1. This question is about the kinematics of an elevator (lift).

(a) Explain the difference between the gravitational mass and the inertial mass of an object.

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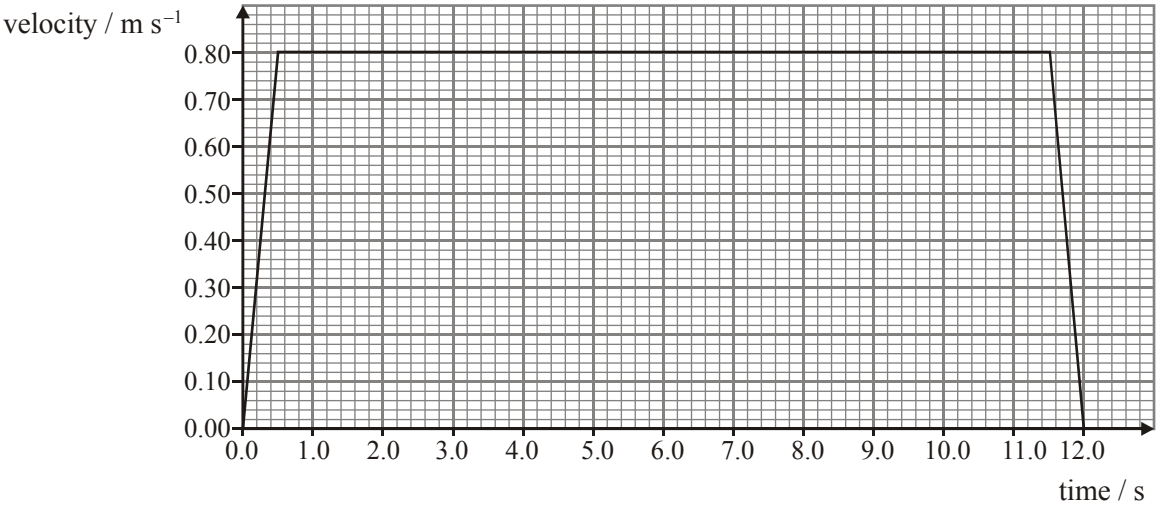
(3)

An elevator (lift) starts from rest on the ground floor and comes to rest at a higher floor. Its motion is controlled by an electric motor. A simplified graph of the variation of the elevator's velocity with time is shown below.



(b) The mass of the elevator is 250 kg. Use this information to calculate

(i) the acceleration of the elevator during the first 0.50 s.

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(2)

(ii) the total distance travelled by the elevator.

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(2)

(iii) the minimum work required to raise the elevator to the higher floor.

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(2)

(iv) the minimum average power required to raise the elevator to the higher floor.

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(2)

(v) the efficiency of the electric motor that lifts the elevator, given that the input power to the motor is 5.0 kW.

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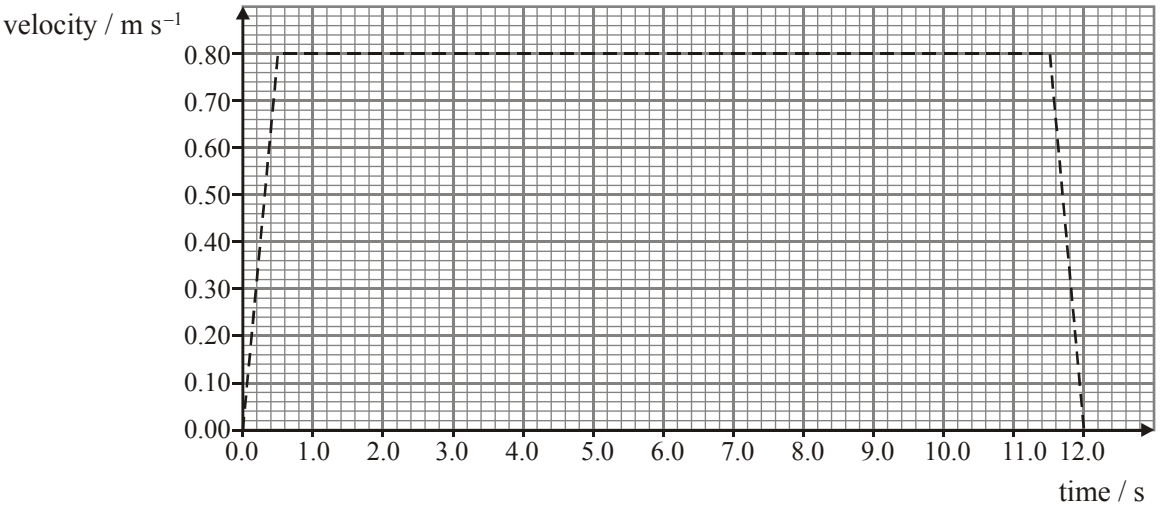
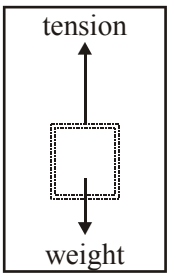
(2)

(c) On the graph axes below, sketch a realistic variation of velocity for the elevator. Explain your reasoning. *(The simplified version is shown as a dotted line)*



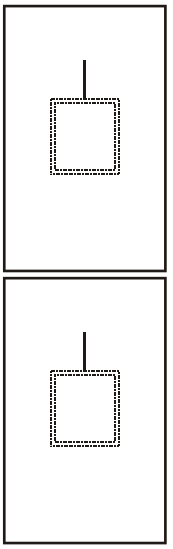
(2)

The elevator is supported by a cable. The diagram below is a free-body force diagram for when the elevator is moving upwards during the first 0.50 s.



(d) In the space below, draw free-body force diagrams for the elevator during the following time intervals.

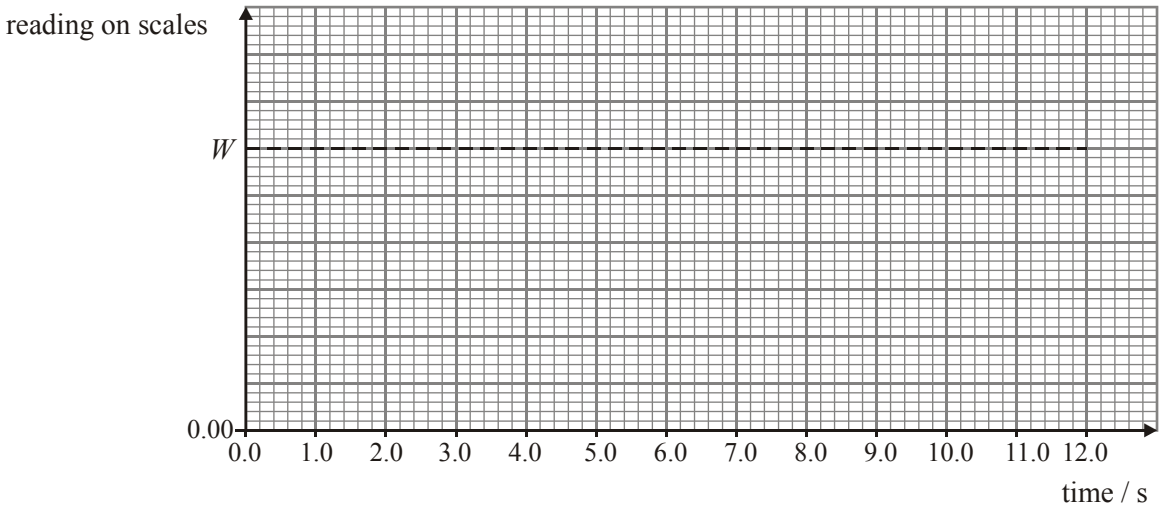
(i) 0.5 to 11.50 s (ii) 11.50 to 12.00 s



(3)

A person is standing on weighing scales in the elevator. Before the elevator rises, the reading on the scales is *W*.

(e) On the axes below, sketch a graph to show how the reading on the scales varies during the whole 12.00 s upward journey of the elevator. *(Note that this is a sketch graph – you do not need to add any values.)*


reading on scales
W
0.00
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
time / s

(3)

(f) The elevator now returns to the ground floor where it comes to rest. Describe and explain the energy changes that take place during the whole up and down journey.

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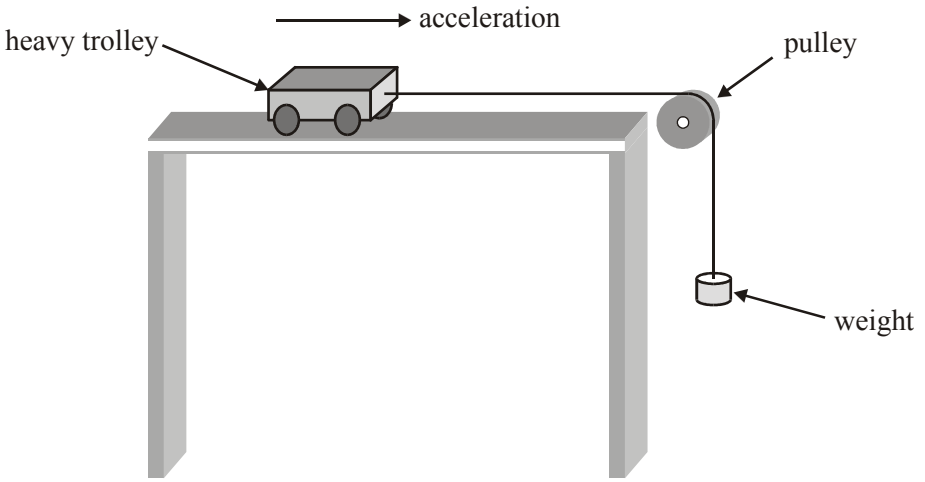
(4)

(Total 25 marks)

2. This question is about an experiment designed to investigate Newton's second law.

In order to investigate Newton's second law, David arranged for a heavy trolley to be accelerated by small weights, as shown below. The acceleration of the trolley was recorded electronically. David recorded the acceleration for different weights up to a maximum of 3.0 N. He plotted a graph of his results.



(a) Describe the graph that would be expected if two quantities are proportional to one another.

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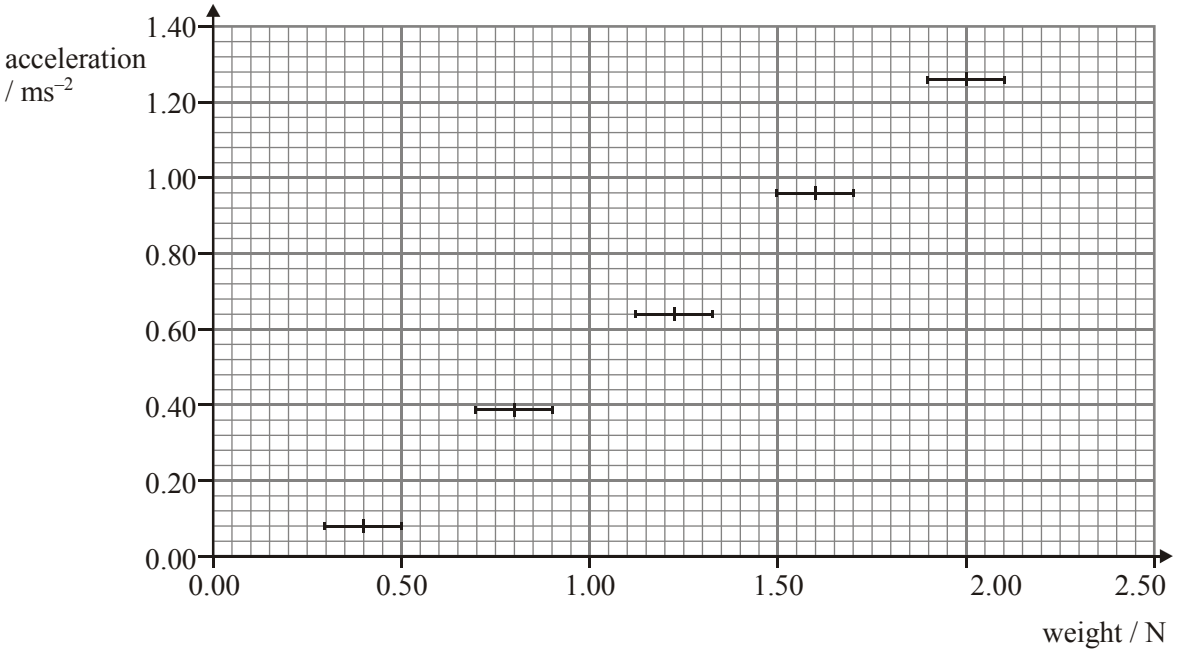
(2)

(b) David's data are shown below, with uncertainty limits included for the value of the weights. Draw the best-fit line for these data.



(2)

(c) Use the graph to

(i) explain what is meant by a *systematic* error.

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(2)

(ii) estimate the value of the frictional force that is acting on the trolley.

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(1)

(iii) estimate the mass of the trolley.

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(2)
(Total 9 marks)

3. This question is about momentum and the kinematics of a proposed journey to Jupiter.

(a) State the law of conservation of momentum.

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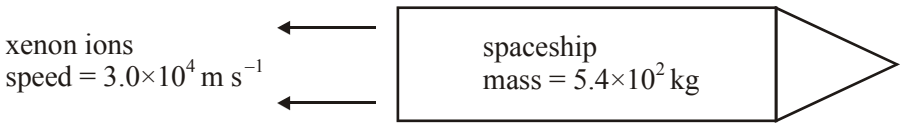
(2)

A solar propulsion engine uses solar power to ionise atoms of xenon and to accelerate them. As a result of the acceleration process, the ions are ejected from the spaceship with a speed of 3.0×10^4 ms^{-1}.



(b) The mass (nucleon) number of the xenon used is 131. Deduce that the mass of one ion of xenon is 2.2×10^{-25} kg.

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(2)

(c) The original mass of the fuel is 81 kg. Deduce that, if the engine ejects 77×10^{18} xenon ions every second, the fuel will last for 1.5 years. (1 year = 3.2×10^{7} s)

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(2)

(d) The mass of the spaceship is 5.4×10^{2} kg. Deduce that the initial acceleration of the spaceship is 8.2×10^{-5} m s^{-2}.

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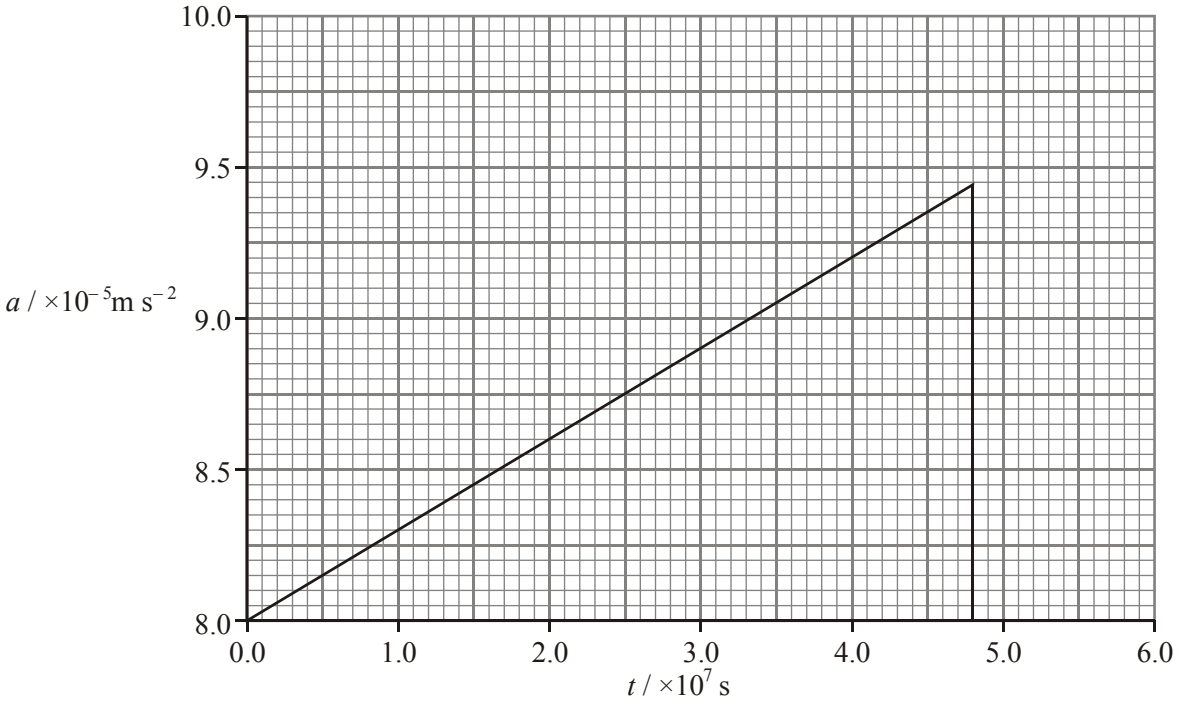
(5)

The graph below shows the variation with time t of the acceleration a of the spaceship. The solar propulsion engine is switched on at time $t = 0$ when the speed of the spaceship is 1.2 × 103 m s^{-1}.



(e) Explain why the acceleration of the spaceship is increasing with time.

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(2)

(f) Using data from the graph, calculate the speed of the spaceship at the time when the xenon fuel has all been used.

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(4)

(g) The distance of the spaceship from Earth when the solar propulsion engine is switched on is very small compared to the distance from Earth to Jupiter. The fuel runs out when the spaceship is a distance of 4.7×10^{-11} m from Jupiter. Estimate the total time that it would take the spaceship to travel from Earth to Jupiter.

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(2)
(Total 19 marks)

4. This question is about conservation of momentum and conservation of energy.

(a) State Newton's third law.

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(1)

(b) State the law of conservation of momentum.

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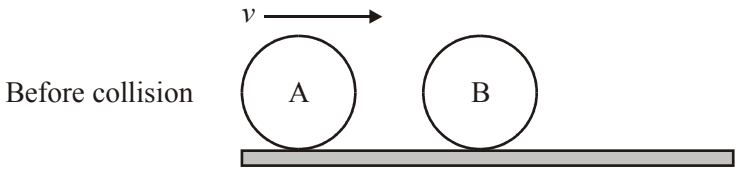
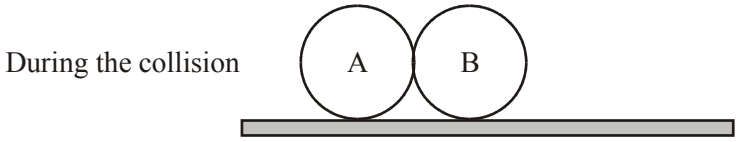
(2)

The diagram below shows two identical balls A and B on a horizontal surface. Ball B is at rest and ball A is moving with speed V along a line joining the centres of the balls. The mass of each ball is M.



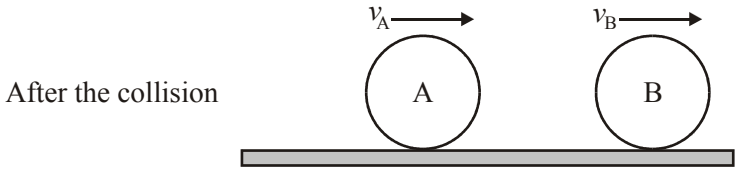
During the collision of the balls, the magnitude of the force that ball A exerts on ball B is F_{AB} and the magnitude of the force that ball B exerts on ball A is F_{BA}.

(c) On the diagram below, add labelled arrows to represent the magnitude and direction of the forces F_{AB} and F_{BA}.



(3)

The balls are in contact for a time Δt. After the collision, the speed of ball A is $+v_A$ and the speed of ball B is $+v_B$ in the directions shown.



As a result of the collision, there is a change in momentum of ball A and of ball B.

(d) Use Newton's second law of motion to deduce an expression relating the forces acting during the collision to the change in momentum of

(i) ball B.

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(2)

(ii) ball A.

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(2)

(e) Apply Newton's third law and your answers to (d), to deduce that the change in momentum of the system (ball A and ball B) as a result of this collision, is zero.

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(4)

(f) Deduce, that if kinetic energy is conserved in the collision, then after the collision, ball A will come to rest and ball B will move with speed V.

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(3)
(Total 17 marks)

5. This question is about the collision between two railway trucks (carts).

(a) Define *linear momentum*.

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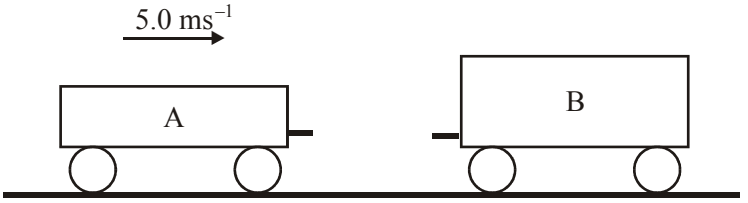
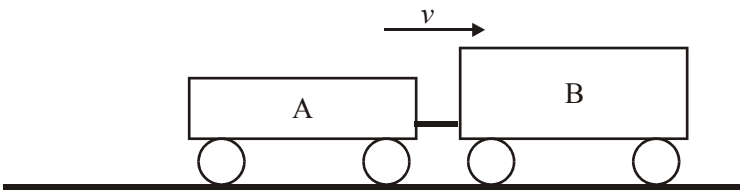
(1)

In the diagram below, railway truck A is moving along a horizontal track. It collides with a stationary truck B and on collision, the two join together. Immediately before the collision, truck A is moving with speed 5.0ms^{-1}. Immediately after collision, the speed of the trucks is *v*.



Immediately before collision



Immediately after collision

The mass of truck A is 800 kg and the mass of truck B is 1200 kg.

(b) (i) Calculate the speed v immediately after the collision.

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(3)

(ii) Calculate the total kinetic energy lost during the collision.

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(2)

(c) Suggest what has happened to the lost kinetic energy.

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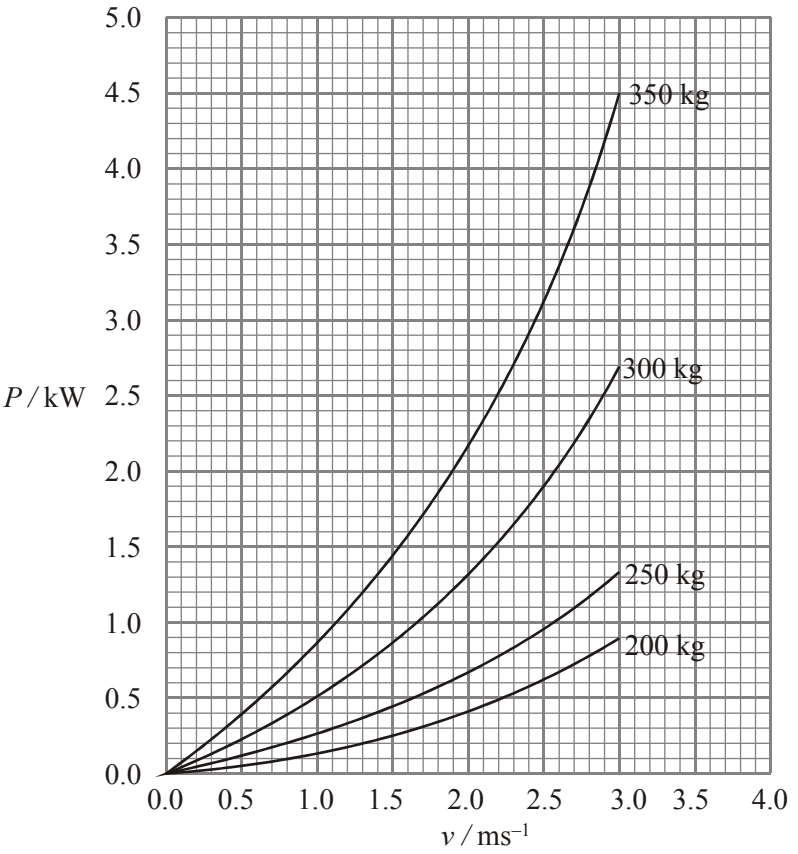
(2)

(Total 8 marks)

6. This question is about power output of an outboard motor.

A small boat is powered by an outboard motor of variable power P. The graph below shows the variation with speed v of P when the boat is carrying different loads.



The masses shown are the total mass of the boat plus passengers,

(a) For the boat having a steady speed of 2.0 m s^{-1} and with a total mass of 350 kg

(i) use the graph to determine the power of the engine.

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(1)

(ii) calculate the frictional (resistive) force acting on the boat.

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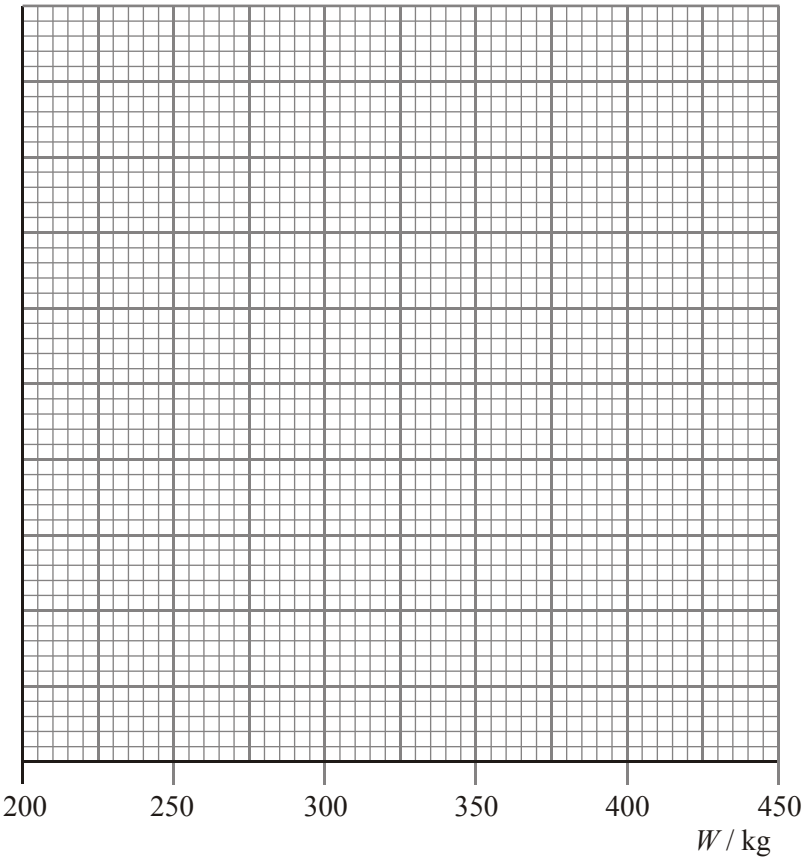
(2)

Consider the case of the boat moving with a speed of 2.5 m s^{-1}.

(b) (i) Use the axes below to construct a graph to show the variation of power P with the total mass W.



(6)

(ii) Use data from the graph that you have drawn to determine the output power of the motor for a total mass of 330 kg.

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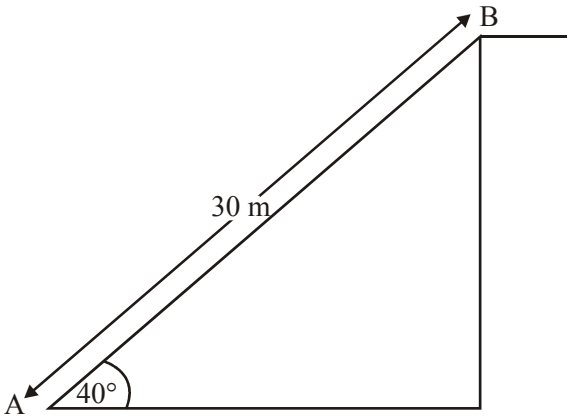
(1)

(Total 10 marks)

7. This question is about estimating the energy changes for an escalator (moving staircase).

The diagram below represents an escalator. People step on to it at point A and step off at point B.



(a) The escalator is 30 m long and makes an angle of 40° with the horizontal. At full capacity, 48 people step on at point A and step off at point B every minute.

(i) Calculate the potential energy gained by a person of weight 700 N in moving from A to B.

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(2)

(ii) Estimate the energy supplied by the escalator motor to the people every minute when the escalator is working at full capacity.

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(1)

(iii) State **one** assumption that you have made to obtain your answer to (ii).

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(1)

The escalator is driven by an electric motor that has an efficiency of 70 %.

(b) (i) Using your answer to (a)(ii), calculate the minimum input power required by the motor to drive the escalator.

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(3)

(ii) Explain why it is not necessary to take into account the weight of the escalator when calculating the input power.

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(1)

(c) Explain why in practice, the power of the motor will need to be greater than that calculated in (b)(i).

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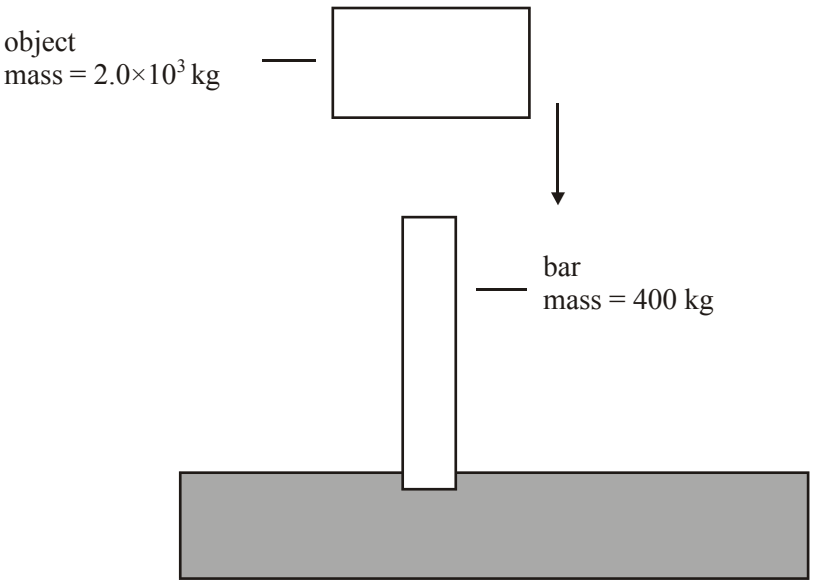
(1)

(Total 9 marks)

8. This question is about driving a metal bar into the ground.

Large metal bars can be driven into the ground using a heavy falling object.



In the situation shown, the object has a mass 2.0×10^3 kg and the metal bar has a mass of 400 kg.

The object strikes the bar at a speed of 6.0 m s^{-1}. It comes to rest on the bar without bouncing. As a result of the collision, the bar is driven into the ground to a depth of 0.75 m.

(a) Determine the speed of the bar immediately after the object strikes it.

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(4)

(b) Determine the average frictional force exerted by the ground on the bar.

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(3)
(Total 7 marks)