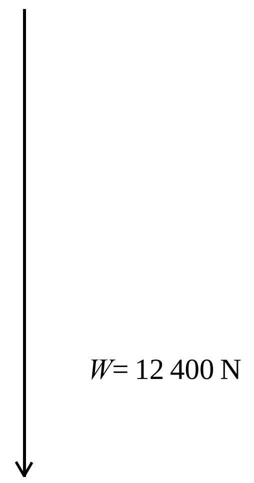
....

....

Magnitude of *T* = ...

(2)

(d) Complete the drawing to find the resultant of *W* and *P*.



scale:
1 cm : 2000 N

Magnitude of resultant = ...

Angle of resultant with horizontal = ...

(4)

(e) State one other force which might act on the real wheel.

....

....

(1)
(Total 12 marks)

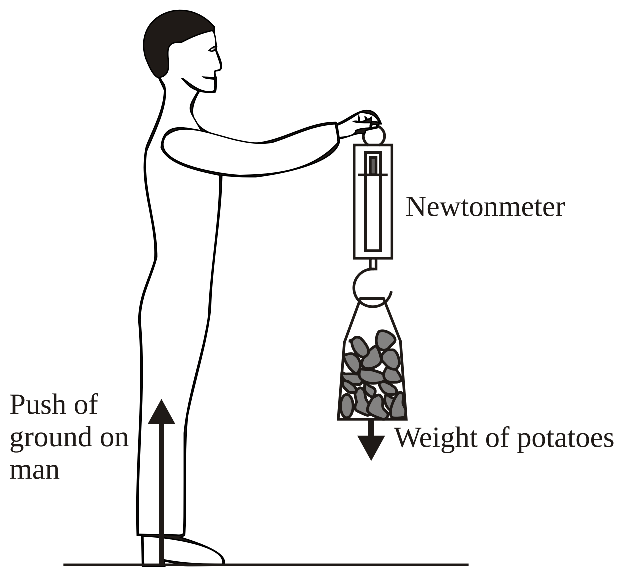
39. (a) Complete the following statement of Newton's third law of motion.

"If body A exerts a force on body B, then body B ....

...."

(2)

(b) A man checks the weight of a bag of potatoes with a newtonmeter. Two of the forces acting are shown in the diagram.



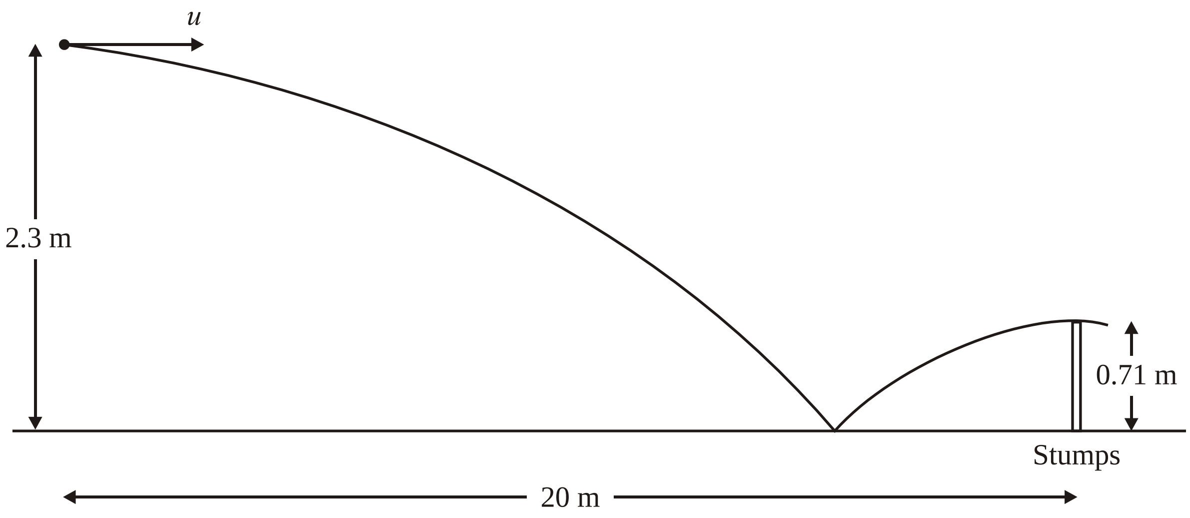
The table below gives these forces. For each force there is a corresponding force, the 'Newton's third law pair force'. In each case state

- the body that the Newton's third law pair force acts upon
- the type of force (one has been done for you)
- the direction of the Newton's third law pair force.

Force	Body the Newton's third law pair force acts upon	Type of force	Direction of the Newton's third law pair force
Weight of potatoes			
Push of ground on man		Normal contact force	

(3)
(Total 5 marks)

40. A cricketer bowls a ball from a height of 2.3 m. The ball leaves the hand horizontally with a velocity u. After bouncing once, it passes just over the stumps at the top of its bounce. The stumps are 0.71 m high and are situated 20 m from where the bowler releases the ball.



(a) Show that from the moment it is released, the ball takes about 0.7 s to fall 2.3 m.

....

....

....

....

....

....

(2)

(b) How long does it take the ball to rise 0.71 m after bouncing?

....

....

....

....

....

....

Time = ……………………………………

(3)

(c) Use your answers to parts (a) and (b) to calculate the initial horizontal velocity *u* of the ball. You may assume that the horizontal velocity has remained constant.

....

....

....

....

Velocity = ……………………………………

(2)

(d) In reality the horizontal velocity would not be constant. State one reason why.

....

....

(1)
(Total 8 marks)

41. A weightlifter raised a bar of mass of 110 kg through a height of 2.22 m. The bar was then dropped and fell freely to the floor.

(i) Show that the work done in raising the bar was about 2400 J.

....

....

....

(2)

(ii) It took 3.0 s to raise the bar. Calculate the average power used.

....

....

....

Power = ……………………………………

(2)

(iii) State the principle of conservation of energy.

....

....

....

(2)

(iv) Describe how the principle of conservation of energy applies to

(1) lifting the bar,

(2) the bar **falling** to the floor. Do not include the impact with the floor.

(1) ....

....

....

(2) ....

....

....

....

(3)

(v) Calculate the speed of the bar at the instant it reaches the floor.

....

....

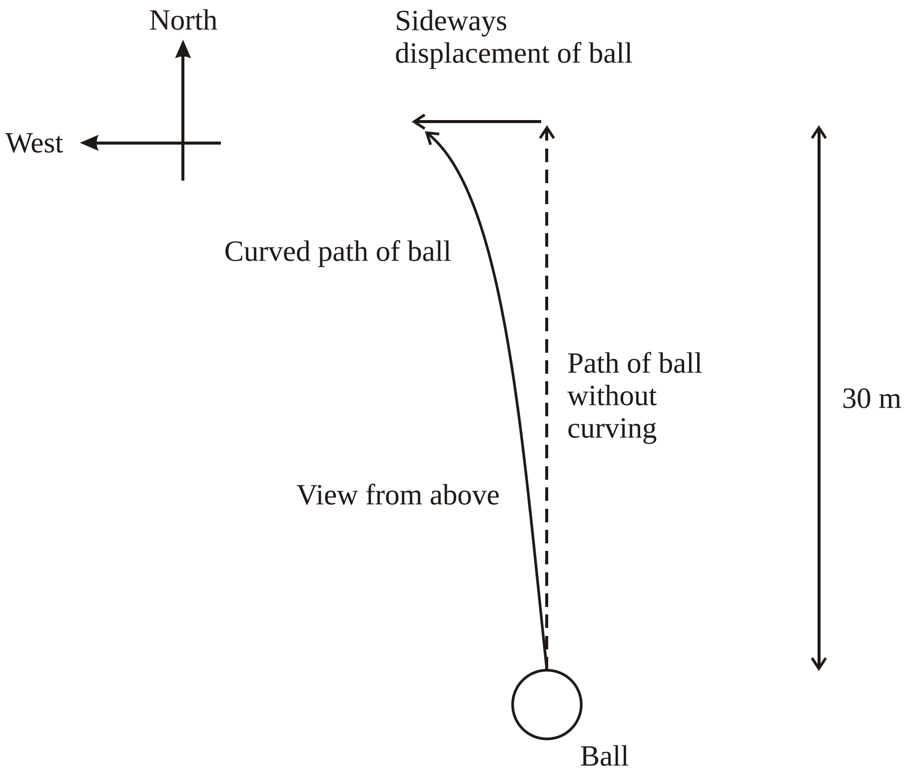
....

....

Speed = ……………………………………

(3)
(Total 12 marks)

42. Some world class soccer players are famous for being able to bend their free kicks, i.e. to make the ball deviate from a straight path. They do this by getting the ball to spin when they kick it. The ball experiences a sideways force due to its spinning motion, so it moves sideways as well as forwards, as shown on the diagram.



Ignore vertical motion throughout the question.

A player kicks a ball, giving it a velocity of 25 m s^{-1} northwards. Calculate the time taken for the ball to travel 30 m North. Assume the component of velocity in this direction remains constant.

....

....

Time = ...

(2)

The sideways force causes an acceleration to the west of 8 m s^{-2}. Calculate the westward component of the ball's velocity after it has travelled 30 m North. Assume the force remains constant and continues to act in a westward direction.

....

....

....

Westward component of velocity = ...

(2)

Calculate the westward displacement of the ball after it has travelled 30 m North.

....

....

....

Displacement = ...

(2)

Determine the velocity of the ball, stating its magnitude and direction, after it has travelled 30 m North.

....

....

....

....

....

....

Magnitude of velocity = ...

Direction of velocity = ...

(4)
(Total 10 marks)

43. A car is travelling at 13 m s^{-1}. It is allowed to slow down naturally without applying the brakes. The distance travelled in coming to rest is 640 m.

Show that the average deceleration of the car is about 0.1 m s^{-2}.

....

....

....

....

(2)

The car has a mass of 1400 kg.

Calculate the average resultant force acting on the car as it slows down.

....

....

....

....

Force = ...

(2)

The car is then allowed to slow down naturally from a speed of 30 m s^{-1}. The distance-time graph shows the first minute of deceleration.

Explain how the shape of the graph shows the car is decelerating.

....

....

(1)

Use the graph to find the speed at 15 s.

....

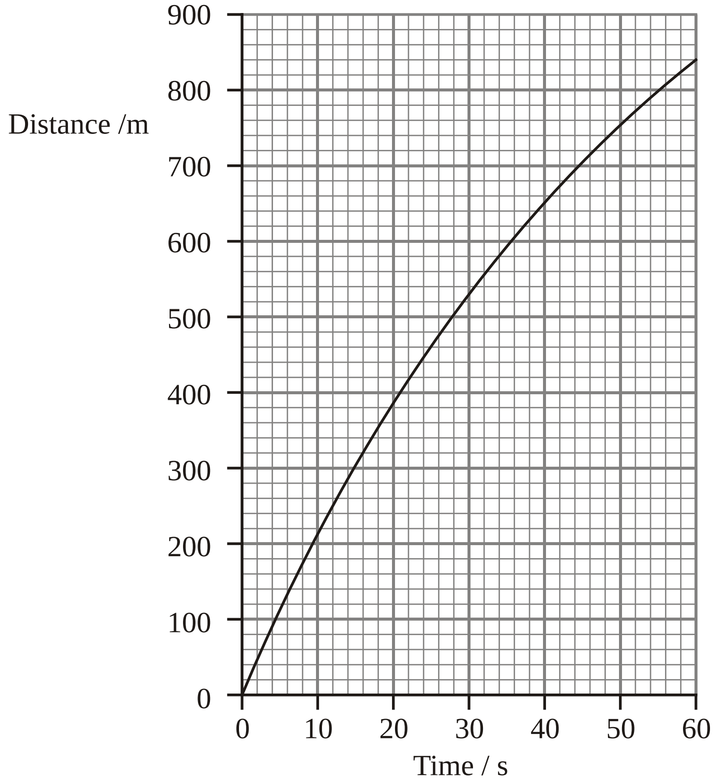
....

....

....

Speed = ...

(3)



Calculate the average deceleration during the first 15 s.

....

....

....

....

Deceleration = ...

(2)

Explain the difference between this deceleration and that calculated at the start of the question.

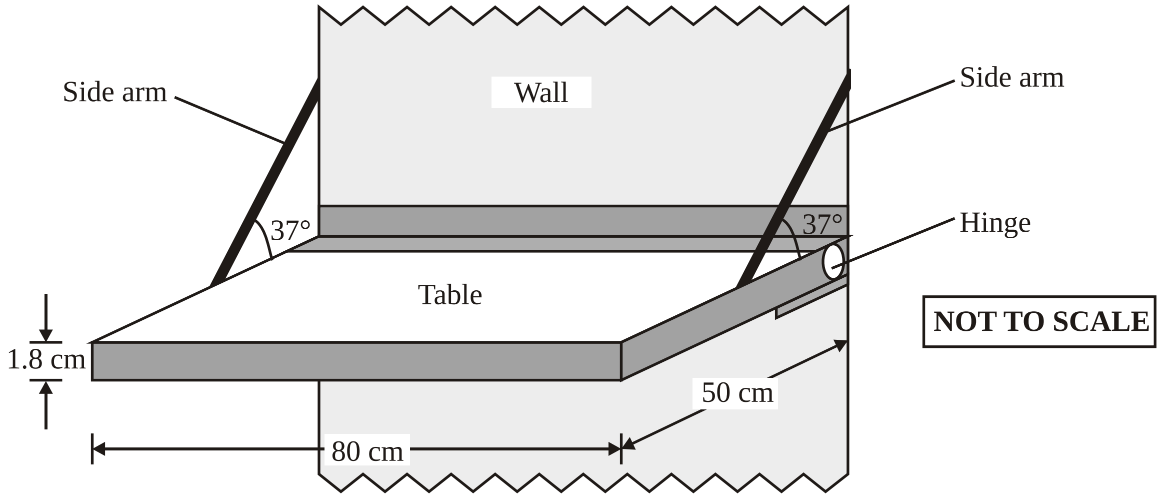
....

....

....

(2)
(Total 12 marks)

44. (a) The diagram below shows a drop-down table attached to a wall. The table is supported horizontally by two side arms attached to the mid-points of the sides of the table.



The table surface is 80 cm long, 50 cm deep and 1.8 cm thick. It is made from wood of density 0.70 g cm^{-3}. Show that its weight is about 50 N.

....

....

....

....

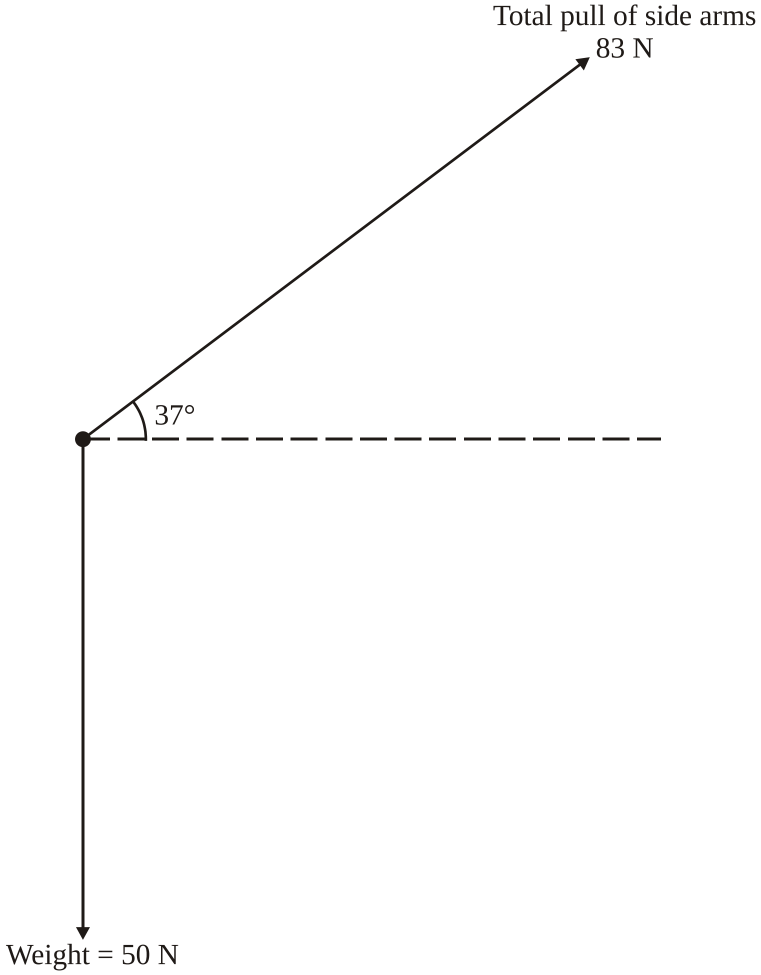
....

....

....

(3)

(b) The free-body force diagram below shows two of the three forces acting on the table top.



(i) Calculate the horizontal and vertical components of the 83 N force.

Horizontal component: ....

....

Vertical component: ....

....

(2)

(ii) Add appropriately labelled arrows to the free-body force diagram to show these components.

(1)

(iii) Hence find the magnitude of the horizontal force that the hinge applies to the table top and state its direction.

....

....

(1)
(Total 7 marks)

45. (a) A car of mass m is travelling in a straight line along a horizontal road at a speed u when the driver applies the brakes. They exert a constant force F on the car to bring the car to rest after a distance d.

(i) Write down expressions for the initial kinetic energy of the car and the work done by the brakes in bringing the car to rest.

Kinetic energy ....

Work done ....

(1)

(ii) Show that the base units for your expressions for kinetic energy and work done are the same.

....

....

....

....

....

(2)

(b) A car is travelling at 13.4 m s^{-1}. The driver applies the brakes to decelerate the car at 6.5 m s^{-2}. Show that the car travels about 14 m before coming to rest.

....

....

....

....

....

....

(3)

(c) On another occasion, the same car is travelling at twice the speed. The driver again applies the brakes and the car decelerates at 6.5 m s^{-2}. The car travels just over 55 m before coming to rest. Explain why the braking distance has more than doubled. You may be awarded a mark for the clarity of your answer.

....

....

....

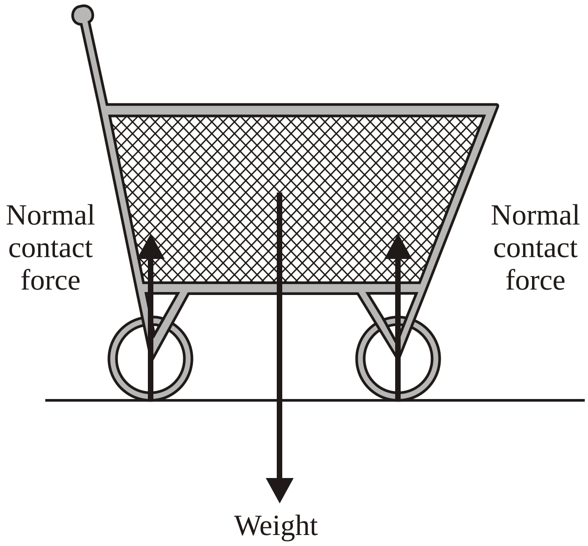
....

....

....

(4)
(Total 10 marks)

46. (a) The diagram below shows the forces acting on a shopping trolley at rest.



(i) State Newton's first law of motion.

....

....

....

....

(1)

(ii) In everyday situations, it does seem that a force is needed to keep an object, for example the shopping trolley, moving at constant speed in a straight line. Explain why.

....

....

....

(1)

(iii) The vertical forces acting on the trolley are in equilibrium. Explain what **equilibrium** means.

....

....

....

(1)

(b) (i) The weight of the trolley is one of a Newton's third law force pair. Identify what the other force in this pair acts upon and what type of force it is.

....

....

....

....

(2)

(ii) Give two reasons why the two normal contact forces do **not** form a Newton's third law pair.

1 ....

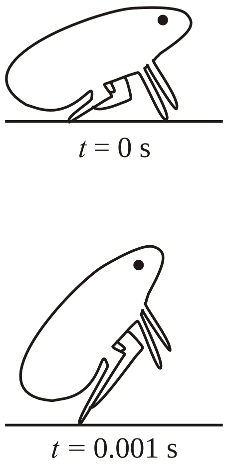
....

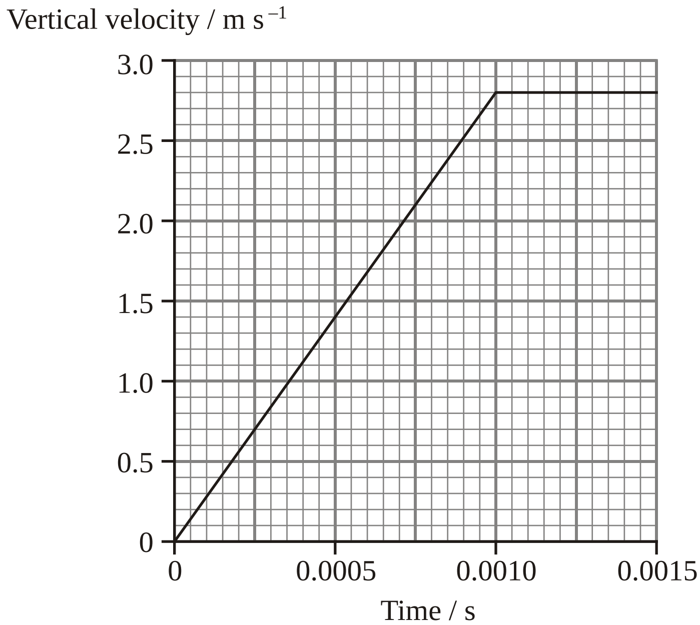
2 ....

....

(2)
(Total 7 marks)

47. High speed photography has shown that froghoppers - tiny insects found in many gardens - are better jumpers for their body size than fleas, previously regarded as the champions of jumping animals. The diagrams below show the froghopper using its hind legs to jump.





The velocity-time graph shows the motion of a froghopper during the first 0.0015 s of a vertical jump from a leaf. Explain how you can deduce from the graph that the legs are in contact with the leaf for the first 0.001 s only.

....

....

....

(2)

Use the graph to show that the froghopper has an acceleration in the first 0.001 s of about 3000 m s^{-2}.

....

....

....

(2)

The froghopper has mass of 1.2×10^{-5} kg.

Calculate the force exerted by the leg muscles during this time.

....

....

Force = ...

(2)

Use the graph to show that the froghopper rises about 0.001 m during the first 0.001 s.

....

....

....

(2)

Calculate the work done by the leg muscles during the jump.

....

....

Work done = ...

(2)

Calculate the power developed by the leg muscles.

....

....

Power = ...

(2)
(Total 12 marks)

48. Two of the world's biggest roller-coasters are Apollo's Chariot in Busch Gardens, USA, and The Big One in Blackpool, England. The principle of all roller-coasters is that gravitational potential energy possessed by the vehicle at the top of a track is converted into kinetic energy at the bottom.

In Apollo's Chariot the vehicle drops a vertical distance of 64 m from rest.

Show that the expected speed of the vehicle at the bottom of the track is about 35 m s^{-1}.

....

....

....

....

(3)

State one assumption you have made in this calculation.

....

(1)

The Busch Gardens brochure states that the speed of Apollo's Chariot at the bottom is in fact 32.5 m s^{-1}. Suggest and explain one reason why the speed might be less than 35 m s^{-1}.

....

....

....

(2)

Calculate the efficiency of this energy conversion as the vehicle runs down the track.

....

....

....

....

Efficiency = ...

(3)

Vehicles on The Big One fall through an almost identical vertical distance to those on Apollo's Chariot; but the owners of The Big One claim that the speed at the bottom is 38 m s^{-1}.

Assume their claim is truthful, and that the vertical falls are the same. Suggest how the vehicles on The Big One could have a speed of 38 m s^{-1} at the bottom.

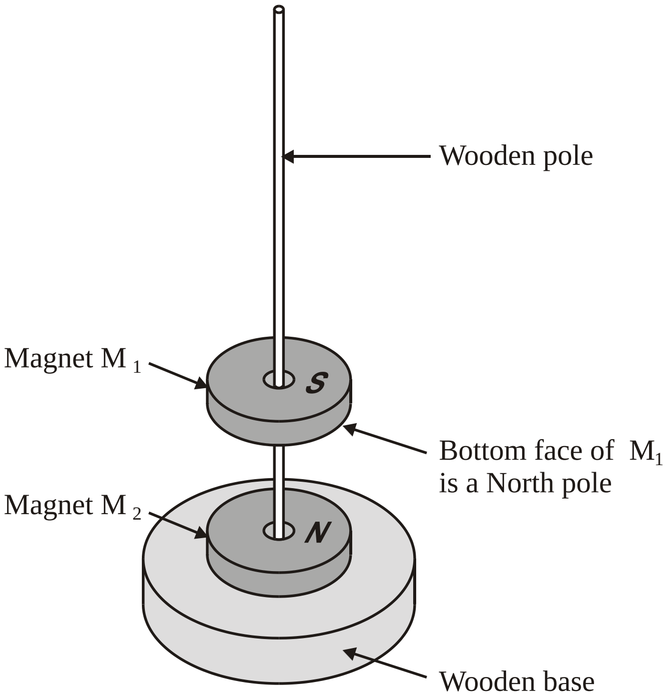
....

....

....

(1)
(Total 10 marks)

49. The diagram shows two magnets, M_1 and M_2, on a wooden stand. Their faces are magnetised as shown so that the magnets repel each other.



(a) Draw a fully labelled free-body force diagram for the magnet M_1 in the space below.

(2)

(b) The table gives the three forces acting on the magnet M_2. For each force on M_2 there is a corresponding force known as its 'Newton's third law pair'. In each case state

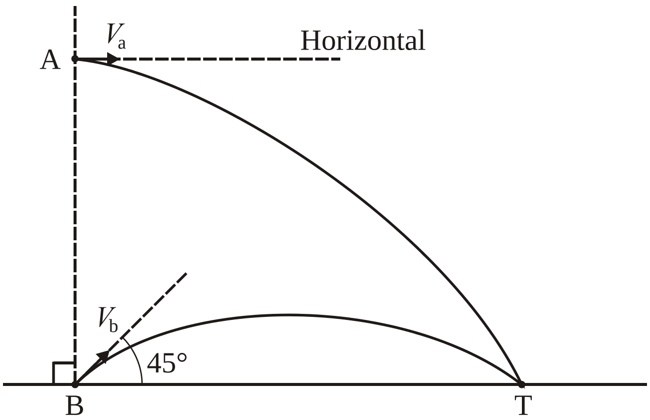
(i) the body on which this corresponding force acts,

(ii) the direction of this corresponding force.

Force on M_2	Body on which corresponding force acts	Direction of the corresponding force
Contact		
Magnetic		
Weight		

(6)
(Total 8 marks)

50. A student is investigating projectiles. He fires two small identical balls, A and B, simultaneously. Their trajectories are shown in the sketch below. The balls land at the same instant at the target, T.



(a) The initial velocity of ball A is V_a and that of ball B is V_b. Explain why the magnitude of V_b must be greater than that of V_a.

....

....

(b) The paths AT and BT have different lengths. However, balls A and B take the same time to reach the target T. Explain how this is possible. You may be awarded a mark for the clarity of your answer.

....

....

....

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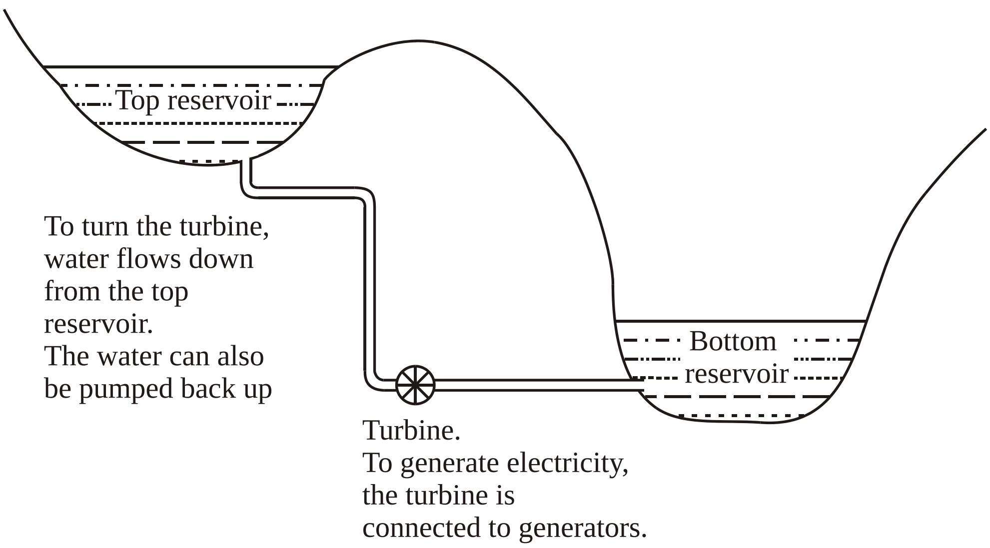
....

(Total 5 marks)

51. A certain power station generates electricity from falling water. The diagram shows a simplified sketch of the system.



(a) (i) In what form is the energy of the water initially stored?

....

(ii) What energy form is this transformed into in order to drive the turbine?

....

(1)

(b) State the principal of conservation of energy.

....

....

....

(2)

(c) The force of the water at the turbine is 3.5×10^8 N and the output power generated is 1.7×10^9 W. Use this data to calculate the minimum speed at which the water must enter the turbine.

....

....

(2)

(d) Explain why, in practice, the speed at which the water enters the turbine is much greater than this.

....

....

(1)

(e) When working at this output power, 390 m^3 of water flows through the turbine each second. The top reservoir holds 7.0×10^6 m^3 of water. For how long will electricity be generated?

....

....

....

Time = ...

(1)

(f) This power station is used at peak periods, after which the water is pumped back to the top reservoir. The water has to be raised by 500 m. How much work is done to return all the water to the top reservoir?

(The density of water is 1000 kg m^{-3}.)

....

....

....

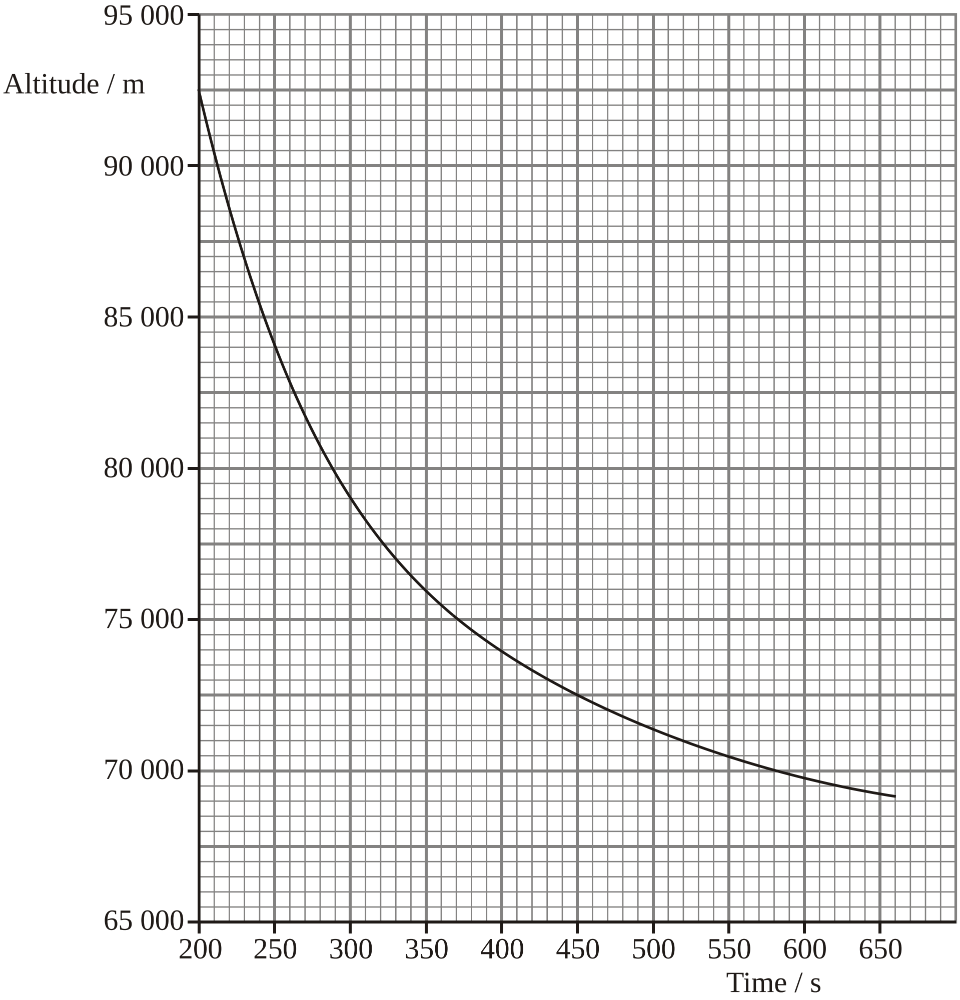
....

....

Work done = ...

(3)
(Total 10 marks)

52. The graph below shows the altitude (height above sea level) of the space shuttle during part of its descent after re-entering the Earth's atmosphere.



Use the graph to show that the vertical component of the shuttle's velocity at 300 s is about 70 m s^{-1} downwards.

....

....

....

....

(3)

The vertical component of the shuttle's velocity at 400 s is 38.0 m s^{-1} downwards.

Calculate the average vertical acceleration between 300 s and 400 s and state its direction.

....

....

....

Acceleration = ...

Direction = ...

(3)

The shuttle has a mass of 2.0×10^6 kg. Calculate the average weight of the shuttle between 300 s and 400 s.
(Over this range of altitudes, average gravitational field strength, $g = 9.6$ N kg^{-1}.)

....

....

Weight = ...

(1)

Calculate the average upward vertical force on the shuttle between 300 s and 400 s.

....

....

....

....

....

Average upward vertical force = ...

(3)
(Total 10 marks)

53. An exciting new ride in a theme park is described as follows:

"The vehicle plus riders takes only a few seconds to accelerate to a spine-tingling 53 m s^{-1}. Then (with motor off) it shoots vertically upwards to the height of a forty-two storey building and pauses."

The mass of the vehicle plus riders is 1800 kg. Calculate the kinetic energy of the loaded vehicle at a speed of 53 m s^{-1}.

....

....

....

Kinetic energy = ...

(2)

Show that from a starting speed of 53 m s^{-1}, the theoretical maximum height the vehicle could reach with the motor off would be about 140 m. Ignore resistive forces.

....

....

....

(3)

The actual height reached is 126 m. Show that the total loss of energy from the vehicle during the vertical climb to 126 m is about 3×10^5 J.

....

....

....

....

....

(2)

Calculate a value for the average resistive force acting on the vehicle during the climb.

....

....

....

Average resistive force = ...

(2)

Calculate the time for the vehicle plus riders to make the vertical climb to 126 m. State an assumption that you make.

....

....

....

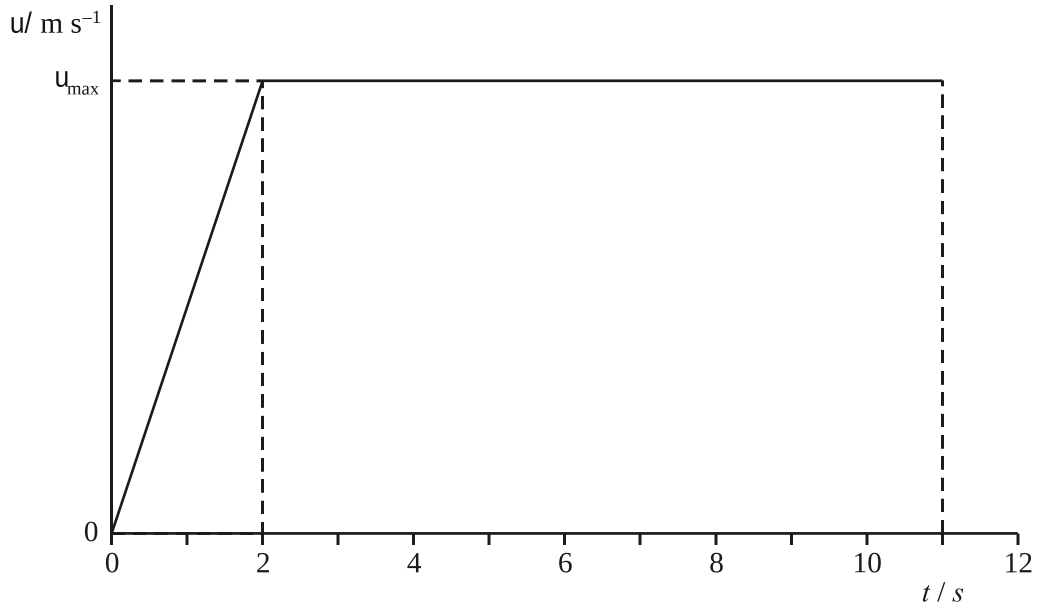
Time = ...

Assumption: ....

....

(3)
(Total 12 marks)

54. An athlete runs a 100 m race. The idealised graph below shows how the athlete's velocity *v* changes with time *t* for a 100 m sprint.



By considering the area under the graph, calculate the maximum velocity v_{max} of the athlete.

....

....

....

....

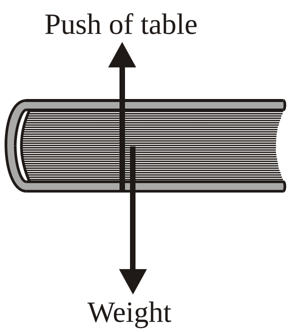
Maximum velocity = ...

(3)

Using the axes below, sketch a graph showing how the acceleration of this athlete changes with time during this race. Mark any significant values on the axes.

(4)
(Total 7 marks)

55. A book is resting on a table. A student draws a correct free-body force diagram for the book as shown below.



The student makes the incorrect statement that “The forces labelled above make a Newton third law pair; therefore the book is in equilibrium”. Criticise this statement.

....

....

....

....

....

....

....

....

(3)

Each of the forces shown in the diagram has a ‘pair’ force related to it by Newton’s third law. Complete the table below.

Force	Type of force	Direction of Newton 3rd law ‘pair’ force	Body ‘pair’ force acts upon
Weight			
Push of table	Electromagnetic		

(4)
(Total 7 marks)

56. A car is travelling along a horizontal road. The driver applies the brakes and the car comes to rest. Describe the principal energy transformation which occurs as the car comes to rest.

....

....

....

(1)

On another occasion, the same car is travelling with the same speed, but down a hill. The driver applies the brakes, which produce the same average braking force as before. With reference to the energy transformations which occur, explain why the braking distance will be greater on the hill than on the horizontal road. You may be awarded a mark for the clarity of your answer.

....

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....

(4)
(Total 5 marks)

57. This is an extract from an article about the launch of the Space Shuttle.

> At lift-off the shuttle assembly (including orbiter, booster rockets and fuel load) has a mass of 2×10^6 kg. The rocket engines initially provide about 3×10^7 N of thrust. During the climb into orbit the crew members can experience forces up to three times their own weight.

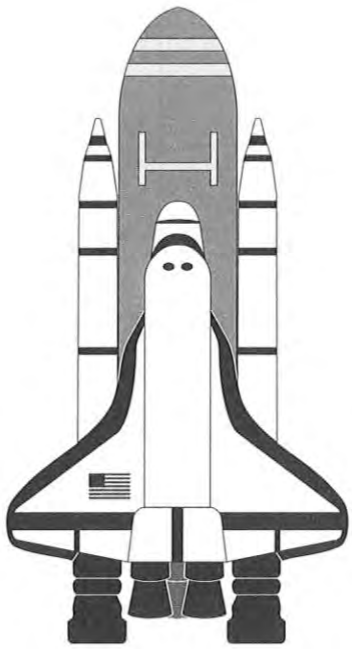
Calculate the weight of the shuttle assembly as it rests on the ground just before lift-off.

....

Weight = ...

(1)

On the diagram below, mark and label (giving magnitudes and directions) the two forces acting on the shuttle assembly at the moment just after it leaves the ground.



(2)

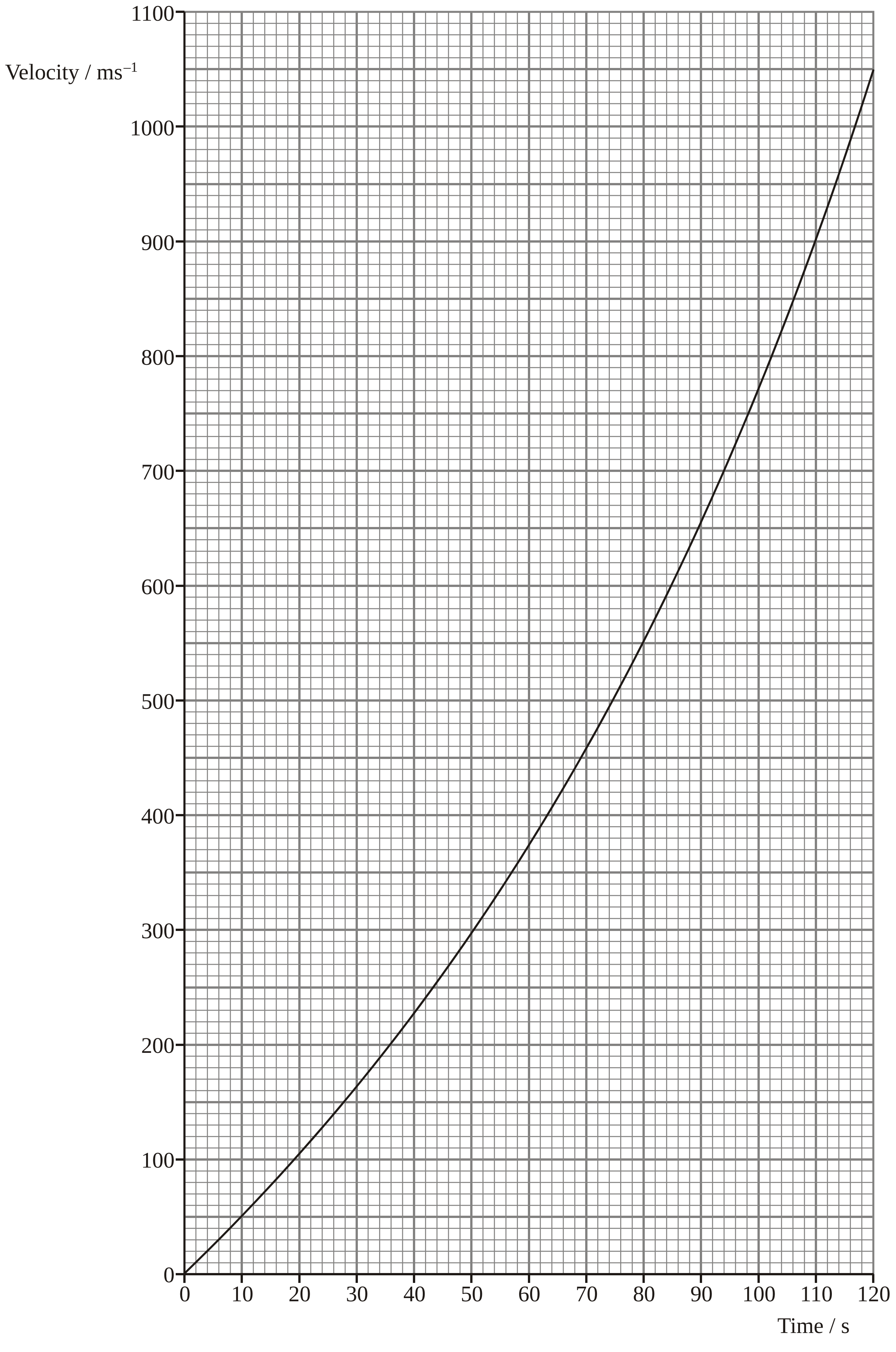
Use your two values that you marked on the diagram above to show that the initial acceleration of the shuttle assembly is about 5 m s^{-2}.

....

....

....

(2)



The graph shows velocity against time for a shuttle launch.

Use the graph to estimate the height of the shuttle after 120 s.

....

....

....

....

....

....

Height = ...

(4)

In the early stages of the flight the acceleration of the shuttle increases rapidly from the initial 5 m s^{-2}, even though the engine thrust remains roughly constant. Suggest and explain a reason for this.

....

....

....

(2)

Later in the climb towards orbit it becomes necessary to reduce the engine thrust. Suggest a reason for this.

....

....

....

(1)

(Total 12 marks)

58. In 1346 the army of King Edward III of England defeated the forces of King Philip VI of France at the battle of Crecy. The following passage gives some details:

> The main reason for Edward III's success was undoubtedly the longbow. The records say that skilled longbowmen could fire as many as 12 arrows a minute – with up to 3 arrows in the air at the same time. They were said to have a lethal effect at a range of 300 m.

The time of flight was about 10 s. Assuming the path of the arrow was symmetrical show that the initial vertical component of the arrow's velocity was about 50 m s^{-1}.

....

....

....

....

(2)

If these arrows were fired at 50° to the horizontal, calculate the velocity at which they left the longbow.

....

....

....

Velocity = ...

(2)

Show that the theoretical range was about 400 m.

....

....

....

....

....

....

(3)

The range calculated is greater than the 300 m quoted in the passage. State and explain one possible reason for the difference in the answers.

....

....

....

....

....

(2)
(Total 9 marks)

59. Complete the table below by giving **one** example of each type of force.

Type of force	Example
Gravitational	
Electromagnetic	
Nuclear	

(3)

The diagram shows forces acting on the Sun and the Earth. These forces form a Newton's third law pair.

State three properties of these forces which are necessary for them to be a Newton's third law pair.

1 ....

2 ....

3 ....

(3)
(Total 6 marks)

60. A man is pushing a shopping trolley at a speed of 1.10 m s^{-1} along a horizontal surface. There is a constant frictional force opposing the motion. The man stops suddenly, letting go of the trolley, which rolls on for a distance of 1.96 m before coming to rest. Show that the deceleration of the trolley is approximately 0.3 m s^{-2}.

....

....

....

....

(3)

The total mass of the trolley and its contents is 28.0 kg. Calculate the frictional force opposing its motion.

....

....

....

Frictional force = ...

(2)

Calculate the power needed to push the trolley at a steady speed of 1.10 m s^{-1}.

....

....

....

Power = ……………………………………

(2)

The man catches up with the trolley. Calculate the steady force he must now apply to it to accelerate it from rest to 1.10 m s^{-1} in 0.900 s.

....

....

....

....

....

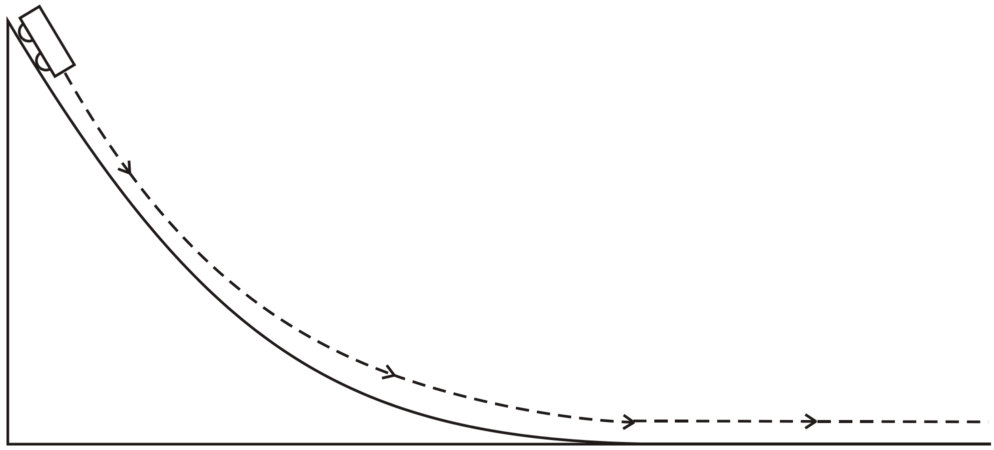
....

Force = ……………………………………

(3)

(Total 10 marks)

61. A Physics teacher is demonstrating conservation of energy. She sets up a curved runway and releases an initially stationary trolley from the top.



She tells the class that, as the trolley runs down the slope, its gravitational potential energy is converted into kinetic energy. Explain why this is only approximately true.

....

....

(1)

Describe an experiment she could perform to find out what percentage of the gravitational potential energy lost is actually converted to kinetic energy. Your answer should include:

(i) any additional apparatus required (add this to the diagram opposite),

(ii) how the apparatus is used,

(iii) how the results are analysed.

....

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(6)
(Total 7 marks)

62. On the River Rhone there is a spectacular series of hydroelectric power plants at Génissiat in the French Jura mountains. At the visitor centre, the following information is given about the biggest of the seven hydroelectric power plants:

Electrical energy supplied in one year	6.1×10^{15} J
Height through which water falls	64.5 m
Maximum output	420×10^{6} W
Average daily capacity	28×10^{6} m^3

Show that the amount of water described as 'average daily capacity' can provide energy of about 2×10^{13} J as it passes through this hydroelectric power plant.
(1 m^3 of water has a mass of 1000 kg.)

....

....

....

....

(2)

Calculate the efficiency of the system over one year.

....

....

....

....

Efficiency = ...

(3)

Calculate the average electrical power output over the whole year. (1 year = 3.16×10^{7} s)

....

....

....

....

Power = ...

(2)

Suggest a reason why the power output varies over the course of a year.

....

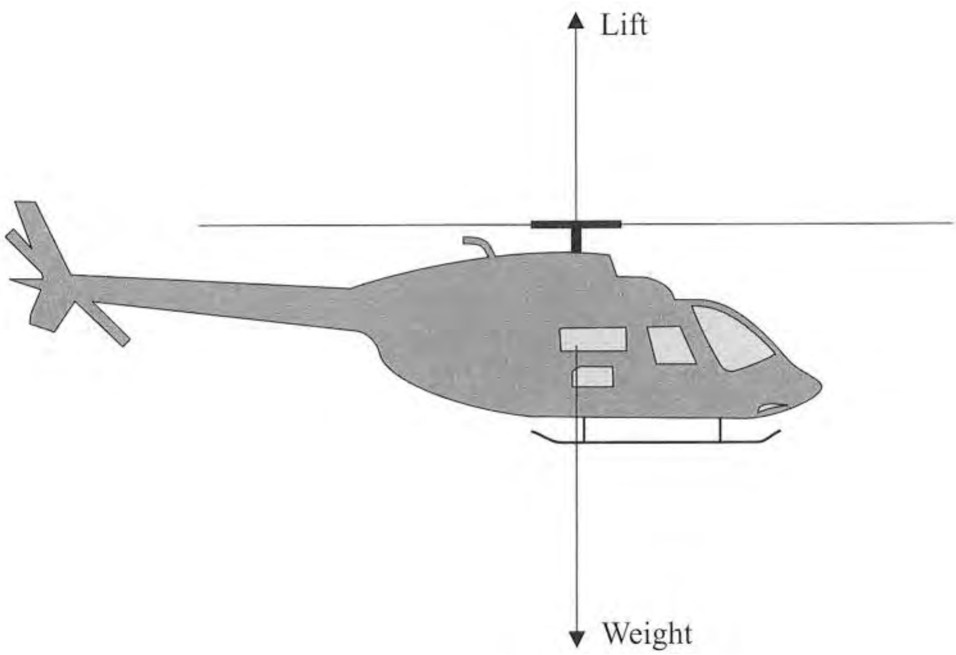
....

....

....

(1)
(Total 8 marks)

63. The diagram shows the two vertical forces acting on a helicopter hovering at a constant height. In this situation the two forces are equal in magnitude.



The mass of the helicopter is 1500 kg.

Calculate the magnitude of the lift force.

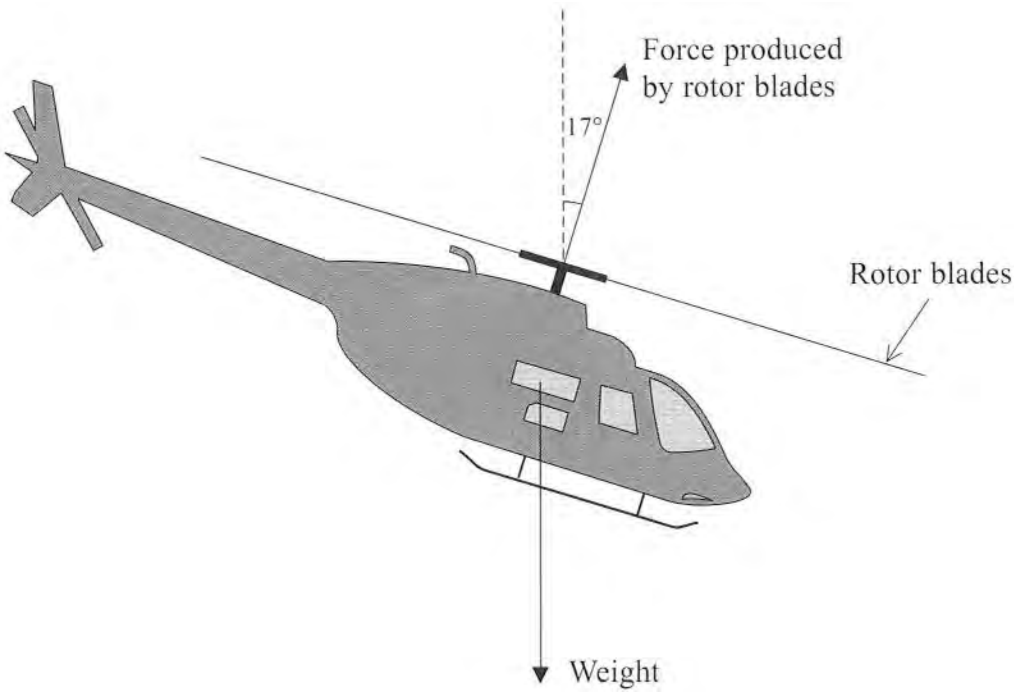
....

....

Lift force = ...

(1)

Forward thrust is obtained by tilting the helicopter forward by 17°. The speed of the rotor blades is increased so that the helicopter remains at the same height as it accelerates forwards.



Explain why the **vertical component** of the force produced by the rotor blades must still be equal in magnitude to the weight.

....

....

(1)

The force produced by the rotor blades is now 15 400 N.

Show that the horizontal component of the force is about 4500 N.

....

....

....

....

(2)

Calculate the forward acceleration of the helicopter.

....

....

....

Acceleration = ...

(2)

Calculate the horizontal distance the helicopter will have travelled from rest after 10 s assuming the acceleration is constant.

....

....

....

....

Distance = ...

(2)

Explain whether this is likely to be the actual distance travelled in this time.

....

....

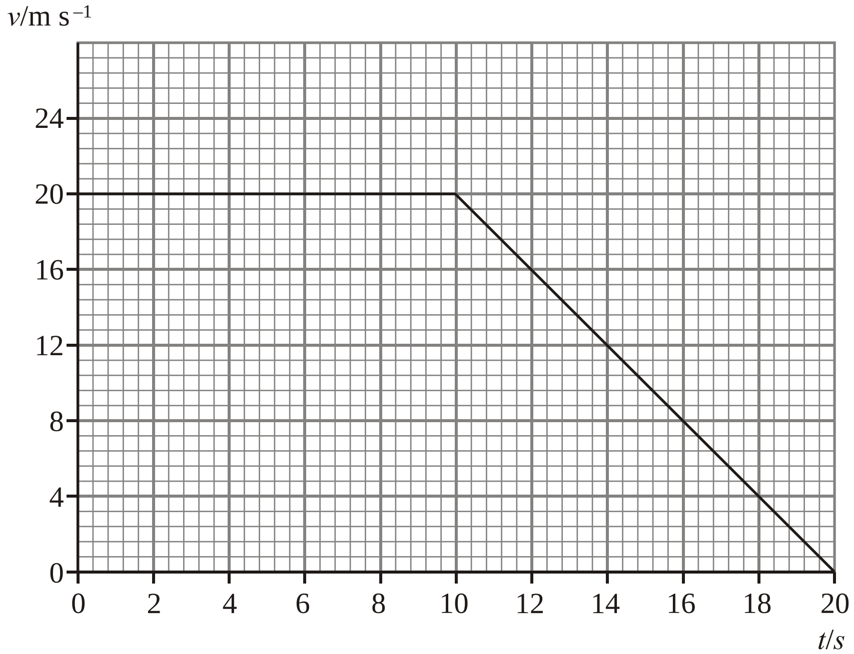
....

....

....

(2)
(Total 10 marks)

64. The graph shows the variation of velocity with time for a body moving in a straight line.



Calculate

(i) the total distance travelled,

....

....

Distance = ...

(ii) the average speed over the 20 seconds.

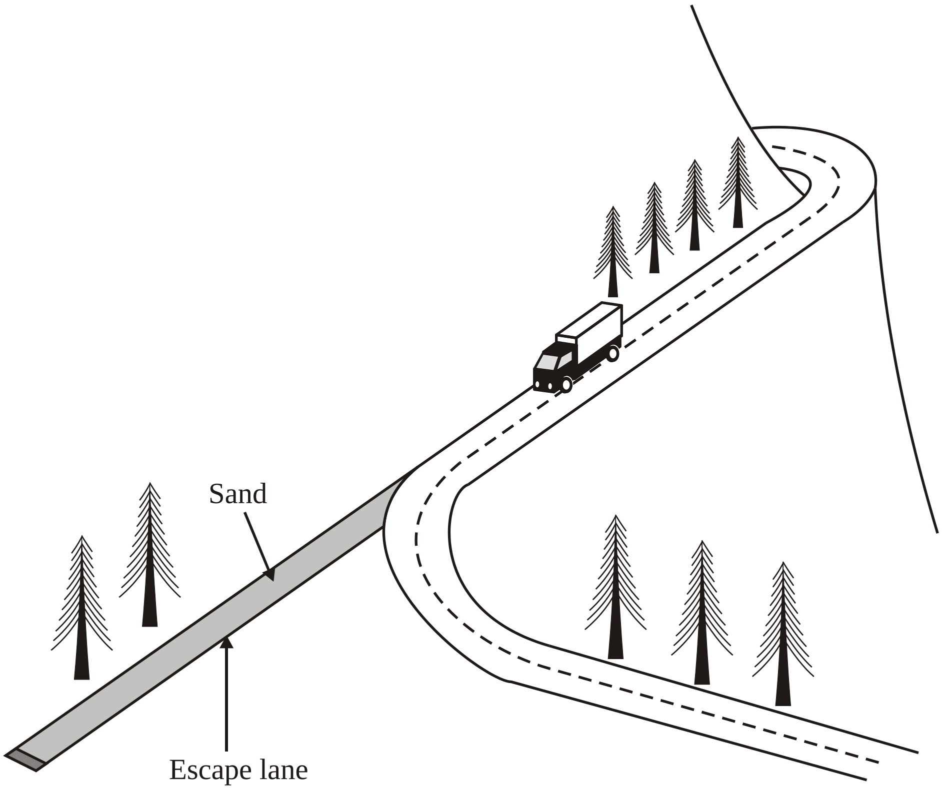
....

....

Average speed = ...

(Total 4 marks)

65. A lorry is travelling at 25 m s^{-1} down a mountain road when the driver discovers that the brakes have failed. She notices that an escape lane covered with sand is ahead and stops her lorry by steering it on to the sand.



The lorry is brought to a halt in 40 m. Calculate the average deceleration of the lorry.

....

....

....

Average deceleration =...........................

(3)

Suggest how the depth of the sand affects the stopping distance.   Justify your answer.

....

....

....

(1)
(Total 4 marks)

66. Determine the resultant force on the object below.

....

(1)

What can be deduced about the motion of an object

(i) when the resultant force on it is zero,

....

....

(ii) when the resultant force on it is vertically upwards,

....

....

(iii) when the resultant force on it is in the opposite direction to its motion?

....

....

(3)

Newton's third law of motion is sometimes stated in the form: "To every action there is an equal and opposite reaction". A student argues that, in that case, the resultant force on an object must always be zero and so it can never be moved. Explain what is wrong with the student's argument.

....

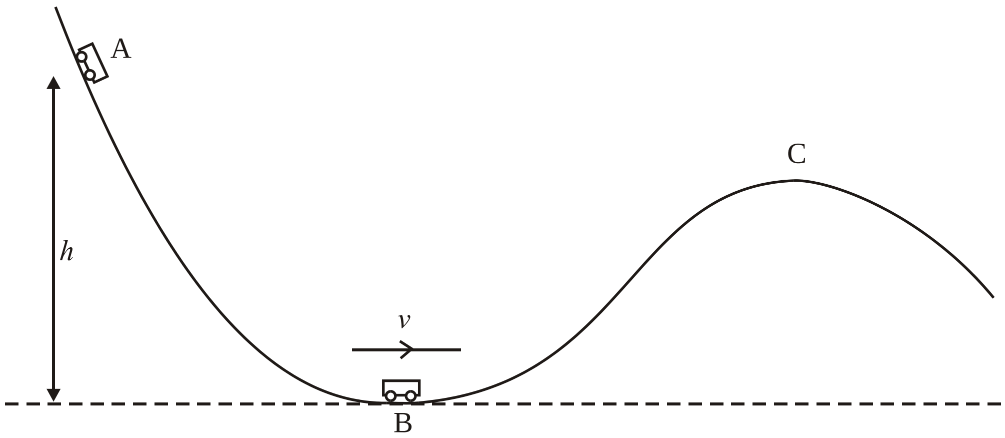
....

....

....

(2)
(Total 6 marks)

67. The diagram shows a small vehicle which is free to move in a vertical plane along a curved track.



The vehicle of mass *m* is released from rest from point A. It runs down to point B, a distance *h* vertically below A. Its speed at point B is *v*.

Write down expressions for

(i) the gravitational potential energy lost by the vehicle as it runs from A to B,

....

(ii) the kinetic energy of the vehicle at B.

....

(1)

Hence derive an expression for the speed *v*.

....

....

....

(2)

State one assumption you have made in your derivation.

....

....

(1)

Would you expect the vehicle to pass point C?   Explain your answer.

....

....

....

....

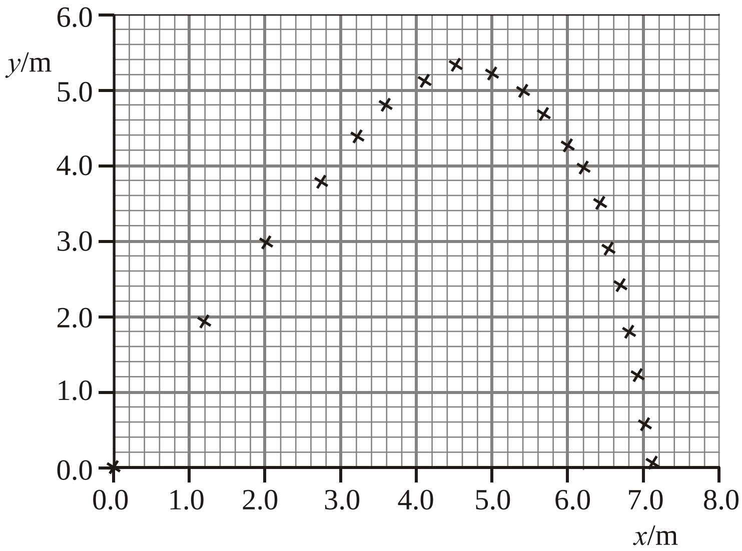
(2)
(Total 6 marks)

68. A student films the flight of a shuttlecock during a game of badminton. He analyses the motion by examining frames of the film which are at equal time intervals of 0.20 s apart. His data are shown below, together with a plot of the *x*-*y* motion of the shuttlecock.

Data:

x/m	*y*/m
0.0	0.0
.1.2	1.9
2.0	3.0
2.7	3.8
3.2	4.4
3.6	4.8
4.1	5.1
4.5	5.3
5.0	5.2
5.4	5.0
5.7	4.7
6.0	4.3
6.2	4.0
6.4	3.5
6.5	2.9
6.7	2.4
6.8	1.8
6.9	1.2
7.0	0.6
7.1	0.0

Plot:



Use the data to estimate the **initial** speed of the shuttlecock in the x-direction.

....

....

Speed in x-direction = ...

Use the data to estimate the **initial** speed of the shuttlecock in the *y*-direction.

....

....

Speed in *y*-direction = ...

(3)

Explain why these values are only estimates.

....

....

....

(1)

Show that the initial velocity of the shuttlecock is about 11 m s^{-1} at an angle of about 60° to the horizontal.

....

....

....

(2)

Estimate a value for the initial kinetic energy of the shuttlecock.
Mass of shuttlecock = 5.2×10^{-3} kg.

....

....

....

Initial kinetic energy = ...

(2)

Use the plot to estimate the gravitational potential energy of the shuttlecock at the top of its flight.

....

....

....

Potential energy = ...

(2)

Discuss why the gravitational potential energy at the top of the flight is not equal to the initial kinetic energy.

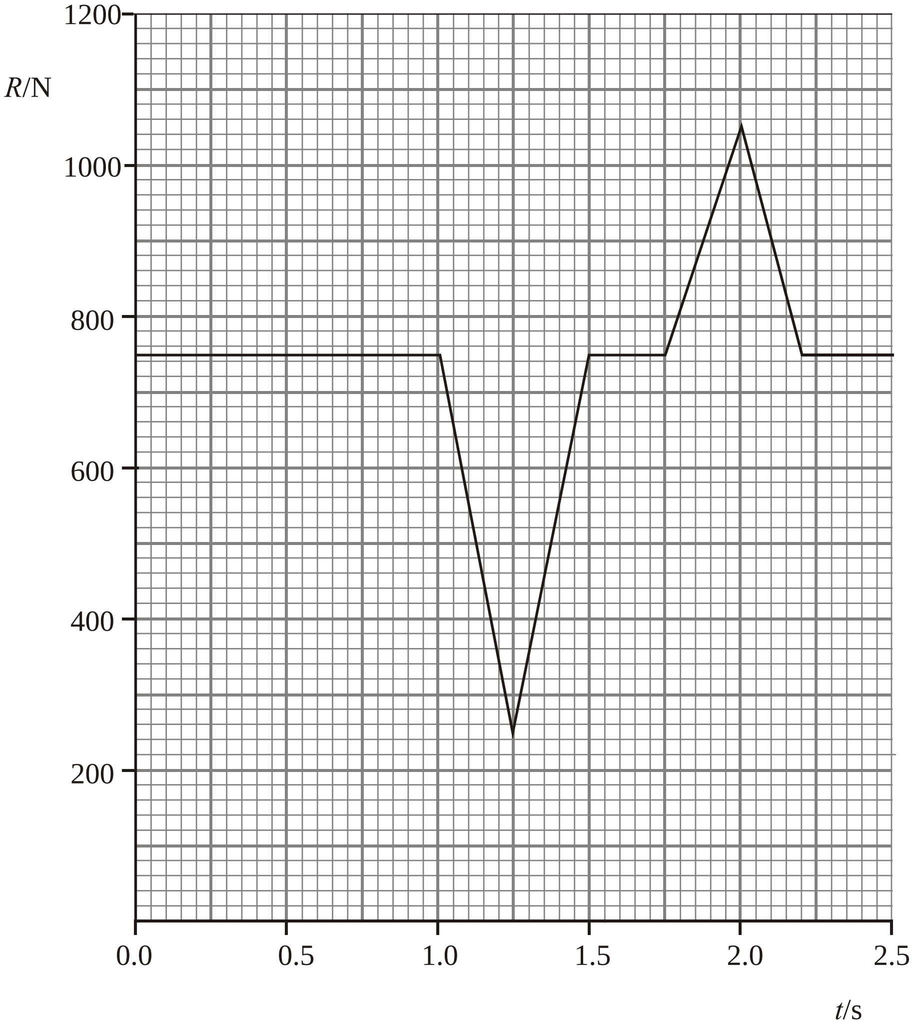
....

....

....

(2)
(Total 12 marks)

69. A student stands on some bathroom scales (which read weight in newtons). At t = 1.0 s she starts to crouch down, taking 1.0 s to do so, and then remains stationary in that position. The graph shows how the reading R on the scales changes.



State the student’s weight.

Weight ....

(1)

Calculate the student’s mass.

....

....

....

Mass = ...

(2)

Figure 1 shows the student standing still on the bathroom scales in the period $t = 0$ s to $t = 1.0$ s. R and W represent the reaction force (the reading on the scales) and the student's weight respectively.

Figure 1

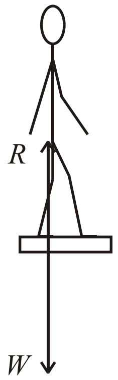
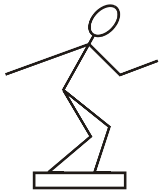


Figure 2



Complete Figure 2 to show the values of the two forces which act on the student at $t = 1.2$ s.

(2)

Calculate the student's acceleration at t = 1.2 s.

....

....

....

....

Acceleration = ...

(3)

Describe the motion of the student’s centre of mass in terms of its velocity and acceleration during the period 1.3 s to 2.0 s.

t = 1.3 s to *t* = 1.5 s:

....

....

....

t = 1.5 s to *t* = 2.0 s:

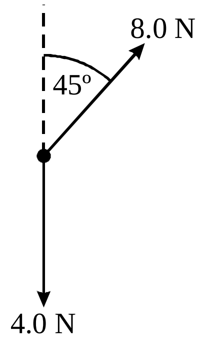
....

....

....

(4)
(Total 12 marks)

70. The diagram shows two forces acting on a body.



On the grid below draw a scale diagram to determine the resultant force acting on the body. Use a scale of 1 cm to 1 N.

State the magnitude of the resultant force.

Force = ...

(4)

What name is given to physical quantities which add by the same rule as forces?

....

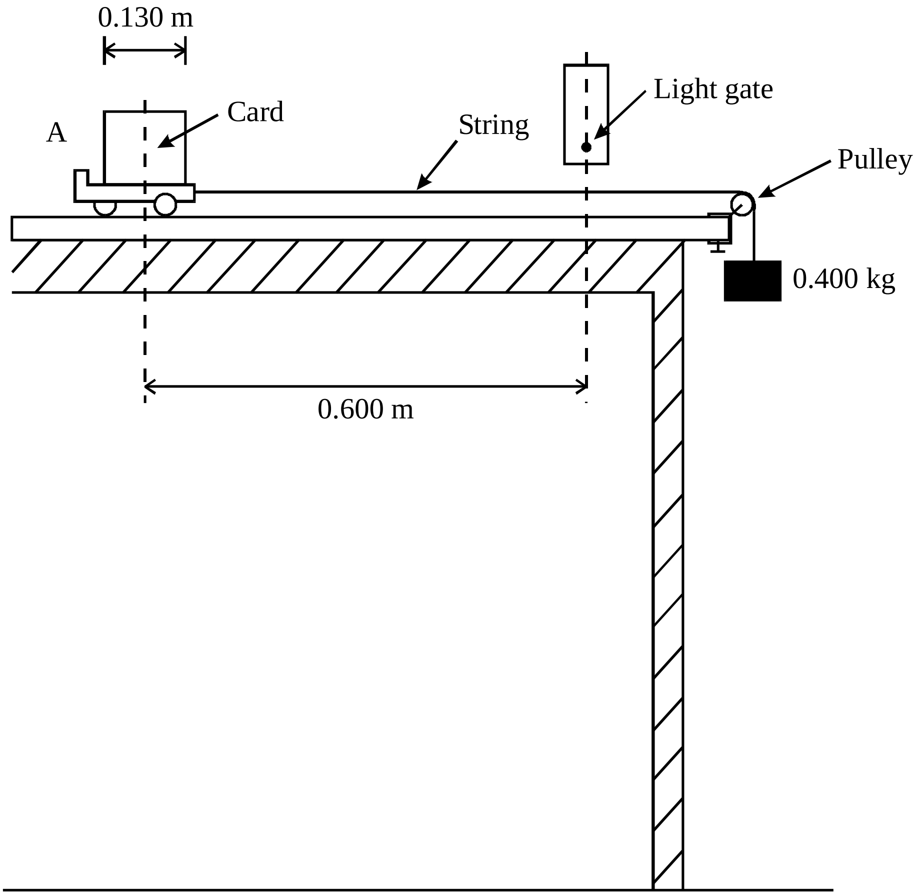
Name **two** other examples of such physical quantities.

....

....

(2)
(Total 6 marks)

71. A student performs an experiment to study the motion of a trolley on a horizontal bench. The trolley is pulled by a horizontal string which runs over a pulley to a suspended mass.



Initially the trolley is held at rest at position A. It is then released. When it has moved some distance, but before the suspended mass hits the floor, a card attached to the trolley passes through a light gate. A clock controlled by the gate records how long the card blocks the light beam.

The card, which is 0.130 in long, takes 0.070 s to pass through the beam.
Calculate the average velocity of the trolley as it passes through the light gate.

....

....

Average velocity = ...

(2)

The light gate is 0.600 in from the start. Show that the acceleration of the trolley is approximately 3 m s^{-2}.

....

....

....

....

....

....

(3)

The mass of the trolley is 0.950 kg. Calculate the tension in the string pulling it, stating any assumption which you make.

....

....

....

....

Tension = ...

(3)

The tension in the string must be less than the weight of the 0.400 kg mass suspended from it. Explain why.

....

....

....

(2)
(Total 10 marks)

72. The acceleration of free fall g can be measured by timing an object falling from rest through a known distance. Explain one advantage and one disadvantage of making this distance as large as possible.

Advantages: ....

....

....

Disadvantages: ....

....

....

(2)

In a typical laboratory measurement of g, a steel sphere is dropped through a distance of the order of one metre. With the help of a labelled diagram, describe and explain an experimental method of measuring the time it takes the sphere to fall.

....

....

....

....

....

....

(4)

At any given place, the weight of a body is proportional to its mass. Explain how measurements of g support this statement.

....

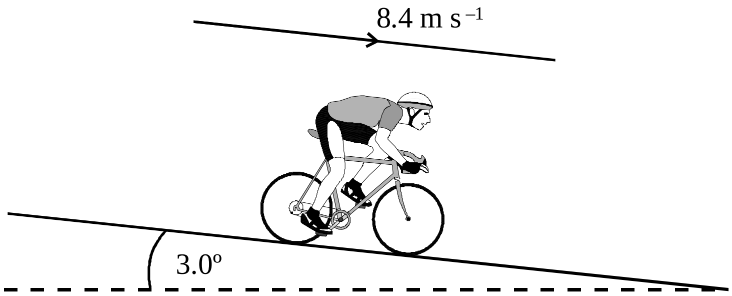
....

....

(2)

(Total 8 marks)

73. A cyclist is free-wheeling down a long slope which is at 3.0° to the horizontal. He is travelling, without pedalling, at a constant speed of 8.4 m s^{-1}.



The combined mass of the cyclist and bicycle is 90 kg. Calculate the gravitational potential energy (g.p.e.) lost per second.

....

....

....

....

G.p.e. lost per second = ...

(3)

What happens to this lost g.p.e.?

....

....

(1)

At the bottom of the slope the cyclist turns round and pedals back up at the same steady speed of 8.4 m s^{-1}. Give an estimate of the rate at which the cyclist does work as he climbs the hill.

....

....

....

Rate of working = ...

(2)

(Total 6 marks)

74. Define **momentum** and state its unit.

Definition: ....

Unit: ....

(2)

A stationary nucleus of thorium-226 decays by alpha particle emission into radium.
The equation for the decay is:

$$^{226}_{90}\text{Th} \rightarrow \, ^{222}_{88}\text{Ra} + \, ^{4}_{2}\text{He}$$

State the value of the momentum of the thorium nucleus before the decay ....

(1)

After the decay, both the alpha particle and the radium nucleus are moving.

Which has the greater speed? Justify your answer.

....

....

....

....

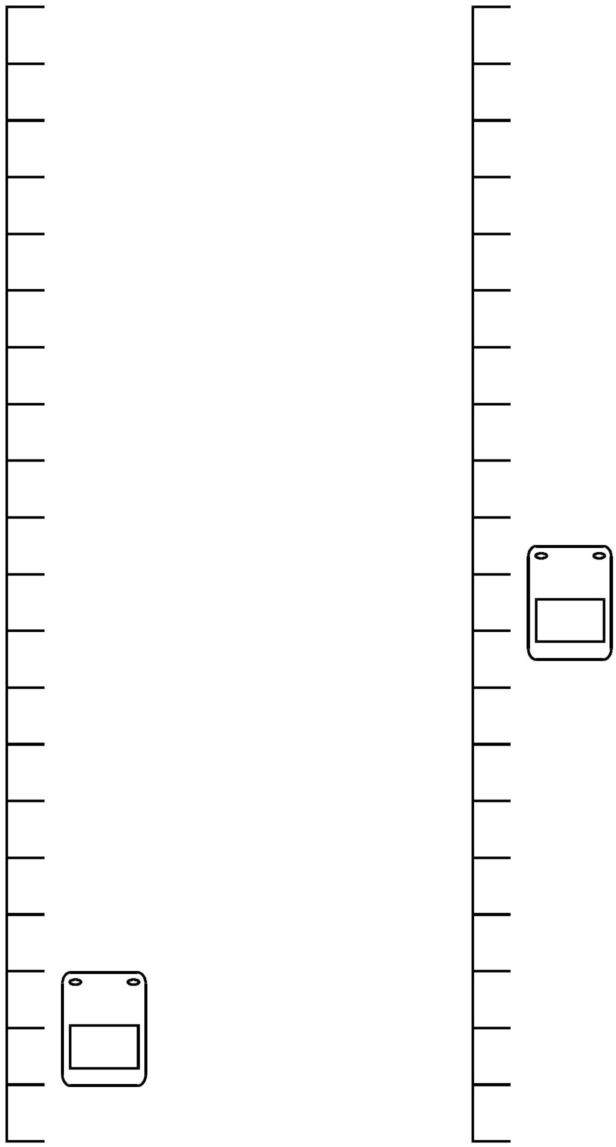
What can be said about the directions of travel of the two particles?

....

....

(3)
(Total 6 marks)

75. Speed cameras are used to record evidence of cars breaking the speed limit. Radar is used to trigger the camera which takes two flash photographs of the car, one 0.70 s after the other. A grid painted on the road shows the distance travelled by the car in this time.



The diagram shows the position of a speeding car in the two photographs. The markings on the grid are 2.0 in apart.

Calculate the average speed of the car.

....

....

....

Speed of car = ...

(2)

A car is travelling at 24.0 m s^{-1}, which is well above the speed limit. The driver notices the camera too late to slow down before the first flash. He still brakes, hoping to travel a small enough distance before the second flash, so that he seems to be travelling below the speed limit.

A car travelling at the speed limit **will** travel 12.6 m in 0.70 s, the time between the flashes.

Show that the deceleration needed for a car initially at a speed of 24.0 m s^{-1} to travel 12.6 m in between the flashes is about 17 m s^{-2}. Assume the brakes are applied at the instant the camera first flashes.

....

....

....

....

....

(4)

Calculate the braking force required to produce this deceleration. The mass of the car is 1400 kg.

....

....

....

Braking force = ...

(2)

(Total 8 marks)

76. Information given about a ski lift states the following:

> This lift transports 2800 people to the top each hour
> The vertical rise is 420 m
> The cable travels at 5.0 m s^{-1}
> The maximum power consumption of the motor is 364 000 W

Assume throughout this question that the average mass of a skier plus equipment is 90 kg.

Show that the rate at which energy is converted to gravitational potential energy is about 300 000 W.

....

....

....

....

(3)

Show that the total kinetic energy given to the skiers on the lift in one hour is about 3×10^6 J.

....

....

....

....

(2)

Calculate the rate, in watts. at which energy is converted to kinetic energy.

....

....

....

Rate of energy conversion = ... W

(1)

A student is asked to explain why the motor power consumption (364 000 W) is considerably more than the rate at which energy is converted to gravitational potential energy (about 300 000 W). His answer is "kinetic energy and heat".

Discuss each of his answers in more detail.

Kinetic energy: ....

....

....

....

Heat: ....

....

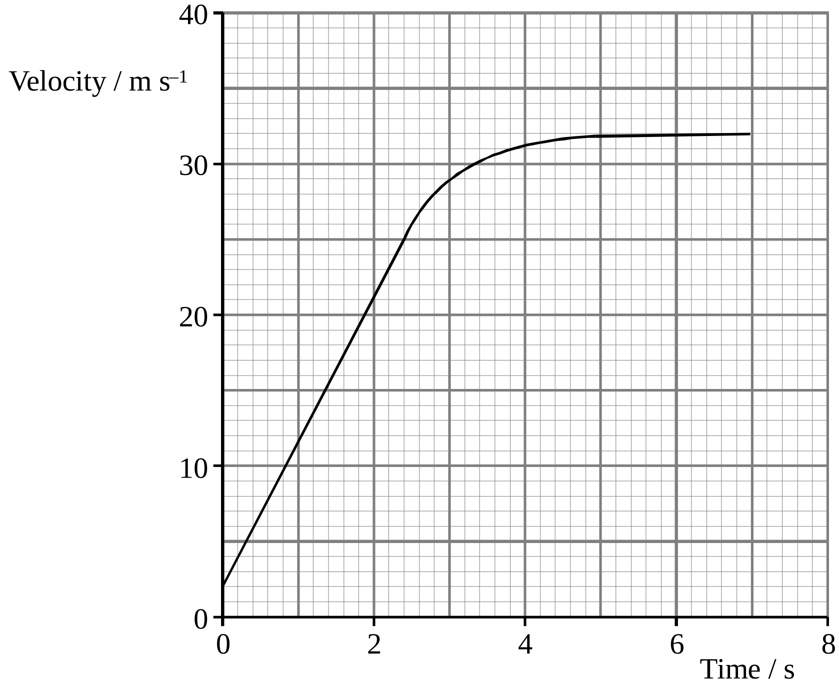
....

....

(4)

(Total 10 marks)

77. A student throws a ball downwards from a high bridge. Its velocity changes with time as shown in the graph.



Take measurements from the graph during the first 2 seconds of the fall to calculate the gradient of the straight line.

....

....

....

(2)

Hence deduce the equation which relates the velocity of the ball to time for the first 2 seconds of the fall.

....

....

....

(2)

The ball has a mass of 0.25 kg. Calculate its weight.

....

....

(1)

A student suggests that the ball reaches terminal velocity when the viscous drag, equals the weight of the ball. Use a suitable value from the graph and the data below to show that this statement is **not** valid.

Radius of ball = 0.040 m
Viscosity of air = 1.71×10^{-5} N s mg^{-2}

....

....

....

....

....

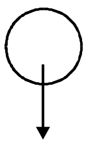
....

....

....

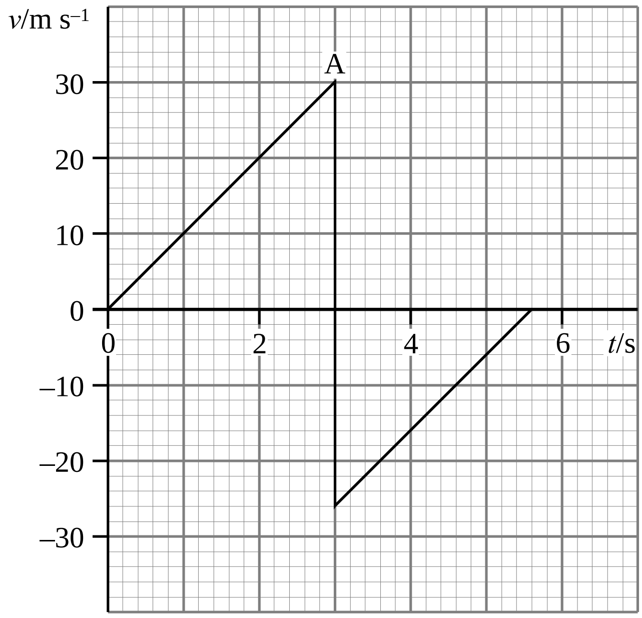
(3)

Another student suggests that there is an extra drag, force due to turbulence. Complete the diagram below to show turbulent flow around the falling ball.



(2)
(Total 10 marks)

78. A ball is dropped from a high window onto a concrete floor. The velocity–time graph for part of its motion is shown.



Calculate the gradient from the origin to A.

....

....

Gradient = ...

Comment on the significance of your answer.

....

(3)

What happened to the ball at point A?

....

(1)

Calculate the height of the window above the ground.

....

....

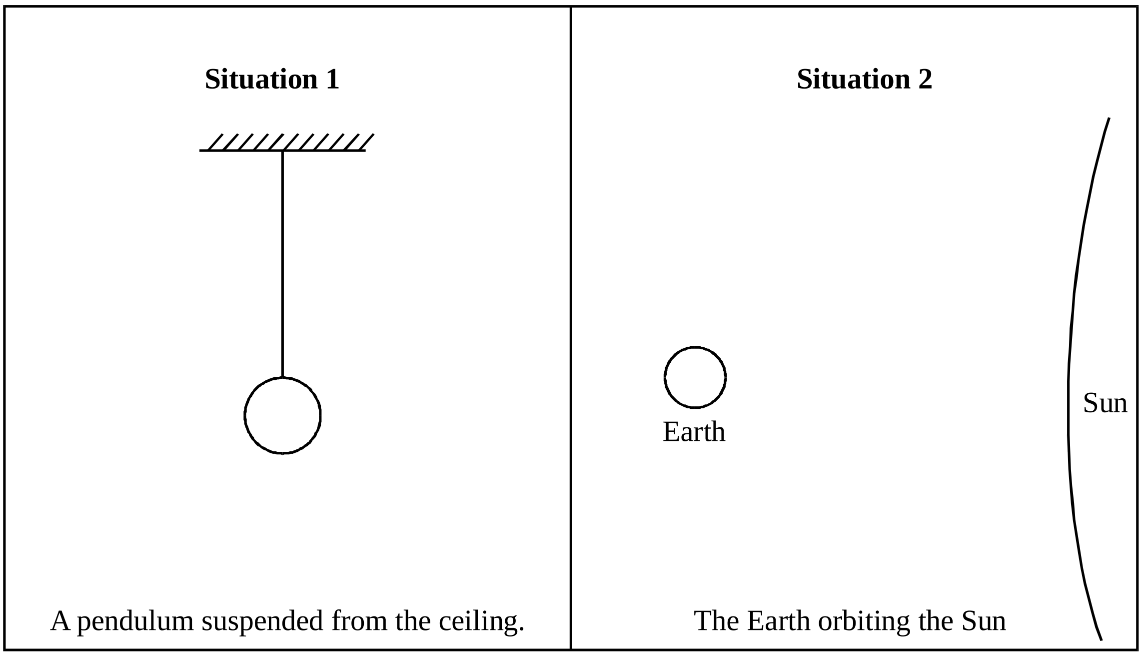
....

Height = ...

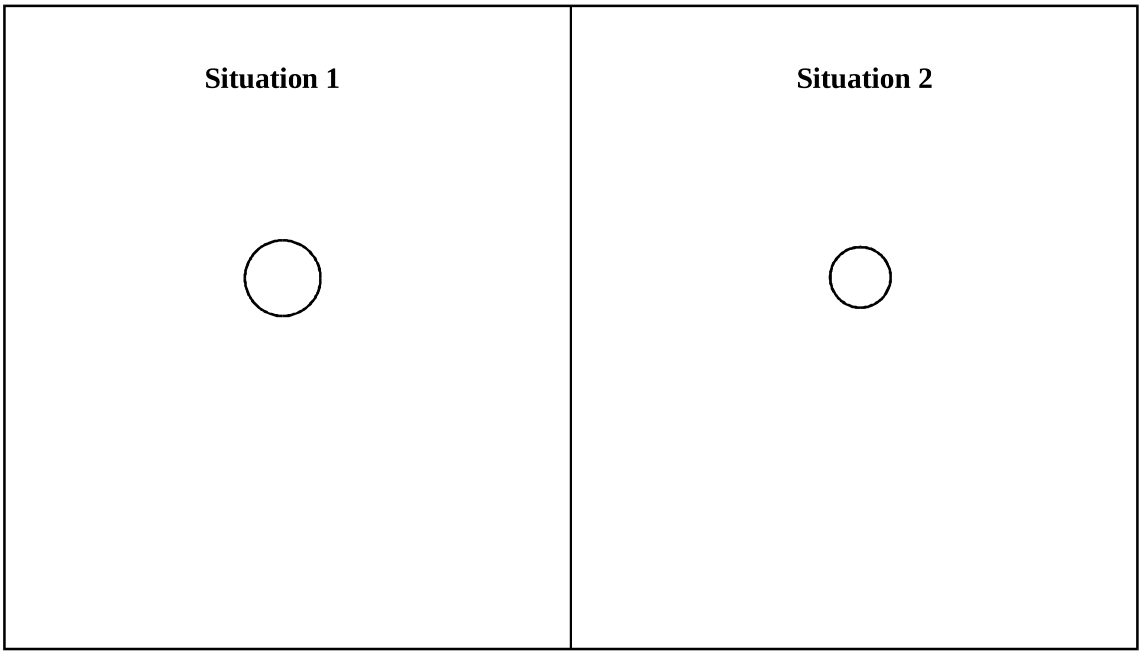
(3)

(Total 7 marks)

79. The diagrams show two situations in which forces act.



Complete labelled free-body force diagrams for the pendulum bob in situation 1 and for the Earth in situation 2.



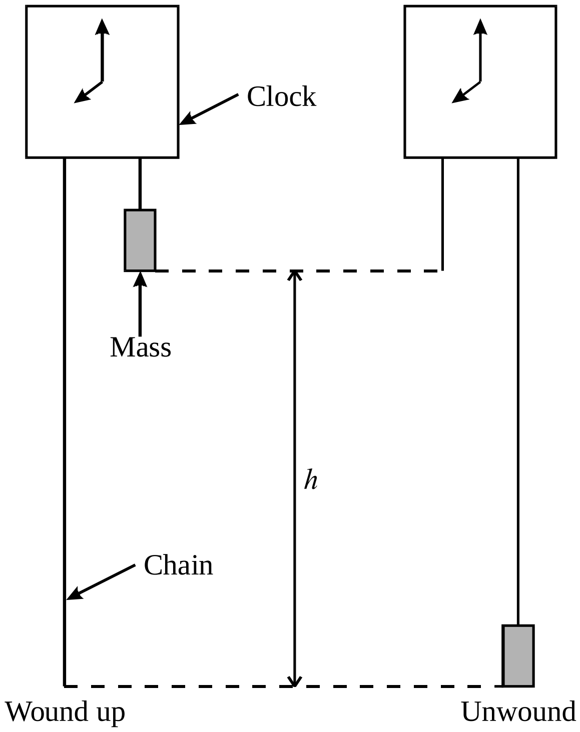
(3)

In the table below, write in the left-hand column each of the forces you have shown. Then complete the right-hand column.

Force	Newton's third law pair, noting its direction and the body on which it acts

(3)
(Total 6 marks)

80. A “grandfather” clock is a type of clock where the energy needed to provide the movement of the hands comes from a falling mass.



To wind up the clock, the mass has to be raised a distance *h*.

In one such clock, the mass is a steel cylinder of diameter 0.060 m and height 0.17 m. Show that its mass is approximately 4 kg.
(The density of steel is 7.8×10^3 kg m^{-3}.)

....

....

....

(3)

The distance fallen by the mass is 1.1 m. Calculate the change in its gravitational potential energy.

....

....

Change in G. P. E. = ...

(2)

The clock has to be wound up once per week. Calculate the average power output of the falling mass.

....

....

Power = ...

(3)
(Total 8 marks)

81. (a) State Newton's second law of motion.

....

....

....

(2)

Describe how you could demonstrate experimentally that the acceleration of a trolley is proportional to the resultant force which acts on it.

....

....

....

....

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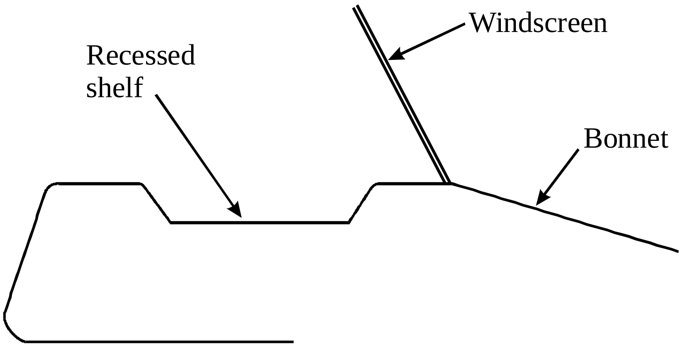
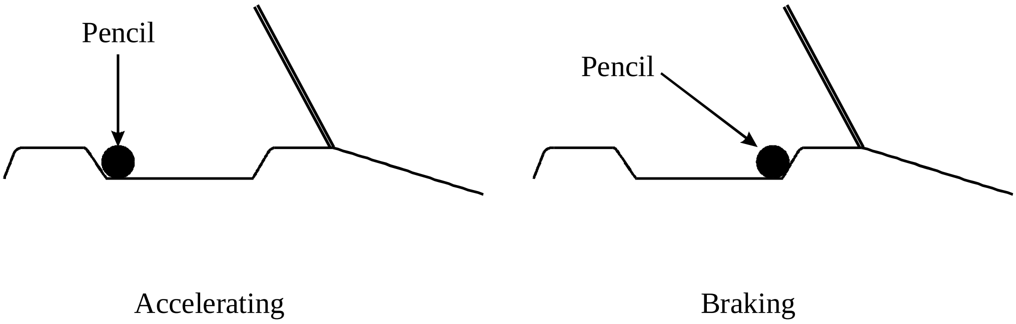
....

(5)

(b) Behind the windscreen of some cars there is a shelf, which is horizontal, but recessed to stop objects from falling off.



A pencil has been left on the shelf. Whenever the car accelerates forwards, the pencil is against the rear edge of the shelf. Whenever the car is braking the pencil is against the front edge.



Explain these observations. You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

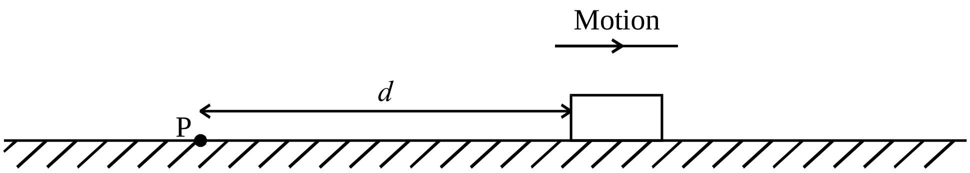
....

....

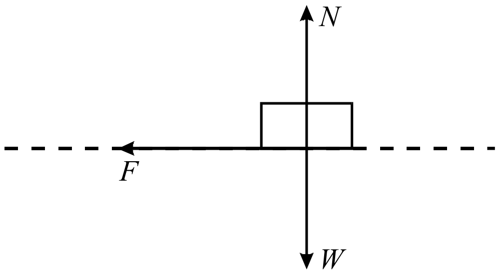
....

(5)
(Total 12 marks)

82. A block is projected from a point P across a rough, horizontal surface.



The block slows down under the influence of a constant frictional force *F* and eventually comes to rest. Below is a free-body force diagram for the block whilst it is moving.



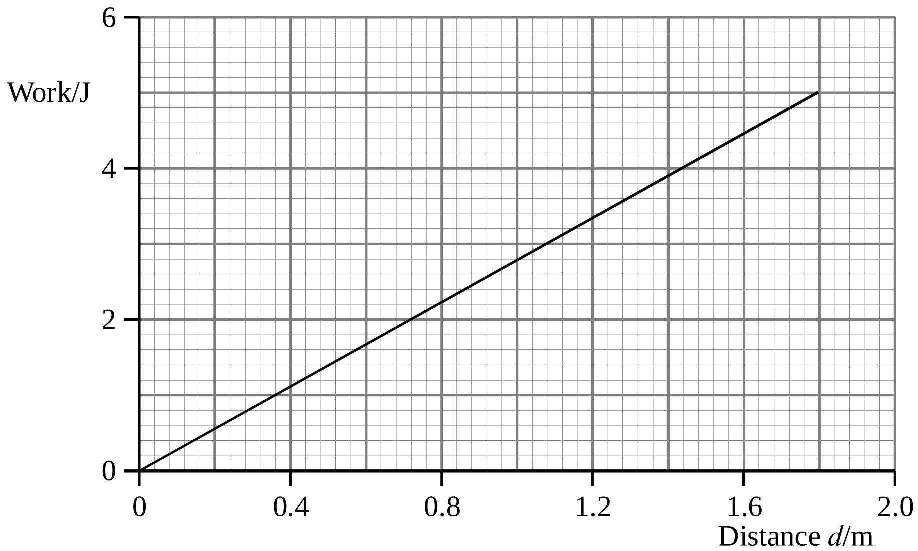
State, with a reason, the amount of work done by each of the forces *W* and *N* as the block moves across the surface.

....

....

(2)

The sliding block does work against friction. The graph shows how the total work done varies with the distance *d* which the block has travelled from the projection point P.



Use the graph to determine the force *F*.

....

....

....

F = ...

(2)

The block comes to rest 1.80 m from P. Add a line to the graph above to show how the kinetic energy of the block varied during the motion.

(2)

The mass of the block was 0.820 kg. Calculate the speed with which it was projected from P.

....

....

....

Speed = ...

(2)

Suppose that, instead of a constant friction force, the block had been brought to rest by a drag force (air resistance) which depends on speed. On the axes below sketch a graph to show qualitatively how you would expect the total work done against air resistance to vary with the distance *d*.

(1)

Explain the shape of your graph.

....

....

(1)
(Total 10 marks)

83. When the driver of a car brakes hard, as in a traffic accident, the car may skid until it comes to rest. The thermal energy generated by friction between the tyres and the road surface melts some of the rubber, leaving a skid mark. The police often use measurements of the skid marks to calculate the speeds of cars involved in accidents.

In order to determine the speed of a car involved in an accident, they must first find the frictional force between the wheels and the ground. This is done using a test car which is put into a deliberate skid.

These are the results obtained for a test car:

Speed when brakes applied = 11.5 m s^{-1}
Stopping time = 1.68 s
Mass of car = 1400 kg

Show that the deceleration of the car is about 7 m s^{-2}. Assume that the deceleration is constant.

....

....

....

(3)

Calculate the frictional force between the wheels and the ground.

....

....

Frictional force = ...

(2)

At the scene of a car accident the length of the skid marks is 20.0 m. The speed limit is 18 m s^{-1}. Use a suitable calculation to show why the driver should **not** be charged with speeding.

....

....

....

(3)

State one assumption you made in the calculation above.

....

....

....

(1)
(Total 9 marks)

84. A Student does some work to predict the flight of a discus. She assumes that the discus is launched from ground level and is not affected by air resistance or any other aerodynamic forces. She uses a spreadsheet to calculate the various quantities connected with the flight, as shown in columns A–D below. The formatting is set to round calculated values to the nearest whole number.

	A	B	C	D	E	F	G	H	I
1	Tim e /s	Vertical component of velocity /m s^{-1}	Horizontal component of velocity /m s^{-1}	Horizontal distance covered /m		Angle of initial velocity from horizontal /degrees	Initial velocity /m s^{-1}	Time interval /s	g /m s^{-2}
2						36	21	0.5	9.8
3	0.0	12	17	0					
4	0.5	7	17	8					
5	1.0	3	17	17					
6	1.5	– 2	17	25					
7	2.0	– 7	17	34					
8	2.5	– 12	17	42					
9	3.0	– 17	17	51					
10	3.5	– 22	17	59					
11	4.0	– 27	17	68					

Shown that the value in cell B3 has been correctly calculated from the values in cells F2 and G2.

....

....

....

(3)

What would be suitable formula for the calculation of cell B4?

....

(1)

Explain why the horizontal component of velocity remains constant (column C).

....

....

....

(2)

Show that the value in cell D7 has been correctly calculated.

....

....

(2)

Explain why these results suggest a flight time of 2.5 s.

....

....

....

(1)

Discuss whether a real discus launched with this initial angle and velocity would be likely to travel further or less far than 42 m.

....

....

....

....

....

(2)
(Total 11 marks)

85. A one-person spherical submarine called *Explorer* is used for underwater exploration.

EXPLORER SPHERICAL SUBMARINE

Diameter: 1.60 m
Mass of empty submarine: 2000 kg
Maximum mass of contents including water in buoyancy tanks: 110 kg

- BUOYANCY

  Buoyancy tanks can be flooded with sea water and emptied by compressed air.

- VIEWING

  Thick acrylic viewports provide visibility.
  Young modulus of acrylic is 3.0×10^9 Pa.

Use the information given above to answer the questions below.

Calculate the weight of the submarine when carrying maximum load.

....

....

Weight = ...

(1)

The submarine is at rest just above the seabed.

(i) State the magnitude of the upthrust on the submarine.

....

(ii) Give a reason for your answer.

....

....

(2)

The weight of the submarine is adjusted so that it rises with a constant velocity of 0.5 m s^{-1}.

(i) How would this change in weight of the submarine be achieved?

....

....

(ii) Calculate the viscous force on the submarine using Stokes' Law. Viscosity of water = 1.2×10^{-3} kg m^{-1} s^{-1}.

....

....

....

....

Viscous drag force = ...

(iii) The actual viscous drag force will be much greater. Suggest why.

....

(4)

At the operating depth, the pressure of water causes a stress on the viewports of 1.1×10^6 Pa.

Calculate the strain which would result from this stress.

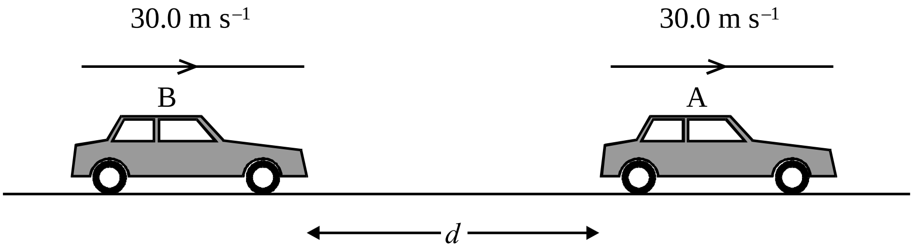
....

....

....

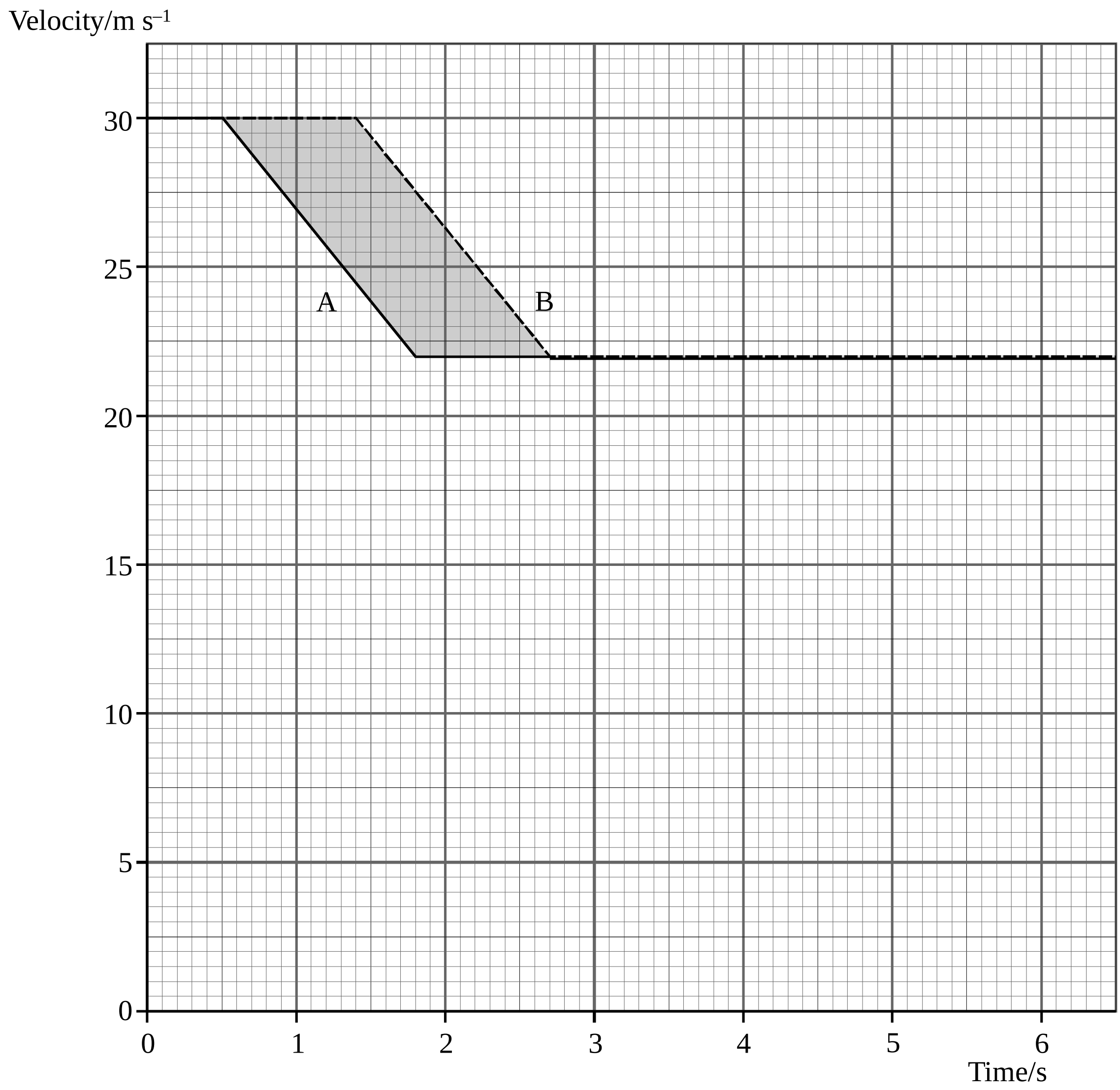
(2)
(Total 9 marks)

86. Two cars, A and B, are travelling along the outside lane of a motorway at a speed of 30.0 m s^{-1}. They are a distance d apart.



The driver of car A sees a slower vehicle move out in front of him, and brakes hard until his speed has fallen to 22.0 m s^{-1}. The driver of car B sees car A brake and, after a reaction time of 0.900 s, brakes with the same constant deceleration as A.

The diagram below shows velocity-time graphs for car A (solid line) and car B (broken line).



Find the deceleration of the cars whilst they are braking.

....

....

....

....

Deceleration = ...

(3)

What does the area under a velocity-time graph represent?

....

(1)

Determine the shaded area.

....

....

....

Area = ...

(2)

State the minimum value of the initial separation *d* if the cars are not to collide.
Explain how you arrived at your answer.

....

....

....

(2)

Suppose that, instead of only slowing down to 22.0 m s^{-1}, the cars had to stop. Add lines to the grid above to show the velocity–time graphs in this case. (Assume that the cars come to rest with the same constant deceleration as before.)

(1)

Explain why a collision is now more likely.

....

....

....

....

(2)
(Total 11 marks)

87. A door which cannot be opened by pushing steadily on it can often be kicked open. By considering what happens to the foot as it hits the door, explain why the kick is more effective. You should refer to Newton's second and third laws of motion in your answer. You may be awarded a mark for the clarity of your answer.

....

....

....

....

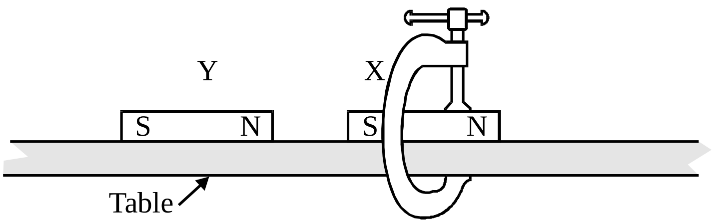
....

....

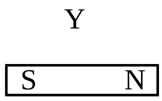
....

(Total 4 marks)

88. A magnet X is clamped to a frictionless table. A second magnet Y is brought close to X and then released.



Add labelled forces to the free-body diagram below for magnet Y to show the forces acting on it just after it is released.



(3)

According to Newton's third law, each of the forces in your diagram is paired with another force. Write down one of these other forces, stating its direction and the body it acts upon.

....

....

....

(2)
(Total 5 marks)

89. One device used for throwing spears is an atlatl (shown below). This device was used by human hunters over 20000 years before the invention of the bow and arrow. It effectively increases the length of the hunter's arm, allowing a spear to be thrown further than it could be by hand alone.

Figure 1 shows an atlatl holding a spear.

Figure 1

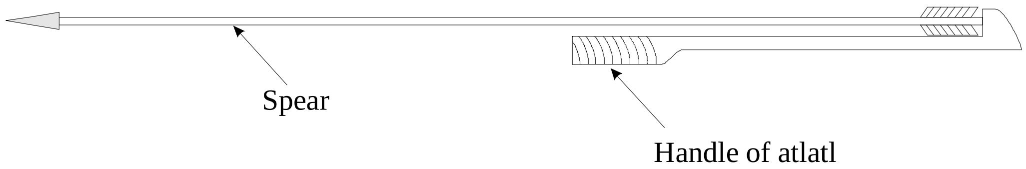
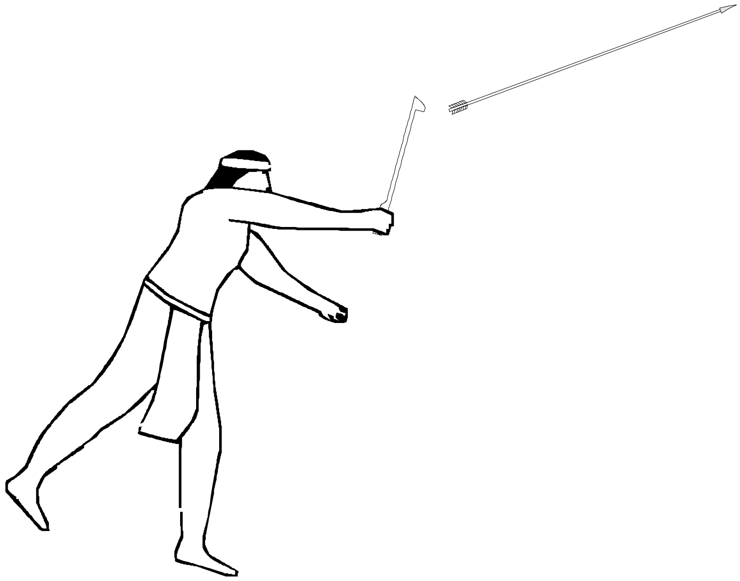


Figure 2 shows an atlatl being used to launch a rigid spear.

Figure 2



A spear is launched from 2.0 m above the ground with a velocity of 22.5 m s^{-1} at an angle of 38° to the horizontal. It strikes a distant target which is also 2.0 m above the ground.

Show that the initial vertical component of the spear's velocity is about 14 m s^{-1}.

....

....

....

....

(2)

Show that time taken for the spear to reach the target is about 3 s. (Ignore the effect of air resistance.)

....

....

....

(3)

Calculate the horizontal distance to the target.

....

....

....

....

Distance = ...

(3)

Starting with a definition of work done, explain why effectively increasing the length of the hunter's arm by use of the atlatl will increase the range that the spear can be thrown.

....

....

....

....

....

....

(3)
(Total 11 marks)

90. The skydiver in the diagram is falling with a constant velocity.

Mark and label the forces acting on the skydiver.

(2)

Discuss the forces acting on the skydiver when he is falling with constant velocity.

....

....

(2)

The weight of the skydiver and parachute is about 690 N. Show that the mass of the skydiver and parachute is about 70 kg.

....

....

(1)

The skydiver falls 2000 m at a constant velocity. Calculate the gravitational potential energy lost during this process.

....

....

Gravitational potential energy lost = ...

(2)

A student suggests “We can use **gravitational potential energy lost** = **kinetic energy gained** to calculate the constant velocity of the skydiver”.
Comment on this suggestion.

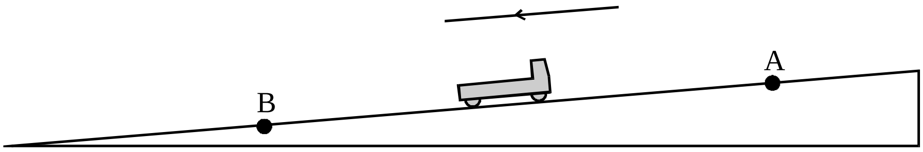
....

....

....

(2)
(Total 9 marks)

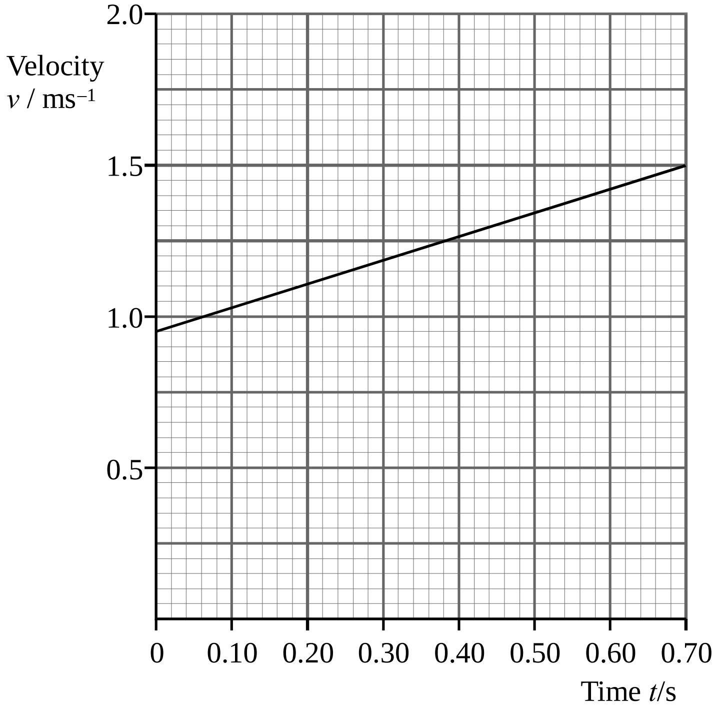
91. The diagram below shows a trolley running down a slope.



Complete the diagram to show an experimental arrangement you could use to determine how the trolley's position varies with time.

(2)

The data is used to produce a velocity-time graph for the trolley. Below is the graph for the motion from point A to point B. Time is taken to be zero as the trolley passes A, and the trolley passes B 0.70 s later.



The motion shown on the graph can be described by the equation $\upsilon = u + at$. Use information from the graph to determine values for u and a.

u = ...

....

a = ...

....

(3)

Determine the distance AB.

....

....

....

....

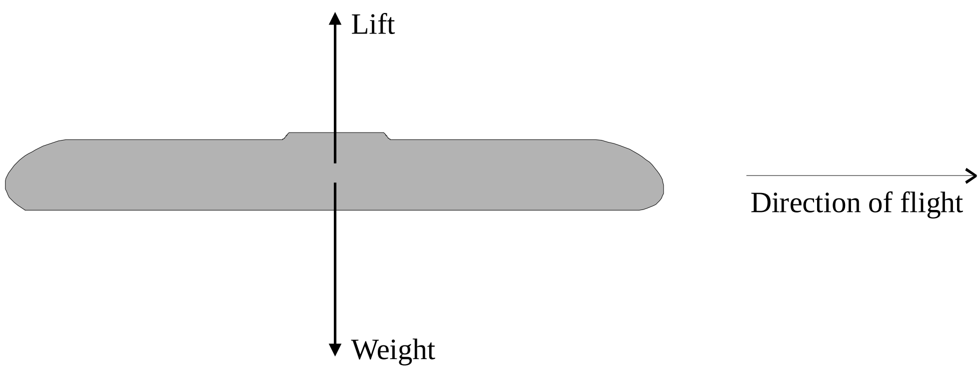
AB = ...

(3)

On the axes below sketch a graph to show how the displacement x of the trolley from point A varies with time t. Add a scale to each axis.

(3)
(Total 11 marks)

92. A Frisbee is a flying, disc used as a toy. The diagram shows the forces acting, on a Frisbee.



The passage of the air over its surface generates an upward lift force when it is thrown.

Some students decided to calculate the lift generated by a Frisbee. They measured the mass of the Frisbee and threw it horizontally from a known height. They measured the time of flight and the horizontal distance travelled.

Identify one vector quantity and one scalar quantity from the sentences above.

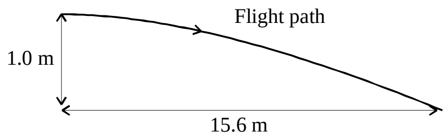
Vector ....

Scalar ....

(2)

The students recorded their data as shown and added a sketch to illustrate what happened.

Launch height	1.0 m
Distance	15.6 m
Time of flight	2.5 s



A Frisbee has a mass of 0.10 kg. Calculate its weight.

....

Weight = ...

(2)

By considering the vertical motion of the Frisbee, show that its vertical acceleration is about 0.3 m s^{-2}. Assume acceleration is constant.

....

....

....

(3)

Hence, calculate the resultant vertical force on the Frisbee.

....

....

Force = ...

(2)

Calculate the lift force acting on the Frisbee.

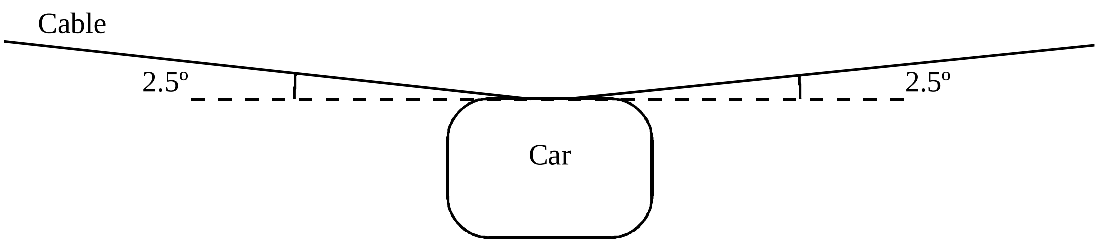
....

....

Lift = ...

(2)
(Total 11 marks)

93. The diagram shows a stationary cable car which is used to take passengers between different areas in a theme park.



Add **labelled** arrows on the diagram above to show the three forces acting on the car.

(2)

The weight of the car plus passengers is 18 000 N. Calculate the tension in the cable for the car in the diagram.

....

....

....

Tension = ...

(3)

A display outside the cable car station gives the following information:

Maximum speed of cars	4 m s^{-1}
Number of cars	54
Mass of empty car	1250 kg
Power of motor	500 kW

The cars are moved by a continuous loop of cable pulled by a motor.

In the morning the system is started from rest, with all 54 cars being accelerated to a speed of 4 m s^{-1}.

Show that the total kinetic energy of all the empty cars is then about 500 000 J.

....

....

(3)

Assuming all of the power of the motor is used to accelerate the cars, calculate how long they will take to reach their maximum speed.

....

....

Time = ...

(2)

Suggest a reason why they are likely to take longer than this to reach their maximum speed.

....

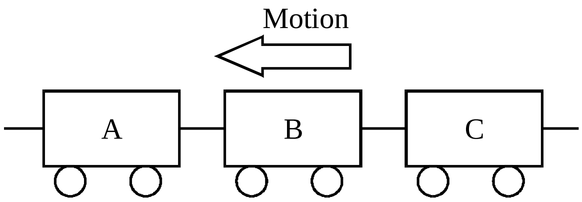
....

....

(1)

(Total 11 marks)

94. The diagram shows three trucks which are part of a train. The mass of each truck is 84 000 kg.



The train accelerates uniformly in the direction shown from rest to 16 m s^{-1} in a time of 4.0 minutes. Calculate the resultant force on each truck.

....

....

....

Resultant force =..

(3)

The force exerted by truck B on truck C is 11 200 N. Draw a free-body force diagram for truck B, showing the magnitudes of all the forces. Neglect any frictional forces on the trucks.

(4)

The total mass of the train is 3.0×10^6 kg. Calculate the average power delivered to the train during the accelerating process.

....

....

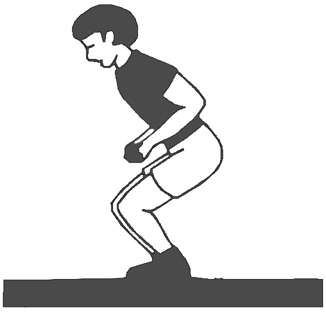
....

Average power =..

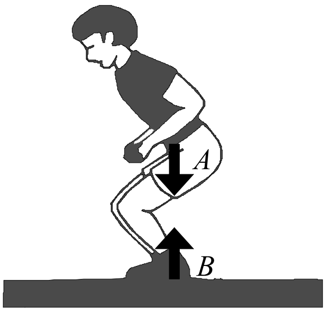
(3)

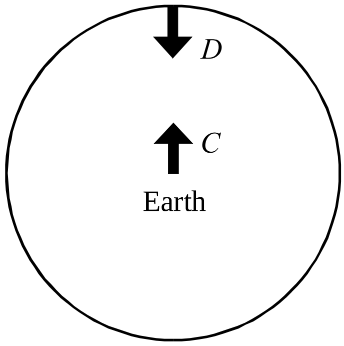
(Total 10 marks)

95. A child is crouching at rest on the ground



Below are free-body force diagrams for the child and the Earth.





Complete the following table describing the forces *A*, *B* and *C*.

Force	**Description of force**	**Body which exerts force**	**Body the force acts on**
A	Gravitational	Earth	Child
B			
C			

(4)

All the forces *A, B, C* and *D* are of equal magnitude.

Why are forces *A* and *B* equal in magnitude?

....

....

Why must forces *B* and *D* be equal in magnitude?

....

.... **(2)**

The child now jumps vertically upwards. With reference to the forces shown, explain what he must do to jump, and why he then moves upwards.

....

....

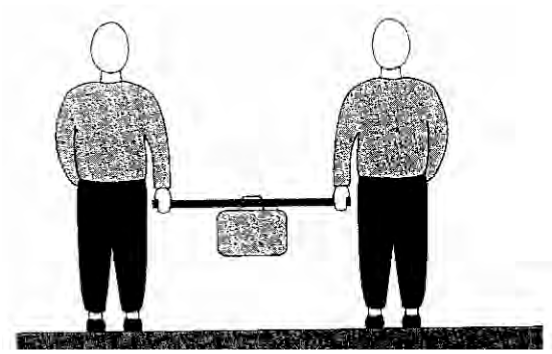
....

....

.... **(3)**

(Total 9 marks)

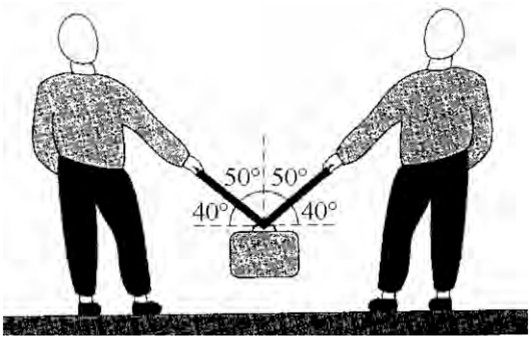
96. Two campers have to carry a heavy container of water between them. One way to make this easier is to pass a pole through the handle as shown.



The container weighs 400 N and the weight of the pole may be neglected. What force must each person apply?

(1)

An alternative method is for each person to hold a rope tied to the handle as shown below.



In the space below draw a free-body force diagram for the container when held by the ropes.

(2)

The weight of the container is 400 N and the two ropes are at 40° to the horizontal. Show that the force each rope applies to the container is about 300 N.

....

....

....

....

Force = ...

(3)

Suggest **two** reasons why the first method of carrying the container is easier.

....

....

....

....

(2)

Two campers using the rope method find that the container keeps bumping on the ground. A bystander suggests that they move further apart so that the ropes are more nearly horizontal. Explain why this would not be a sensible solution to the problem.

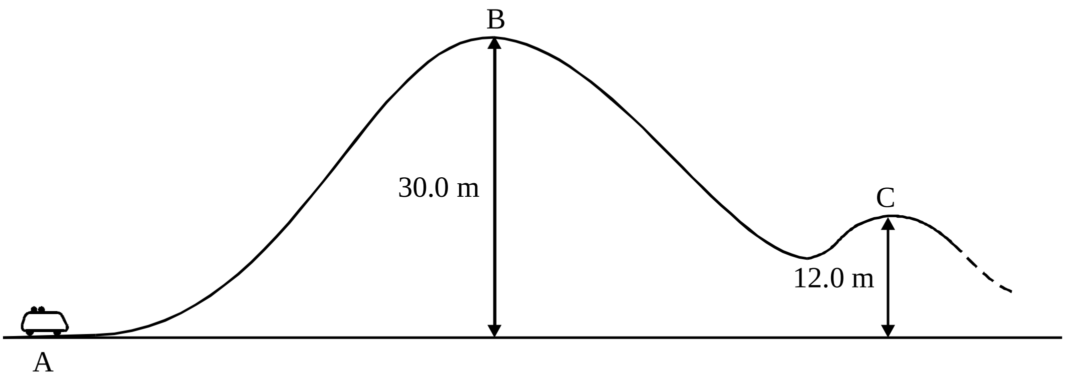
....

....

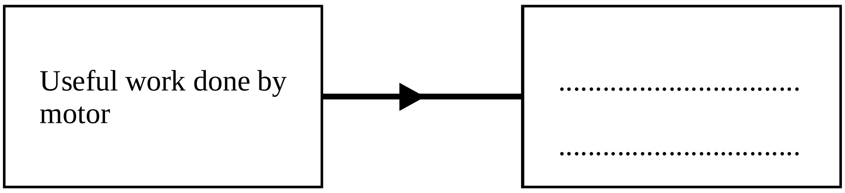
....

(1)
(Total 9 marks)

97. The diagram shows part of a roller coaster ride. **In practice, friction and air resistance will have a significant effect on the motion of the vehicle, but you should ignore them throughout this question**.



The vehicle starts from rest at A and is hauled up to B by a motor. It takes 15.0 S to reach B, at which point its speed is negligible. Complete the box in the diagram below, which expresses the conservation of energy for the journey from A to B.



(1)

The mass of the vehicle and the passengers is 3400 kg. Calculate

(i) the useful work done by the motor.

....

....

Work done = ...

(ii) the power output of the motor.

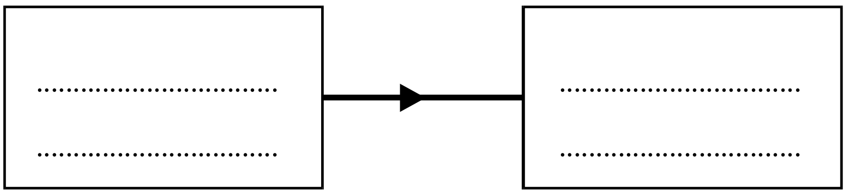
....

....

Power = ...

(4)

At point B the motor is switched off and the vehicle moves under gravity for the rest of the ride. Describe the overall energy conversion which occurs as it travels from B to C.



(1)

Calculate the speed of the vehicle at point C.

....

....

....

Speed = ...

(3)

On another occasion there are fewer passengers in the vehicle; hence its total mass is less than before. Its speed is again negligible at B. State with a reason how, if at all, you would expect the speed at C to differ from your previous answer.

....

....

....

....

....

(2)
(Total 11 marks)

98. Define power.

....

.... **(1)**

State an appropriate unit for power.

.... **(1)**

Express this unit in terms of base units.

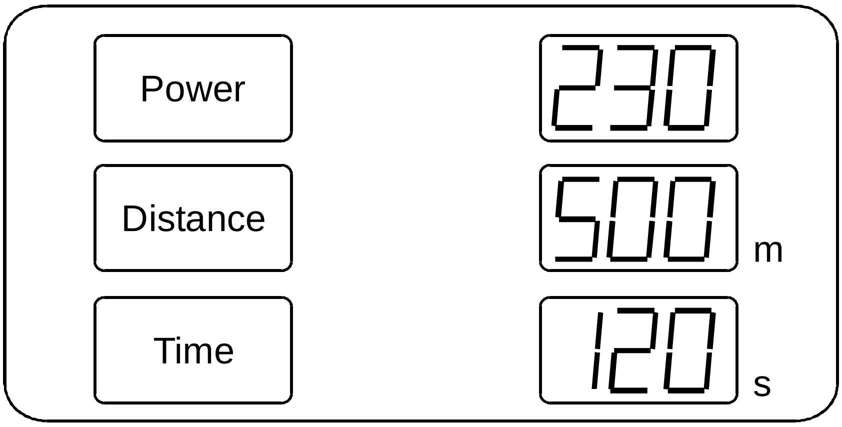
....

....

.... **(2)**

(Total 4 marks)

99. Julie uses a rowing machine at the local gym. The machine gives an electronic read-out which shows how far she would have travelled if she had been rowing a real boat on a real lake. After a short hard burst of rowing, the display showed the values below.



The SI. unit for power has been omitted. What should it be?

.... **(1)**

Calculate her average speed through the "water".

....

....

Speed = ………………………..

(1)

Calculate the average resistive force of the "water" on the "boat".

....

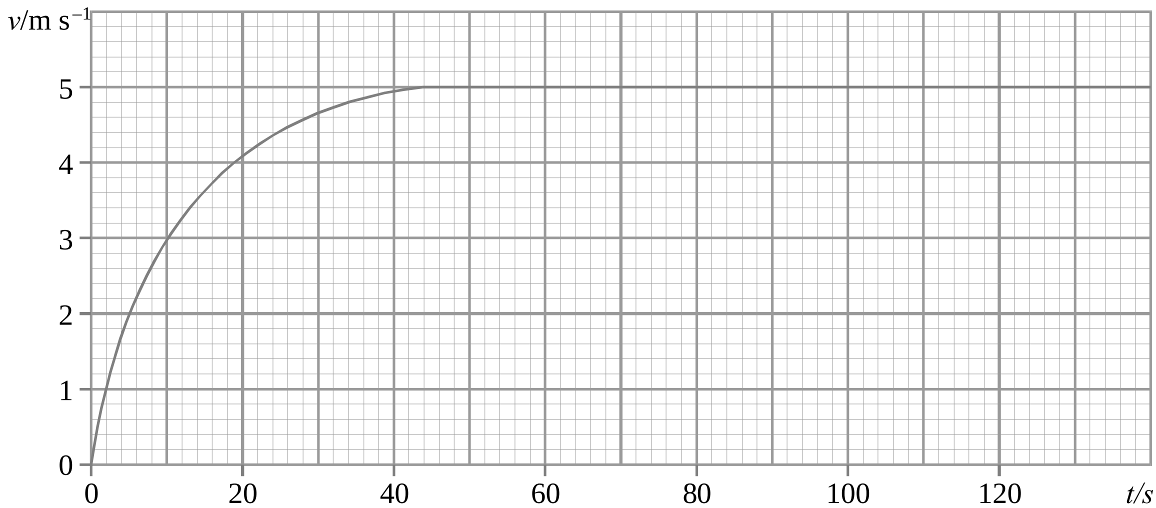
....

....

Resistive force = ………………………..

(2)

The next day, Julie takes out a real boat fitted with data-recording equipment. The graph below shows how her speed varies with time on one burst of rowing.



Use the graph to determine a value for her initial acceleration.

....

....

Initial acceleration = …………………………

(3)

Use the graph to estimate how long it takes her to travel 500 m from her starting point.

....

....

....

Time to travel 500 m = ……………………….

(3)

Explain why Julie's speed becomes constant.

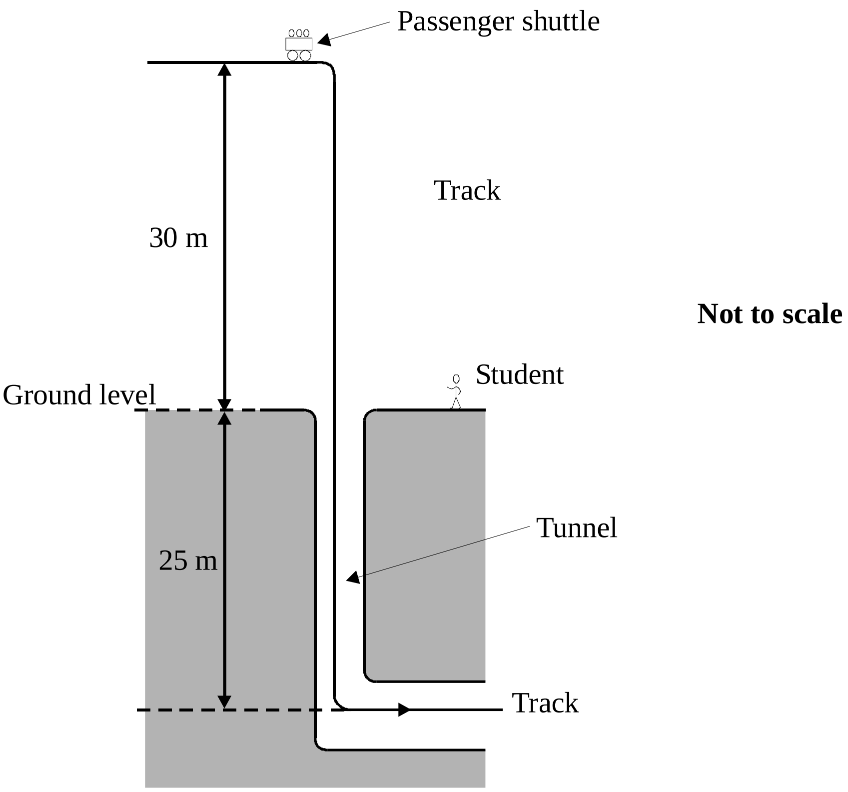
....

....

....

(2)
(Total 12 marks)

100. The diagram shows part of a theme park ride.



The ride commences with a vertical fall which starts from rest 30 m above ground level. It then continues a further 25 m down a vertical tunnel before levelling out.

Calculate the speed at the bottom of the vertical tunnel.

....

....

....

....

Speed = ………………………..

(2)

State one assumption you have made.

....

....

(1)

A student decided that this would be a good opportunity for a large-scale experiment to measure *g*, the acceleration of free-fall due to gravity.

She stood near the tunnel entrance and used a stop-watch to measure the time for the passenger shuttle to fall to ground level. The measured time was 2.1 s. Show that this gives a value for *g* of about 14 m s^{-2}.

....

....

....

(2)

Suggest why this result is very different from the accepted value. Explain your answer.

....

....

....

....

(2)

Suggest **two** ways in which the student could have improved this experiment.

1. ....

....

2. ....

....

(2)

The data sheet for the ride says "Maximum *g*-force = 4.5". This means that the maximum acceleration of the shuttle is 4.5g. Calculate the maximum resultant force on the shuttle. (Mass of shuttle = 5000kg)

....

....

....

Maximum force = ………………………..

(2)
(Total 11 marks)

101. Some people think that all raindrops fall at the same speed; others think that their speed depends on their size.

Calculate the speed of a raindrop after it has fallen freely from rest for 0.2 s.

....

....

Speed = ………………………….

(1)

The raindrop falls for longer than 0.2 s. Explain why its acceleration does not remain uniform for the whole of its fall.

....

....

....

....

(2)

Show that the mass of a 0.5 mm diameter spherical raindrop is less than 1×10^{-7} kg.

1.0 m^3 of water has a mass of 1.0×10^3 kg

....

....

....

....

....

(2)

Calculate the raindrop's terminal velocity. Assume that the upthrust from the air is negligible. Explain your working clearly.

Viscosity of air = 1.8×10^{-5} kg m^{-1} s^{-1}.

....

....

....

....

....

Terminal velocity = ...

(3)

Sketch a graph to show how the raindrop's velocity increases from rest to terminal velocity. Add a scale to the velocity axis.

(3)

Explain how the terminal velocity would be different for a larger raindrop.

....

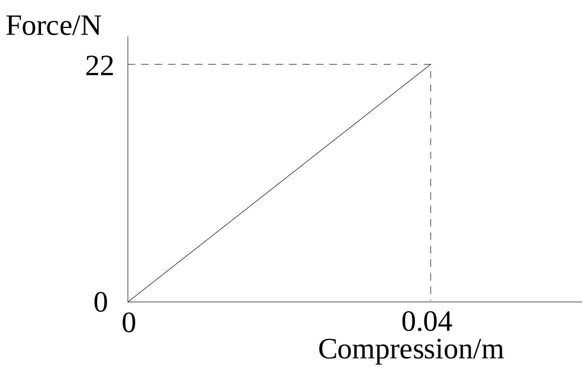
....

....

....

(1)
(Total 12 marks)

102. A toy frog has a spring which causes it to jump into the air. The force-compression graph for the spring is shown below.



Calculate the work done on the spring when it is compressed by 4.0 cm.

....

....

....

Work done =...........................

(3)

The frog has a mass of 24 g and rises 0.60 m vertically into the air. Calculate the gravitational potential energy gained by the frog.

....

....

....

Energy =......................................

(2)

Compare your two answers for energy and explain how they are consistent with the law of conservation of energy.

....

....

....

....

(2)
(Total 7 marks)

103. Explain why a body moving at constant speed in a circular path needs a resultant force acting on it.

....

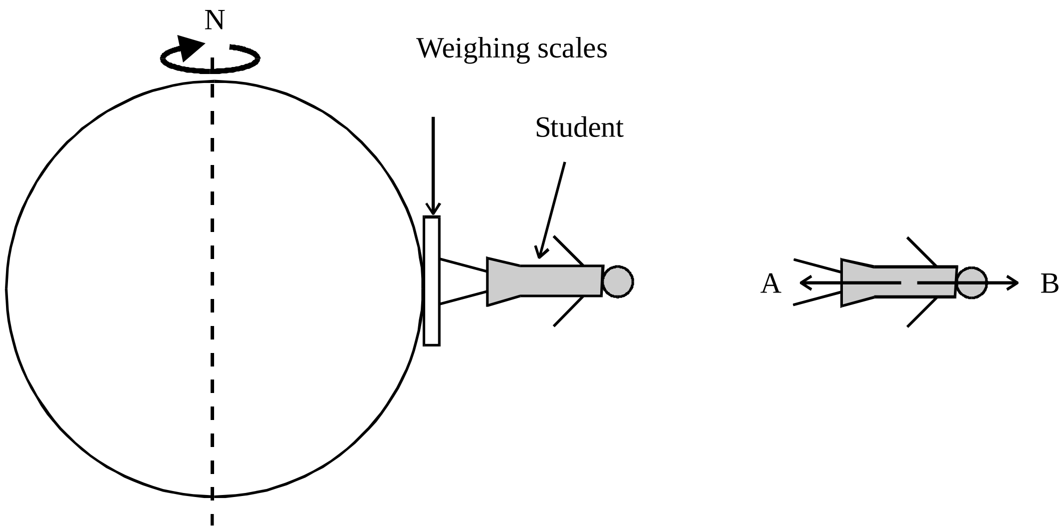
....

....

....

(2)

The diagram shows a student at the equator standing on a set of weighing scales, and a free-body force diagram for the student.



Identify the bodies applying forces A and B.

....

....

(2)

Because of the Earth's daily rotation the student is performing circular motion about the Earth's axis. Calculate the angular speed of the student.

....

....

....

Angular speed =.................................

(2)

The radius of the Earth is 6400 km. The student's mass is 55 kg. Calculate the resultant force on the student.

....

....

....

Resultant force =......................................

(3)

Force A is 539 N. Calculate the value of force B.

....

....

Force B =..................................

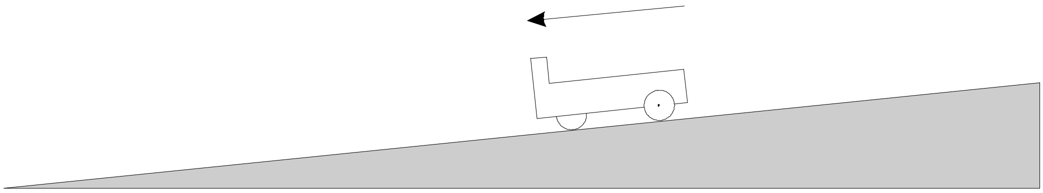
State, with a reason, the force indicated by the weighing scales.

....

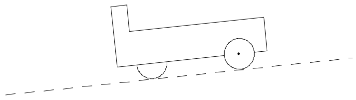
....

(3)
(Total 12 marks)

104. The diagram shows a trolley moving down a gentle slope.

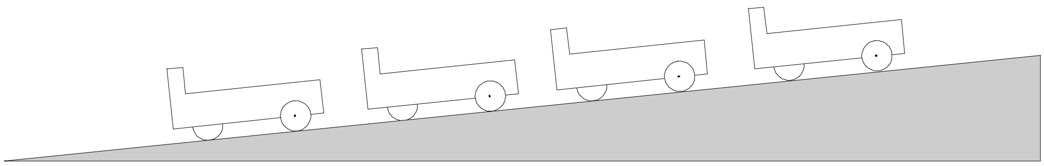


Add forces to the diagram below to produce a free-body force diagram for the trolley.



(3)

The trolley is photographed by a multiflash technique. The result is shown below.



What evidence is there that the trolley is moving with constant velocity?

....

(1)

State the acceleration of the trolley down the slope.

....

(1)

What does the value of the acceleration indicate about the forces acting on the trolley?

....

(1)
(Total 6 marks)

105. Iain decides to buy a dynamo lamp for his bicycle to save having to buy batteries but his friend Clare tells him that the dynamo will cause a large increase in the effort he has to make to pedal.

Iain decides to test this before buying the dynamo by measuring the resistive forces which act while he is cycling. He attempts to measure the force by finding the distance in which he comes to rest from a steady speed along a level stretch of road once be stops pedalling.

Iain estimates his speed by cycling at a steady rate between marked lamp posts. He cycles a distance of 130 m in a time of 18s.

Show that his speed is about 7 m s^{-1}.

....

....

(1)

He then stops pedalling and comes to rest after travelling a further 110 m.

Calculate his average deceleration.

....

....

Average deceleration = ...

(2)

Calculate the average decelerating force if the combined mass of rider and bicycle is 99kg.

....

....

....

Decelerating force = ………………………..

(2)

Discuss what forward force would be required to maintain a steady speed of 7 m s^{-1}.

....

....

....

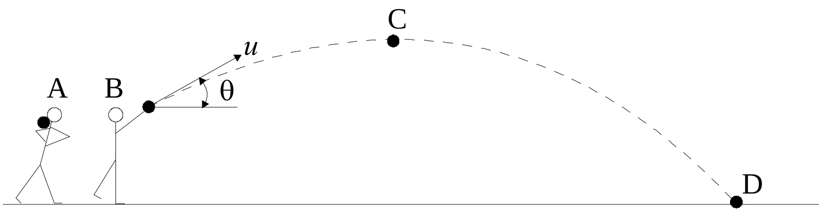
....

....

(2)

(Total 7 marks)

106. A shot putter asks an A level physics student to help improve his performance. The student sketches the diagram shown below and makes some measurements.



The shot is stationary at position A.
The shot leaves the putter's hand at point B.
θ (angle from horizontal at which shot leaves hand) = 34.5°
u (speed at which shot leaves hand) = 12.9 m s^{-1}

Show that the initial vertical component of u is about 7 m s^{-1}.

....

....

....

(1)

Calculate the time between the athlete releasing the shot at B and it reaching C, the highest point in its path.

……………………………………………………………………………………………

……………………………………………………………………………………………

Time = …………………………

(2)

The total time of flight of the shot, from it leaving B to landing at D, is 1.71 s. Comment on this time in relation to your previous answer.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

(2)

Calculate the *horizontal* distance travelled by the shot between B and D.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

Horizontal distance = …………………………

(2)

The shot has mass 5.00 kg. Show that the shot's kinetic energy as it leaves his hand at B is about 420J.

……………………………………………………………………………………………

……………………………………………………………………………………………

(1)

The acceleration of the shot from A to B takes 0.229 s. The student suggests that the average power the shotputter is developing during the putt might be calculated as follows:

Power = energy transferred/time taken
= 420 J/0.229 s
= 1830 W

Suggest *two* reasons why this figure is lower than the actual power developed.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

(2)

Suggest briefly how the student might have made the measurements of *u*.

…………………………………………………………………………………………

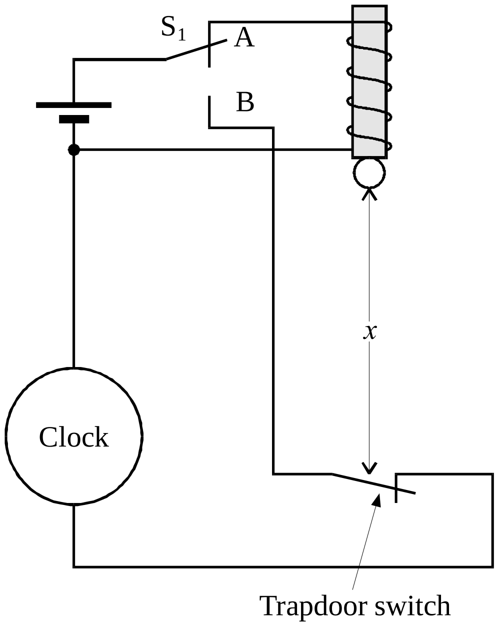
…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

(2)
(Total 12 marks)

107. The diagram shows an apparatus for timing a falling ball.



State what happens at the instant when the switch S_1 is moved from A to B.

....

....

....

....

(2)

The distance x is 1.00 m. Calculate the time for the ball to fall this distance.

....

....

....

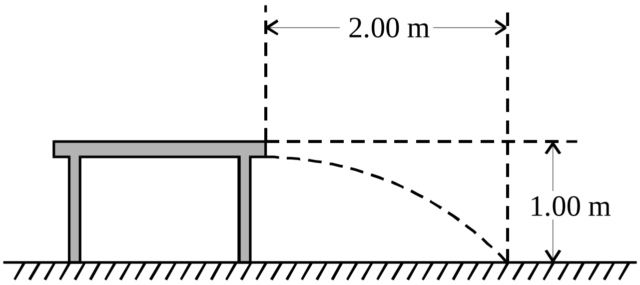
....

....

Time = ...

(3)

In a second experiment the ball is fired horizontally from the edge of a table 1.00 m high.



State with a reason the time for the ball to reach the ground.

....

....

(2)

The ball hits the floor a horizontal distance of 2.00 m from the edge of the table. Calculate the speed at which the ball was fired.

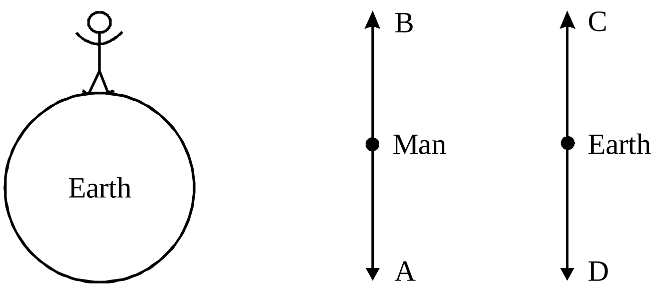
....

....

Speed = ...

(2)
(Total 9 marks)

108. The diagrams show a man standing on the Earth and two free-body force diagrams, one for the man and one for the Earth.



Force A can be described as 'the Earth pulling the man down with a gravitational force'. Use a similar form of words to describe force C which forms a Newton third law pair with force A.

....

....

....

(2)

Noting that forces A and C are a Newton third law pair, write down three similarities and two differences between these two forces.

Similarities:

(i) ....

(ii) ....

(iii) ....

Differences:

(i) ....

(ii) ....

(5)

Which two forces show whether or not the man is in equilibrium?

....

(1)
(Total 8 marks)

109. Twin engine aircraft use less fuel than those with four engines. Recent improvements in engine reliability mean that they are now considered safe for long commercial flights over water. An aircraft powered by two Rolls-Royce Trent engines demonstrated its endurance by flying nonstop round the world. During this flight it used 1.7×10^5 litres of aviation fuel.

Each litre of fuel releases 38 MJ when combined with oxygen in the air.

Calculate the total amount of energy released during the flight.

....

....

....

Energy = ………........……...............

(2)

The flight lasted 47 hours. Calculate the average input power to the engines.

....

....

Power = .………........……...............

(2)

The distance covered by the aircraft was 41000 km. Calculate the aircraft's average speed.

....

....

....

Speed = ……………..……...............

The *maximum* thrust of each engine is 700 kN. Multiply the total maximum thrust by the average speed and comment on your answer.

....

....

....

....

(6)

(Total 10 marks)

110. A careless soldier shoots a bullet vertically into the air at 450 m s^{-1}. Calculate the time the bullet takes to reach the top of its flight. State any assumption you have made.

....

....

....

....

Time ………………………………

(3)

Sketch and label fully a velocity-time graph for the bullet's complete flight.

Explain the shape of your graph.

....

....

....

Use your graph to calculate the distance travelled by the bullet before it hits the ground.

....

....

....

(7)
(Total 10 marks)

111. State the difference between scalar and vector quantities.

....

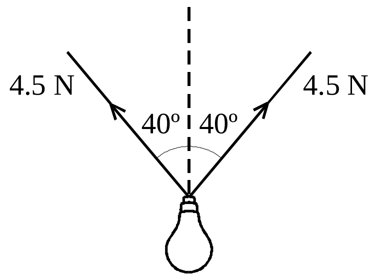
....

....

....

(2)

A lamp is suspended from two wires as shown in the diagram. The tension in each wire is 4.5N.



Calculate the magnitude of the resultant force exerted on the lamp by the wires.

....

....

....

(3)

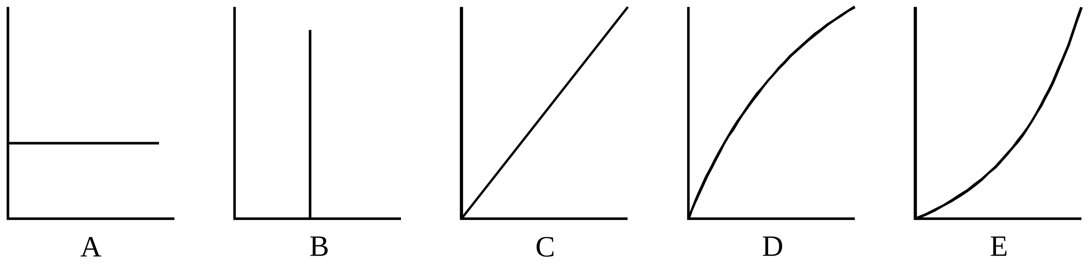
What is the weight of the lamp? Explain your answer.

....

....

(2)
(Total 7 marks)

112. Each of the following graphs can be used to describe the motion of a body falling from rest. (Air resistance may be neglected.)



Which graph shows how the kinetic energy of the body (*y*-axis) varies with the distance fallen (*x*-axis)?

Graph ....

Explain your answer.

....

....

....

(3)

Which graph shows how the distance fallen (*y*-axis) varies with the time (*x*-axis)?

Graph ....

Explain your answer.

....

....

....

(3)

Which graph shows the relationship between acceleration (*y*-axis) and distance (*x*-axis)?

Graph ....

Explain your answer.

....

....

....
(3)
(Total 9 marks)

113. An athlete of mass 55 kg runs up a flight of stairs of vertical height 3.6 m in 1.8 s. Calculate the power that this athlete develops in raising his mass.

....

....

....

....

Power = ...
(3)

One way of comparing athletes of different sizes is to compare their power-to-weight ratios. Find a unit for the power-to-weight ratio in terms of SI base units.

....

....

....

....
(2)

Calculate the athlete's power-to-weight ratio.

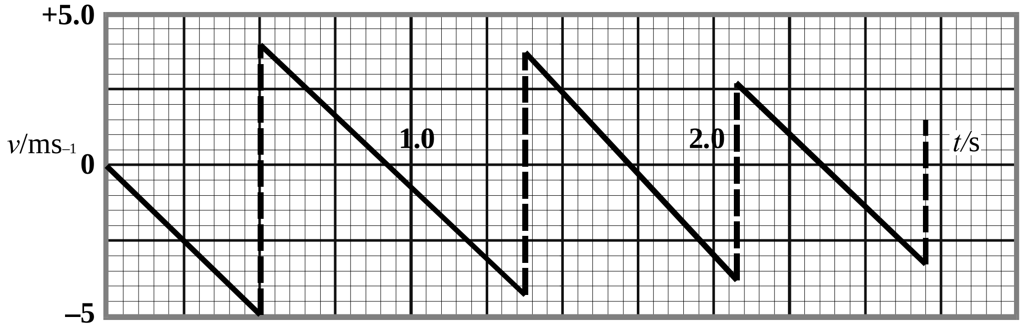
....

....

Power-to-weight ratio = ...

(2)
(Total 7 marks)

114. The diagram shows a velocity-time graph for a ball bouncing vertically on a hard surface.



At what instant does the graph show the ball to be in contact with the ground for the third time?

....

(2)

The downwards-sloping lines on the graph are straight. Why are they straight?

....

....

....

....

(2)

Calculate the height from which the ball is dropped.

....

....

....

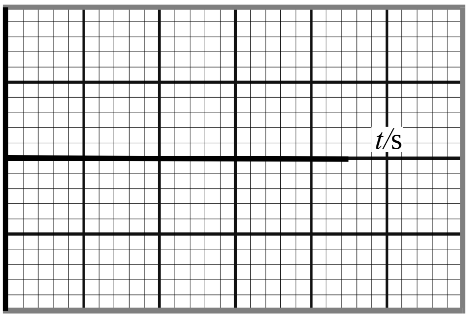
....

Height = ...

(3)

Sketch a displacement-time curve on the axes below for the first second of the motion.

Displacement/m



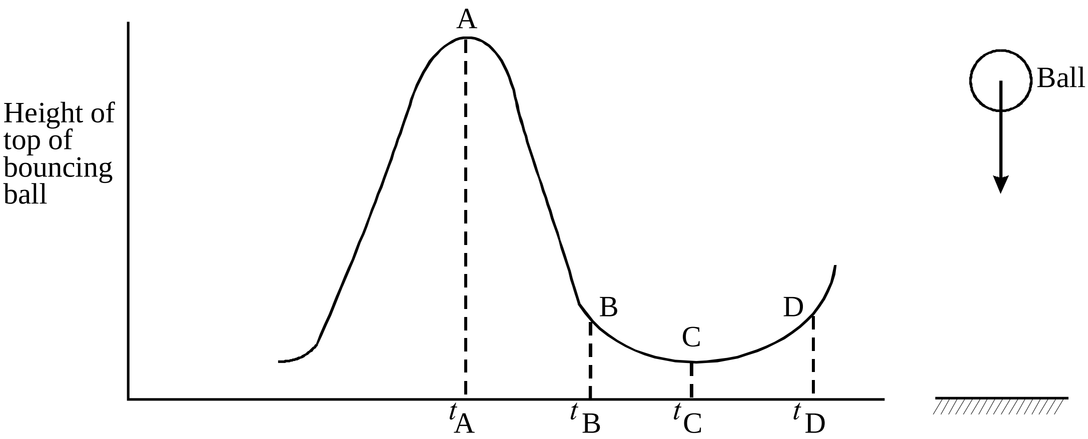
(3)

What is the displacement of the ball when it finally comes to rest?

....

(1)
(Total 11 marks)

115. The graph shows how the height above the ground of the top of a soft bouncing ball varies with time.



Describe briefly the principal energy changes which occur between the times

t_A and t_B ....

....

....
(2)

t_A and t_C ....

....

....
(3)

t_C and t_D ....

....

....
(1)
(Total 6 marks)