1 (a) State, in words, the relationship between the force acting on a body and the momentum of the body.

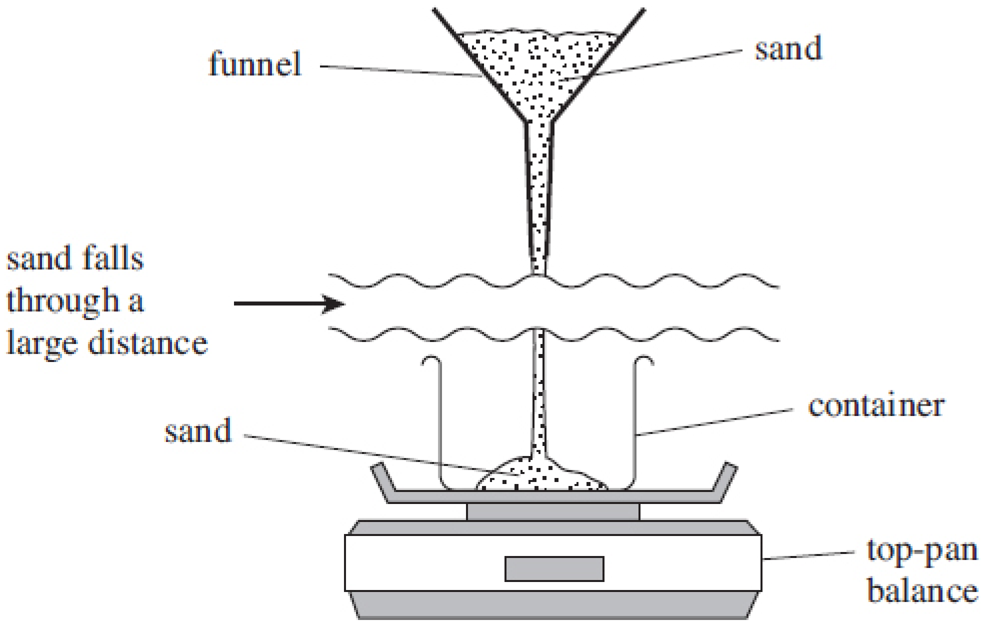
____

____

____

(1)

(b) A container rests on a top-pan balance, which measures mass in kg. A funnel above the container holds some sand. The sand falls at a constant rate of 0.300 kg s^{-1} into the container, having fallen through an average vertical height of 1.60 m.
This arrangement is shown in the figure below.



(b) (i) Show that the velocity of the sand as it lands in the container is 5.6 ms^{-1}.

(1)

(ii) Calculate the magnitude of the momentum of the sand that lands in the container in each second.

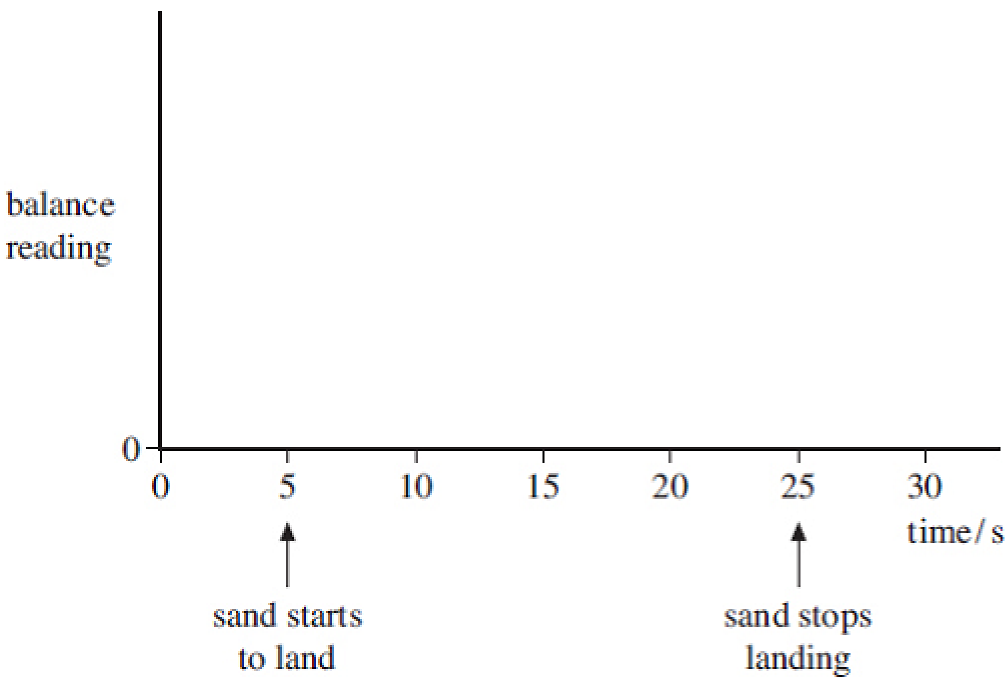
answer = ____________________ Ns

(1)

(iii) The mass of the container is 0.650 kg. Show that the reading of the balance, 10.0 s after the sand starts landing continuously in the container, will be 3.82 kg. You may assume that the sand comes to rest without rebounding when it lands in the container.

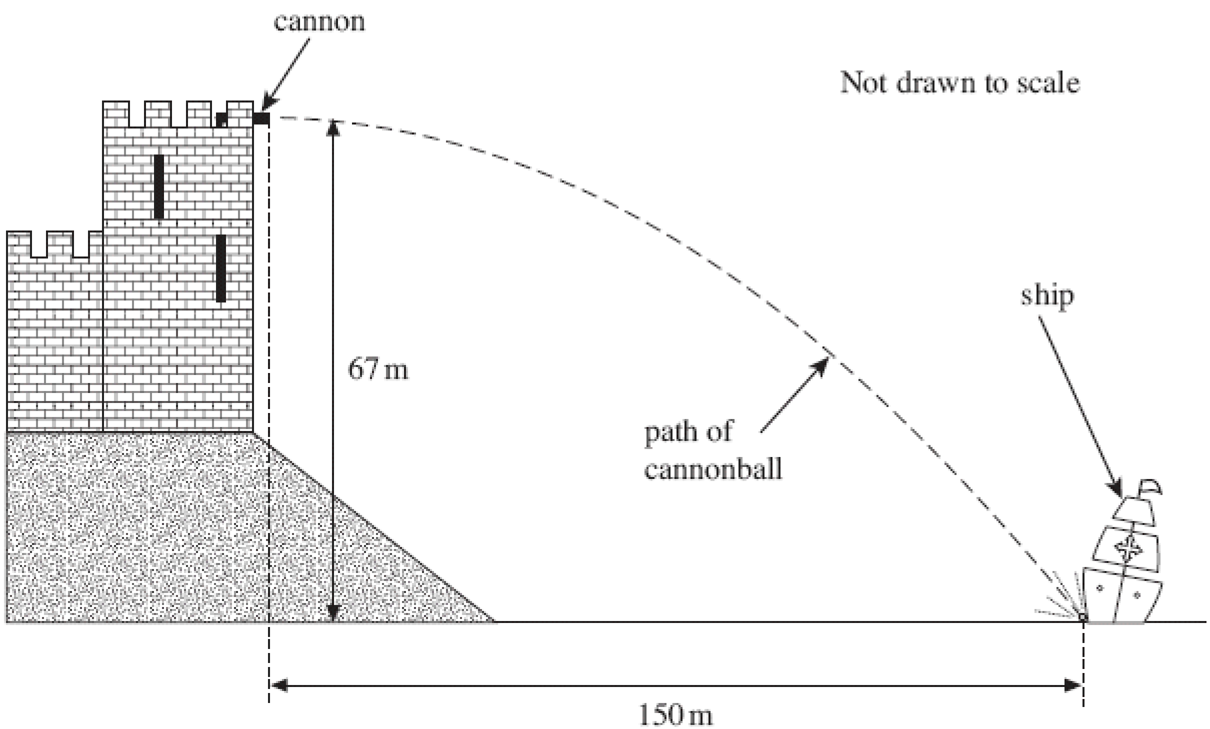
(3)

(c) It takes 20.0 s for all of the sand to fall into the container.
On the axes below, sketch a graph to show how the reading of the balance will change over a 30.0 s period, where t = 5.0 s is the time at which the sand starts to land in the container. No further calculations are required and values need not be shown on the vertical axis of the graph.



(3)
(Total 9 marks)

2 In a castle, overlooking a river, a cannon was once employed to fire at enemy ships.
One ship was hit by a cannonball at a horizontal distance of 150 m from the cannon as shown in the figure below. The height of the cannon above the river was 67 m and the cannonball was fired horizontally.



(a) (i) Show that the time taken for the cannonball to reach the water surface after being fired from the cannon was 3.7 s. Assume the air resistance was negligible.

(2)

(ii) Calculate the velocity at which the cannonball was fired. Give your answer to an appropriate number of significant figures.

answer = ______________________ m s^{-1}

(2)

(iii) Calculate the vertical component of velocity just before the cannonball hit the ship.

answer = ______________________ $m\ s^{-1}$

(2)

(iv) By calculation or scale drawing, find the magnitude and direction of the velocity of the cannonball just before it hit the ship.

velocity = ______________________ $m\ s^{-1}$

direction = ______________________

(4)

(b) (i) Calculate the loss in gravitational potential energy of the cannonball.
mass of the cannonball = 22 kg

answer = ______________________ J

(1)

(ii) Describe the energy changes that take place from the moment the cannonball leaves the cannon until just before it hits the water. Include the effects of air resistance.

____

____

____

____

(2)

(Total 13 marks)

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

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

___

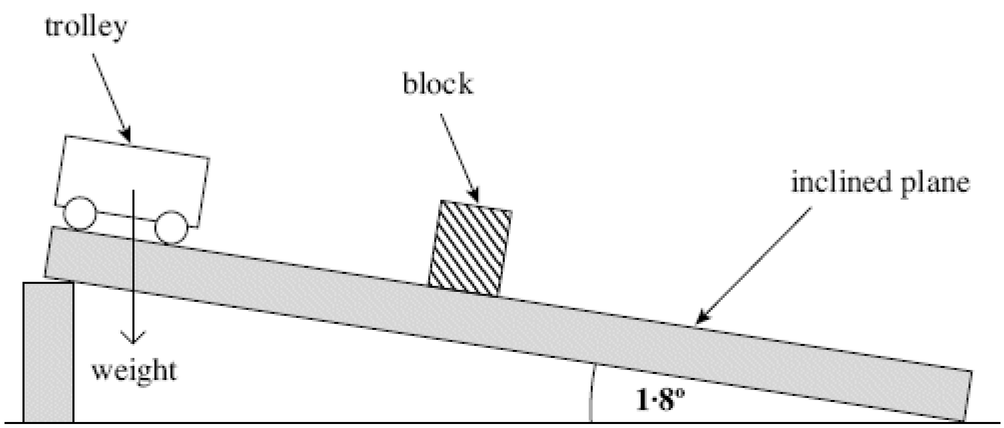
___

___

___

(2)

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



The mass of the trolley in the figure above is 0.20 kg and the slope is at an angle of 1·8° to the horizontal.

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

(2)

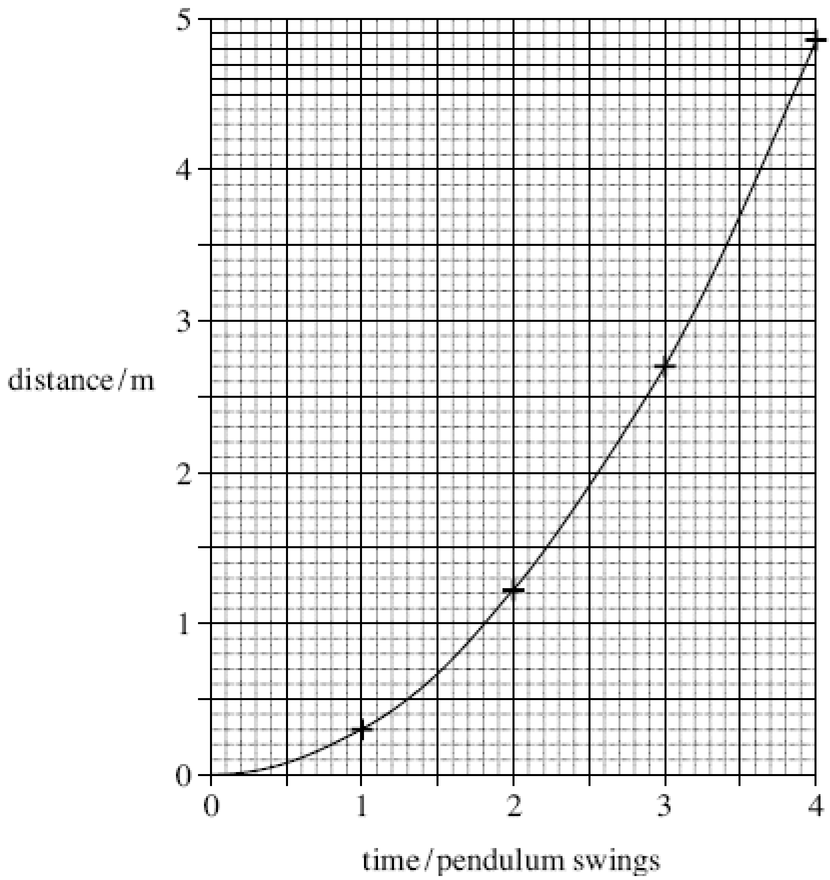
(ii) Calculate the initial acceleration down the slope.

answer = ______________________ m s^{-2}

(2)

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

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



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

____

____

____

____

(2)

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

answer = ______________________ m s^{-1}

(3)

(Total 11 marks)

4 A girl sits at rest on a garden swing. The swing consists of a wooden seat of mass 1.2 kg supported by two ropes. The mass of the girl is 16.8 kg. The mass of the ropes should be ignored throughout this question.

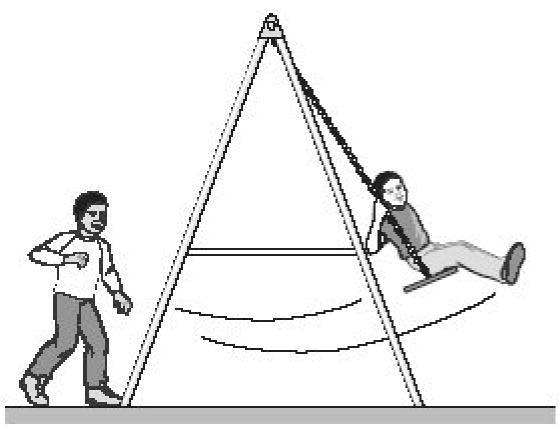


Figure 1

(a) A boy grips the seat and gives a firm push with both hands so that the girl swings upwards as shown in **Figure 1**. The swing just reaches a vertical height of 0.50 m above its rest position.

(i) Show that the maximum gain in gravitational potential energy of the girl and the swing is about 88 J.

acceleration due to gravity = 9.8 m s^{-2}

(3)

(ii) The work done against resistive forces as the swing moves upwards is 20 J. Calculate the work done on the swing by the boy during the push.

(1)

(iii) As he pushed, the boy‘s hands were in contact with the seat of the swing for a distance of 0.40 m. Calculate the average force applied to the swing.

(2)

(b) Calculate the speed of the girl as she passes back through the lowest point of her ride for the first time. Assume that the work done against resistive forces is the same in both directions.

(4)

(c) The girl is not pushed again. On the axes in **Figure 2**, sketch a graph to show how the kinetic energy of the girl varies with time over two complete cycles of the motion. Start your graph from the time when she is 0.50 m above the rest position. You are not required to mark a scale on either axis.

Figure 2

(3)

(Total 13 marks)

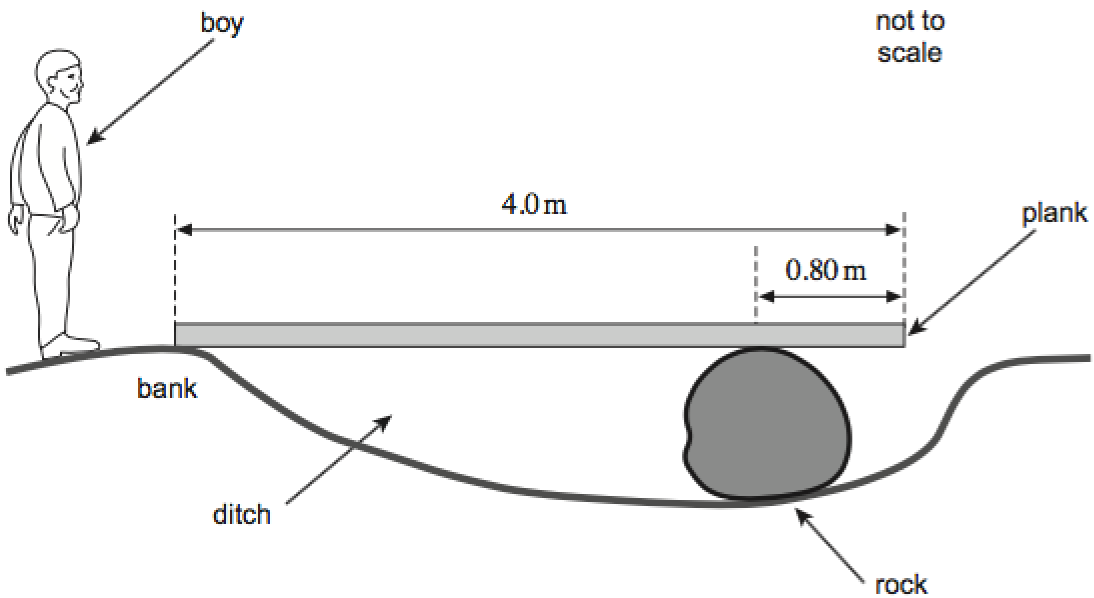
5 (a) State what is meant by the centre of mass of an object.

____

____

(1)

(b) A uniform plank of wood of mass 32 kg and length 4.0 m is used by a boy to help him cross a ditch. In the ditch is a rock, which is used to support the plank horizontally 0.80 m from one end, as shown in the diagram. The other end of the plank is supported by the bank.



Calculate the vertical supporting force from the rock when the plank is placed in position as shown in the diagram.

supporting force = ____________________ N

(2)

(c) The boy has a mass of 46 kg.

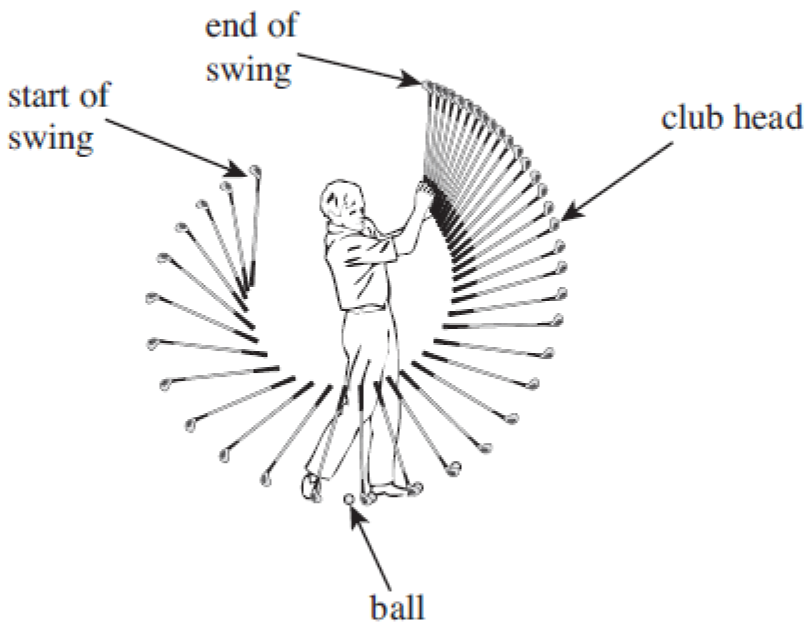
Determine whether the boy can walk to the far end of the plank without it tipping.
Support your answer with a calculation.

(3)

(Total 6 marks)

6 When hitting golf balls long distances, golfers *follow through* with the swing. Doing this increases the time for which the club head is in contact with the ball.

The figure below is a stroboscopic photograph of a golf swing. The images were taken at equal time intervals.



(a) Sketch, on the axes below, how the speed of the club head varies with time over the whole swing.

(2)

(b) Explain in terms of the impulse acting on the ball the advantage to the golfer of following through with the swing.

____

____

____

____

(2)

(c) The club head is in contact with the ball for a time of 180 μs. The mass of the club head is 0.17 kg and that of the ball is 0.045 kg. At the moment of contact the ball is at rest and the club head is moving with a speed of 35 ms^{-1}. The ball moves off with an initial speed of 58 ms^{-1}.

(i) Calculate the average force acting on the ball while the club head is in contact with it.

average force on ball ____________________ N

(2)

(ii) Deduce the average force acting on the club head due to its collision with the ball.

average force on club head ____________________ N

(1)

(iii) Explain why it is not possible to transfer all the kinetic energy of the club head to the ball.

____

____

____

____

____

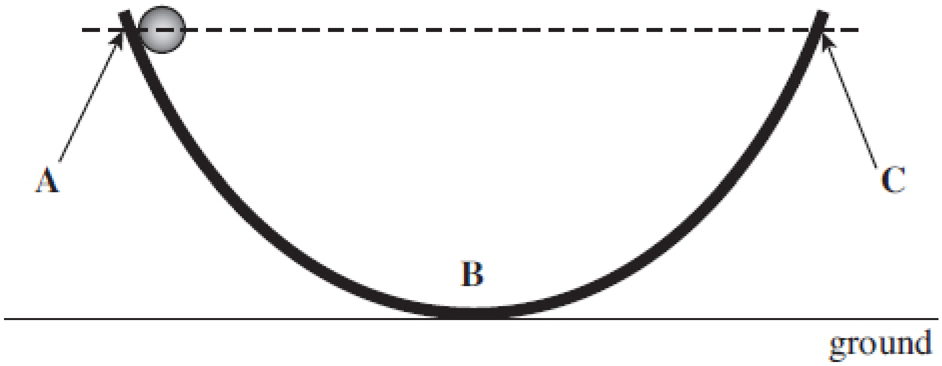
____

(2)

(Total 9 marks)

7 In the 17th century, when thinking about forces, Galileo imagined a ball moving in the absence of air resistance on a frictionless track as shown in **Figure 1**.

Figure 1



(a) Galileo thought that, under these circumstances, the ball would reach position **C** if released from rest at position **A**. Position **C** is the same height above the ground as **A**.

Using ideas about energy, explain why Galileo was correct.

____

____

____

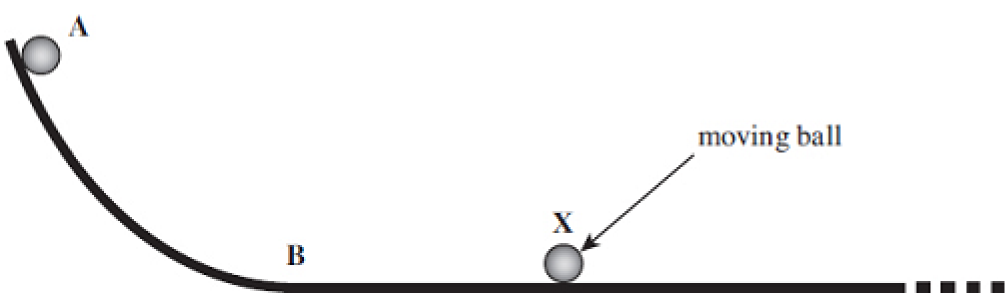
____

____

(3)

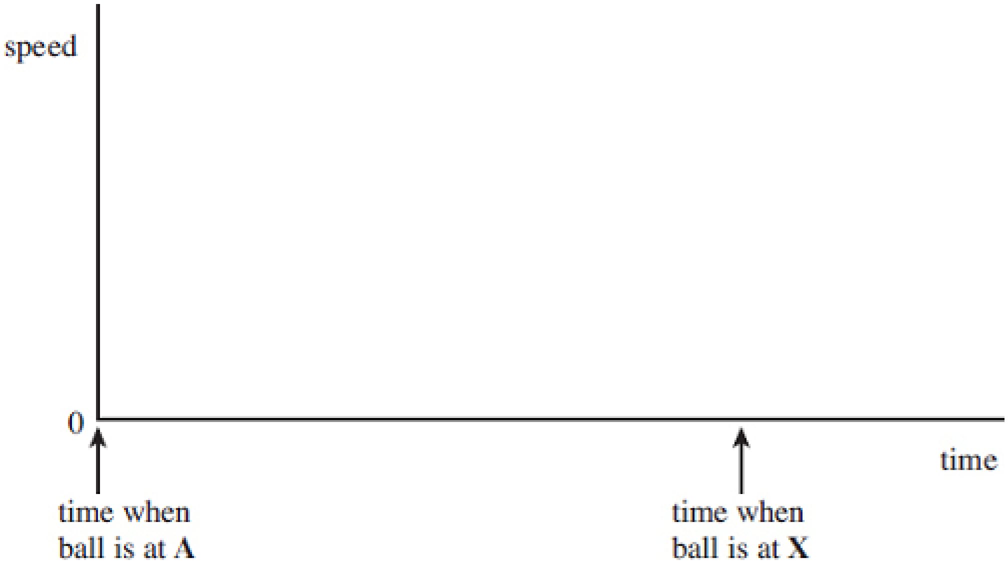
(b) Galileo then imagined that the track was changed, as shown in **Figure 2**.

Figure 2



The slope beyond **B** was now horizontal.

On the axes below, sketch a speed – time graph for the ball from its release at **A** until it reaches the position **X** shown in **Figure 2**. Indicate on your graph the time when the ball is at **B**.



(3)

(c) Newton later published his three laws of motion.

Explain how Newton's first law of motion is illustrated by the motion of the ball between **B** and **X**.

____

____

____

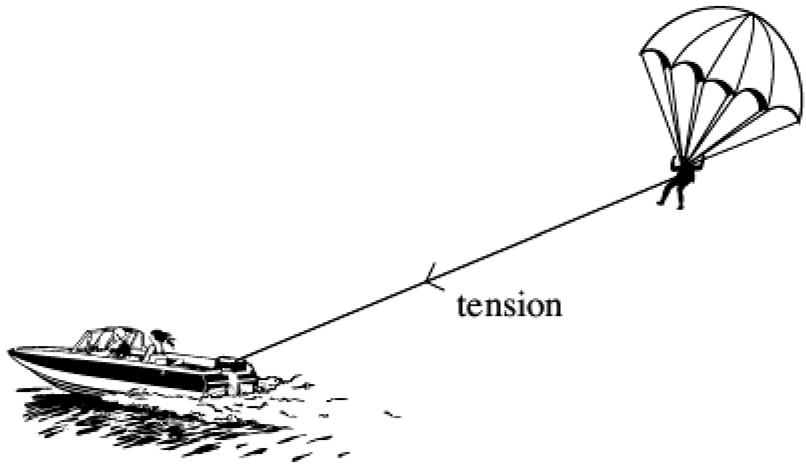
____

(2)

(Total 8 marks)

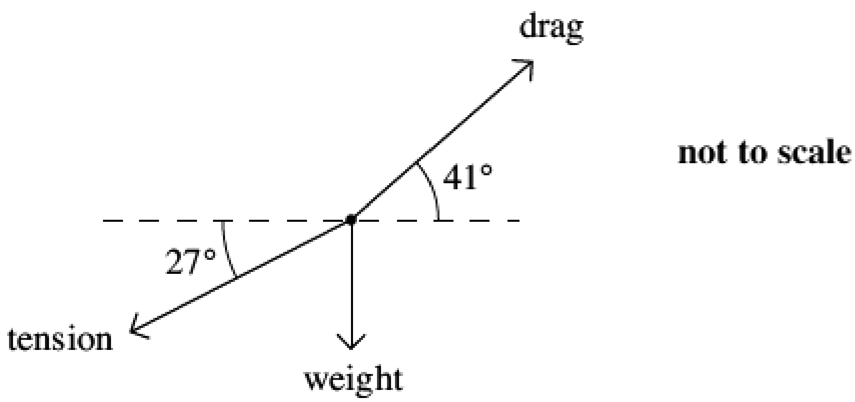
8 **Figure 1** shows a parascender being towed at a constant velocity.

Figure 1



The forces acting on the parascender are shown in the free-body diagram in **Figure 2**.

Figure 2



The rope towing the parascender makes an angle of 27° with the horizontal and has a tension of 2.2 kN. The drag force of 2.6 kN acts at an angle of 41° to the horizontal. Calculate the weight of the parascender.

weight ______________________ N

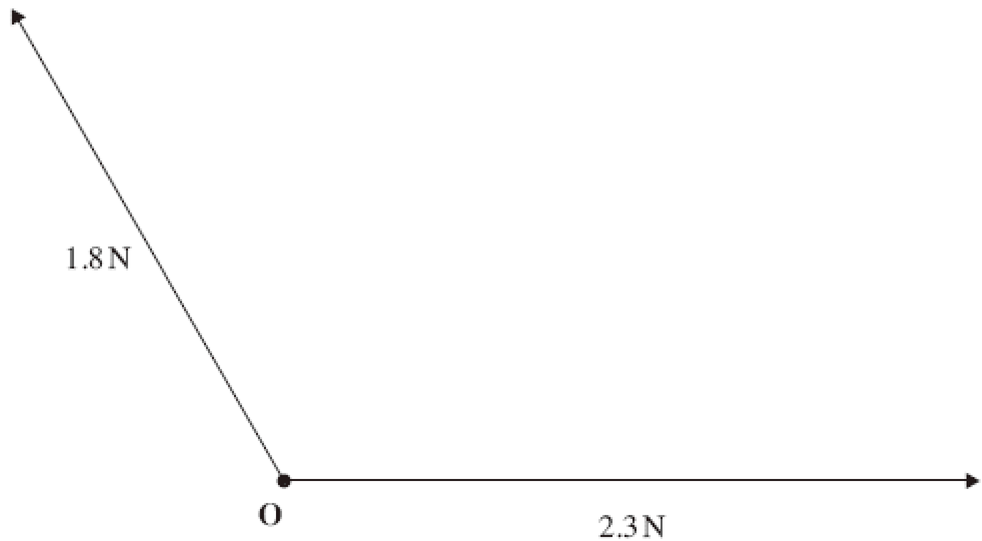
(Total 3 marks)

9 (a) What is meant by a scalar quantity?

____

(1)

(b) The figure below shows two forces acting on an object at **O**. The forces have been drawn to scale.



(i) State the scale used in the figure above

____

(1)

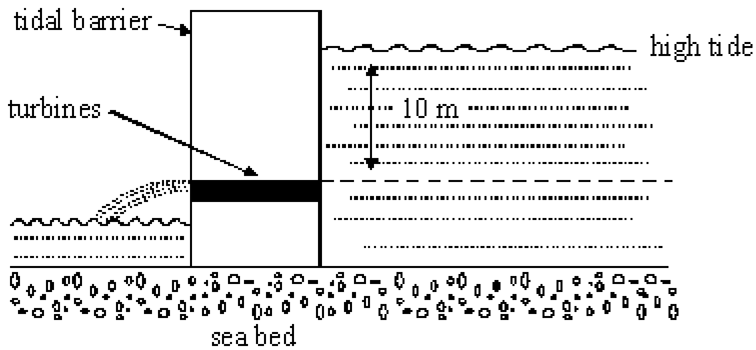
(ii) Complete the scale drawing, the figure above, to determine the magnitude of the resultant force.

magnitude of resultant force ______________________ N

(3)

(Total 5 marks)

10 Tidal power could make a significant contribution to UK energy requirements. This question is about a tidal power station which traps sea water behind a tidal barrier at high tide and then releases the water through turbines 10.0 m below the high tide mark.



(i) Calculate the mass of sea water covering an area of 120 km^2 and depth 10.0 m.

density of sea water = 1100 kg m^{-3}

____

____

____

(ii) Calculate the maximum loss of potential energy of the sea water in part (i) when it is released through the turbines.

____

____

____

____

(iii) The potential energy of the sea water released through the turbines, calculated in part (ii), is lost over a period of 6.0 hours. Estimate the average power output of the power station over this time period. Assume the power station efficiency is 40%.

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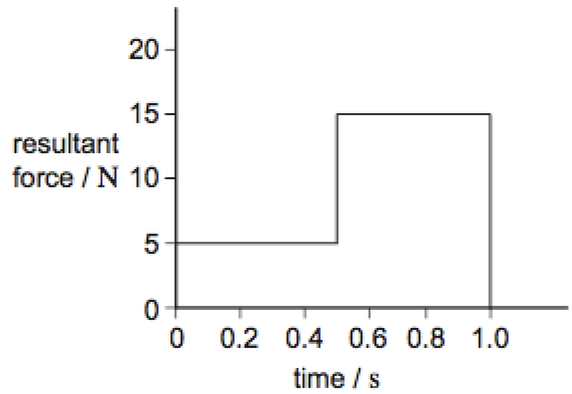
(Total 7 marks)

11 The graph shows how the resultant force applied to an object of mass 2.0 kg, initially at rest, varies with time.



What is the speed of the object after 1.0 s?

A 2.5 m s^{-1}
B 5.0 m s^{-1}
C 7.5 m s^{-1}
D 10 m s^{-1}

(Total 1 mark)

12 Which line, **A** to **D**, in the table correctly shows what is conserved in an elastic collision?

	Mass	Momentum	Kinetic energy	Total energy
A	conserved	not conserved	conserved	conserved
B	not conserved	conserved	conserved	not conserved
C	conserved	conserved	not conserved	conserved
D	conserved	conserved	conserved	conserved

(Total 1 mark)

13 In a test a 500 kg car travelling at 10 m s^{-1} hits a wall. The front 0.30 m of the car crumples as the car is brought to rest.

What is the average force on the car during the impact?

A 830 N ☐
B 7500 N ☐
C 8300 N ☐
D 83 000 N ☐

(Total 1 mark)

14 A roller coaster car is raised to a height of 65 m and released from rest.

What is the maximum possible speed of the car?

A 11 m s^{-1} ⬭

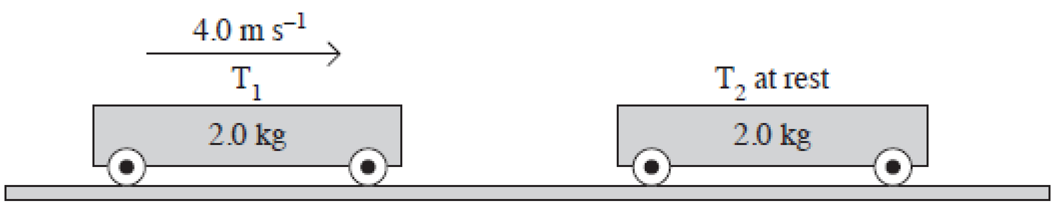
B 25 m s^{-1} ⬭

C 36 m s^{-1} ⬭

D 130 m s^{-1} ⬭

(Total 1 mark)

15 Trolley T_1, of mass 2.0 kg, collides on a horizontal surface with trolley T_2, which is also of mass 2.0 kg. The collision is elastic. Before the collision T_1 was moving at 4.0 m s^{-1} and T_2 was at rest.



Which one of the following statements is correct?

Immediately after the collision

A T_1 is at rest and T_2 moves at 4.0 m s^{-1}.

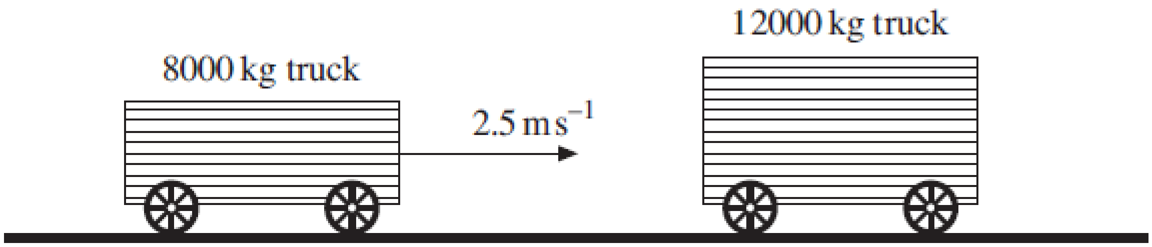
B T_1 will rebound from T_2 at 4.0 m s^{-1}.

C T_1 and T_2 will both move at 2.8 m s^{-1}.

D T_1 and T_2 will both move at 1.4 m s^{-1}.

(Total 1 mark)

16 A railway truck of mass 8000 kg travels along a level track at a velocity of 2.5 ms^{-1} and collides with a stationary truck of mass 12000 kg. The two trucks move together at the same velocity after the collision.



What is the change in momentum of the 8000 kg truck due to the impact?

A 8000 N s

B 12000 N s

C 20000 N s

D 25000 N s

(Total 1 mark)

1 (a) force is equal to (**or** proportional to) rate of <u>change of</u> momentum ✓

[**or** impulse = force × time = <u>change of</u> momentum]

[Answer should **not** be in symbols unless all the symbols are explained]

1

(b) (i) use of $mg\Delta h = ½ mv^2$ gives v = $\sqrt{2gh} = \sqrt{2 \times 9.81 \times 1.6}$ ✓ (= 5.60 m s^{-1})

1

(ii) momentum per second (= 0.30 × 5.60) = 1.68 (Ns) ✓

1

(iii) mass of sand falling in 10s = (0.30 × 10) (= 3.00 kg) ✓

force due to arriving sand = momentum arriving per second = 1.68(N)

equivalent mass reading = $\frac{1.68}{9.81}$

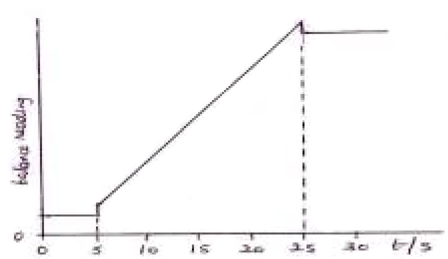
✓ (= 0.17 kg)

so balance reading is 3.00 + 0.65 + 0.17 ✓ (= 3.82 kg)

3

(c) horizontal lines up to 5 s and beyond 25 s ✓

line of constant positive gradient between 5 s and 25 s ✓



(near) vertical steps up at 5 s and down at 25 s ✓

3

[9]

2 (a) (i) t = $\sqrt{\frac{2s}{g}}$ (evidence for correct rearrangement or substitution) **(1)**

= $\sqrt{\frac{2 \times 67}{9.81}}$ (correct substitution leading to answer) **(1)**

(= **3.7** (3.696) (s))

2

(ii) $\left(v = \frac{s}{t} = \frac{150}{3.696}\right)$ = **41** (m s^{-1}) **(1)** 2sf **(1)**

2

(iii) $(v = (u+)gt =) 9.81 \times 3.696$ **(1)** = **36** **(1)** (m s^{-1})

2

(iv) $v = \sqrt{40.586^2 + 36.257^2}$ (or correct scale drawing) **(1)**

= 54 (m s^{-1}) **(1)**

ecf from (ii) (iii) [for scale drawing allow range 53 → 56]

tan $\theta = \frac{36.257}{40.586}$ **(1)** or correct alternative

(angle from horizontal =) **42** (°) or correct alternative angle
and clear indication of direction (1)

[for scale drawing allow range 40 → 44 **(1)**
for scale drawing: quality of construction **(1)**]

4

(b) (i) (= *mgh* = 22 × 9.81 × 67) = 14000 (14460) (J) **(1)**

1

(ii) (G)PE → KE **(1)**

(KE to) internal/thermal/'heat' (energy) **(1)**

2

[13]

3 (a) any **two** from

freefall is too quick (any indication of slower motion) **(1)**

(Galileo had) no (accurate) method to **time** freefall (or valid comment regarding timing of freefall or inclined plane) **(1)**

correct reference to **air** resistance or **drag** (not 'wind') **(1)**

max 2

(b) (i) 0.20 × 9.81 = 1.962 (N) **(1)**

(1.962 sin 1.8 =) 0.0616 or 0.062 seen **(1)** (allow 0.061)
(0.0628 for use of g = 10 gets 1 mark)

2

(ii) 0.06(16)/0.20

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

or g sinθ = g sin 1.8° **(1)**

0.31 (m s^{-2}) **(1)** (0.308)

accept 0.3 or 0.30 correct answer only for second mark

or ($a = 2s/t^2$)

= 2 × 0.29/1.4^2 **(1)** = 0.31 **(1)** or use of other values from table

2

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

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

2

(d) **tangent used:**

tangent drawn at 3.0 m ± 0.3 on graph **(1)**

their time from graph × 1.4 **(1)**

= 1.28 to 1.44 (m s^{-1}) **(1)**

or suvat used:

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

(t =) 4.4 to 4.5 (s) **(1)**

(speed =) 1.3 to 1.4 (m s^{-1}) **(1)**

3

[11]

4 (a) (i) ΔE = mgΔh

B1

= (16.8+1.2)9.8 × 0.5 *or a mass × 9.8 × 0.5*

B1

= **88.2** (J)

B1

3

(ii) 108 J *or answer to (a) (i) + 20 J*

B1

1

(iii) 108/0.40 *allow ecf from (ii) (i.e. their (ii)/0.40)*

C1

270 N {*68/.4 = 170*}

A1

2

(b) gain in KE = loss in PE - work done

C1

= 88-20 = 68

C1

KE = ½ mv^2

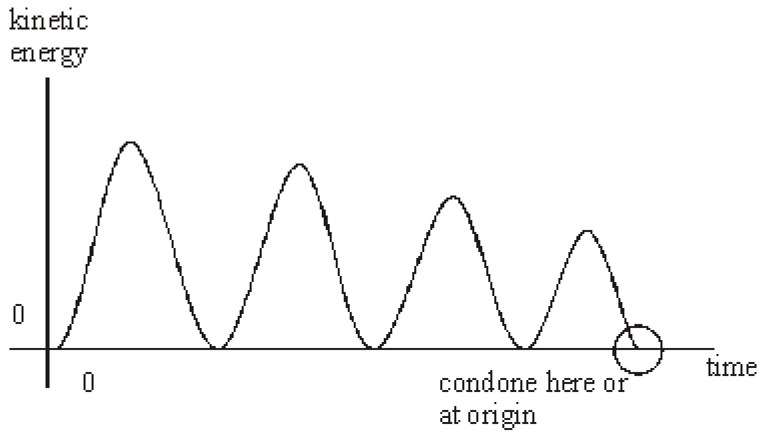
C1

v = 2.7(5) m s^{-1} *no ecf*

A1

4

(c)



graph starts at origin and forms a full rounded peak

B1

exactly two cycles (4 peaks) shown but not arches

B1

height of peaks decreases **and** peaks approximately equally spaced

B1

3

[13]

5 (a) a (resultant) force directed through the centre of mass of an object will not give it a moment / will not cause the object to rotate owtte
or all the mass of the object appears to be concentrated at the centre of mass owtte
or point at which all the (object's) weight acts ✓ owtte

We are not distinguishing between c of g and c of m. So allow point at which all the mass acts.

If a balance idea is given the situation described must be achievable.

Don't allow answers like:

Where mass is most concentrated It has the same mass on both sides All forces act through this point

1

(b) (moment of plank from the bank = $mg \times d$) = 32 × 9.81 × 2.0 or 32 × g × 2.0 ✓
this moment is balanced by F × 3.2 giving F = 200 (N) ✓ (196 N)

Award 2 marks if 196 (N) is seen but 200 (N) only gains 1 mark with the second mark available if working is shown

9.8m s^2 is ok for g.

2

(c) (At the point of tipping) there is no (reaction) force from the bank ✓ (This point must be in words not implied from a calculation)

Taking moments about the rock

LHS = 1.2 × 32 × g = 38.4 × g = 380 (Nm) ✓ (377 N m)

RHS = 0.80 × 46 × g = 36.8 × g = 360 (Nm) ✓ (361 N m)

Or show a moment calculation that gives the maximum boy's weight that can be supported (471 N)

Or show a moment calculation that gives the maximum distance the boy can be from the rock without tipping (0.83 m) Score any two of the above marks

(Therefore) plank will not tilt ✓ (to score this mark the answer must be justified)

NB the first 3 marking points score a maximum of 2 marks.

The last mark makes up the total to 3 marks

Note it is the RHS mark that has the alternative approaches

Condone missing 'g' provided it is cancelled / missed out in both moment calulations.

The last mark can come from an ecf as long as the reason is clearly stated in terms of the answers given earlier

3

[6]

6 (a) smooth curve with a maximum value shown

B1

condone non-zero at start and finish

gradient fairly constant or slight increase for half time

B1

falls gradually on second half of swing

B1

oscillations score zero

2 max

(b) impulse is product of force and time

B1

clear reference to impulse

prolonging the time (of contact) increases momentum / velocity

B1

being force time product needed for first mark

2

(c) (i) use of $F = mv/t$ $= 0.045 \times 58 / 180 \times 10^{-6}$

C1

use of 35 can gain first mark

or $a = 58 / 180 = 3.2 \times 10^5$ (ignore power for first mark) 1.45×10^4 (N)

A1

2

(ii) $(-)1.45 \times 10^4$ (N)

B1

numerically equal to c(i)

1

(iii) club head has inertia

C1

do not credit reference to friction

club head only slows slightly on impact

A1

club head still has kinetic energy / collision not elastic increase in internal energy / 'heat' / temperature of ball / club head

treat references to sound neutrally

2 max

[9]

7 (a) *GPE* to *KE* to *GPE* ✓

no energy lost (from system) / no <u>work done</u> against resistive forces ✓

initial *GPE* = final (*GPE*) / initial (*GPE*) = final *GPE*

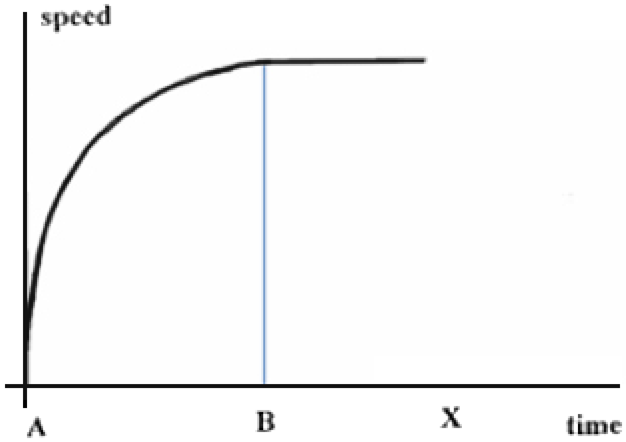
OR $h = GPE/mg$ and these are all constant so h is the same ✓

3

8 (b) Initial curve with decreasing gradient and reaching constant maximum speed before X and maintaining constant speed up to X ✓

B labelled in correct place ✓

B labelled in correct place **AND** constant speed maintained for remainder of candidates graph and line is straight ✓



3

(c) (first law) ball travels in a <u>straight line</u> at a constant speed / constant <u>velocity</u> / (maintains) <u>uniform</u> / <u>no change in</u> motion / zero acceleration ✓

there is no (external) **unbalanced / resultant** <u>force</u> acting on it ✓

2

[8]

8 statement that forces up = forces down/correctly resolved vertical component of either drag or tension

C1

2600 *sin* 41 = *W* + 2200 *sin* 27 seen (or equivalent kN)

C1

1705.8 = *W* + 998.8 (condone power 10 error)

707/710 (N)

A1

3

[3]

9 (a) (has magnitude but) no direction/has only magnitude

B1

1

(b) (i) 1N: 3.9 or 4 cm/1 cm: 0.25 or 0.26 N

B1

1

(ii) completes parallelogram correctly/or 'nose to tail'

M1

measures/draw correct diagonal

M1

2.1 ± 0.1 N

A1

3

[5]

10 (a) (i) area = 120×10^6 (m^2) **(1)**
mass = $120 \times 10^6 \times 10 \times 1100 = 1.3 \times 10^{12}$ kg **(1)**

(ii) (use of $E_p = mgh$ gives) $\Delta E_p = 1.3 \times 10^{12} \times 9.8 \times 5 = 6.4 \times 10^{13}$ J **(1)**
(allow C.E. for incorrect value of mass from (i))

(iii) power (from sea water) = $\frac{6.4 \times 10^{13}}{6 \times 3600}$

[or correct use of $P = Fv$]
= 3000 (MW) **(1)**
(allow C.E. for incorrect value of ΔE_p from (ii))
power output = 3000 × 0.4 **(1)**
= 120 MW **(1)**
(allow C.E. for incorrect value of power)

[7]

11 **B**

[1]

12 **D**

[1]

13 D

[1]

14 C

[1]

15 A

[1]

16 B

[1]

Examiner reports

1 In part (a), the relationship was well known. The principal failings were omission of the word change in “change of momentum” and unclear references to time. “Change of momentum over a period of time”, with the period of time undefined, is not as satisfactory as “change of momentum divided by the time taken for change to occur”. Most correct answers quoted the familiar “force equals the rate of change of momentum”.

Either energy considerations or the equations for uniform acceleration offered a route to the answer in part (b)(i), where most attempts were correct. Some students tried to get the required 5.6 m s^{-1} by ingenious misuse of the numbers in the question, typically 1.60 m ÷ 0.300 kg s^{-1} (which is 5.33). Calculation of the momentum that arrives per second in part (b)(ii) caused little difficulty.

This contrasts with part (b)(iii), where relatively few fully acceptable answers were seen. The majority of students readily saw that the balance reading must be at least 3.65 kg – their problem was to account for the extra 0.17 kg, reflecting the force produced by the change of momentum of the sand as it arrived in the container. Answers which got to 0.17 kg by dividing 1.68 N (from part (b)(ii)) by 10 were discounted, because the 10 usually referred to a time of 10.0 s rather than a value for the gravitational field strength. Examiners expected to see 1.68 divided by either 9.81 (the data booklet value) or 9.8 to arrive at a mass of 0.171 kg. Perhaps the most convincing answers were those that converted the 3.65 kg mass into a force of 35.81 N, and then added the 1.68 N, before dividing by 9.81 N kg^{-1} to obtain 3.82 kg.

Only a few answers to part (c) deserved all three marks. The numbers in part (b)(iii) should have made it clear that the balance had not been tared, so a horizontal line at a finite mass value (i.e. 0.65 kg) was expected over the first 5 s. The horizontal line between 25 and 30 s, and a line of constant positive gradient between 5 and 25 s, were usually drawn correctly. The features of this graph that caused most difficulty were the abrupt increase in reading at 5 s, and corresponding abrupt decrease at 25 s, caused by the momentum of the falling sand and its sudden cessation.

2 The majority of candidates were successful in part (a) (i). A few worked backwards by substituting 3.7 and getting 67.15 m. This only received two marks if there was a clear statement that this showed 3.7 to be the correct time. Candidates should be encouraged to write down their answer to more than two significant figures for ‘show that’ questions like this one, although this was not penalised here.

A very large number of candidates expressed their answer to part (a) (ii) to three significant figures (eg 40.5) rather than two significant figures. Many used 67 m instead of 150 m. As a result, few gained both marks.

The majority gained two marks in part (a) (iii). A common incorrect answer was v = 67/3.7 = 18, where candidates were not aware that this was not appropriate for constantly accelerated motion.

Most candidates realised that Pythagoras’ theorem was needed in part (a) (iv). However, a surprising number incorrectly used the values 150 m and 67 m, rather than their answers to parts (a) (ii) and (a) (iii). Many candidates gave bearings from north instead of an angle from the horizontal or vertical. The best way to convey direction here would be to calculate the angle and then show this on a sketch and also write ‘angle from horizontal’. If there is not a clear diagram then the candidate would need to say ‘from the horizontal and downwards to the right’ or words to that effect.

Very few candidates had a problem with part (b) (i).

For part (b) (ii), there was some confusion about energy changes. Most candidates mentioned transfer of PE to KE but did not go beyond 'energy lost due to air resistance' and did not gain the second mark. The question asks for 'energy changes' so they needed to say *kinetic energy* changes to *internal energy* (*heat/thermal* are also accepted at AS). Some described the motion in terms of forces, velocity and acceleration – these gained no marks. Quite a few described the kinetic energy changing to gravitational as the cannonball emerges from the cannon.

3 In part (a), candidates did not have to have encountered Galileo's method for investigating freefall to be successful. Many showed awareness that either air resistance would not be a significant factor or that timing would be easier due to the lesser speeds when using an inclined plane.

Considerably less than half candidates were able to resolve to find the component of the weight acting down the slope in part (b) (i). Some used just the mass rather than mg and this response gained zero marks.

Part (b) (ii) was a straight forward use of $a = F/m$ and the majority of candidates gained full marks.

In part (c), many candidates thought the trolley was accelerating at an increasing rate because of the upward curve. Some did not use the term 'acceleration' in their answer and some thought that the rate of acceleration was decreasing because the curve was getting straighter. The data plotted on the graph does not support the view that the acceleration decreases. The distance between each pendulum swing increases in such a way to support uniform acceleration.

A very large majority of candidates did not recall that the gradient of a distance time graph gives the speed in part (d). Most of these calculated the average speed using $v = s/t$ with $s = 3.0$ and $t = 3.15 \times 1.4$ rather than the instantaneous speed at 3.0 m.

4 This question discriminated well, with nearly every candidate being able to achieve some marks and the more able scoring well. A few candidates achieved full marks.

(a) (i) This part was generally done well, but some candidates lost a mark by not clearly stating the formula they were using.

(ii) This part was less well answered. Common errors included 20 J being subtracted rather than added, and the answer being quoted to 4 significant figures. Also a surprising number of candidates were unable to add 88 to 20 successfully.

(iii) Most candidates gained both marks for this part, albeit, in some cases, with an error carried forward from part (ii).

(b) Only those candidates who read the question carefully accounted for the work done against friction on the downward swing.

(c) Most curves were sufficiently well drawn to gain at least two of the three marks. A common error was to draw arches rather than sine curves or to show only two peaks instead of four. The decreasing height of the peaks was well known.

5 (a) Very few students could distinguish between centre of mass and centre of gravity. On this matter the marking was made lenient. So the main issue was lack of clarity in answers such as, 'The point that has no turning' or 'the point where most of the mass is' etc.

(b) A majority of students tackled the question using moments very well. A minority became unstuck over their use of 'g' because some of the data was given in kg but the question asked for a force.

(c) The ability to show a logical approach that could be seen through to the end was a major requirement to achieve a good mark. The question itself had half a dozen acceptable approaches, some more involved than others. About half the students scored full marks, with the majority using the easiest option of taking moments about the rock. The most common error was to take moments about the bank and not take the reaction force from the rock into consideration. As usual in these calculations, there were a number of students who simply gave a number of calculations almost in a random order without introduction.

6 Most candidates were able to interpret the photograph sketching a sensible graph of club head speed against time. Many went on to describe how increasing the time of contact between the club head and the ball meant a greater change of momentum for the ball.

Although most candidates were able to attempt the calculation in (c)(i) there was frequent confusion regarding the choice of mass and velocity and also converting 180 μs into seconds. Approximately half the candidates recognised that the force acting on the club head and the ball were equal and opposite but it was rare for a minus sign to be included in answers to (c)(ii).

Answers to (c)(iii) were often too vague gain any marks – many simply saying that energy was lost as heat and/or sound but without explaining how the change occurred. Many recognised that the club head must retain kinetic energy to allow the follow through.

7 The answers to part (a) were generally very detailed with many students continuing to write to the bottom of the page. Answers could have been more succinct perhaps. eg *No energy lost, so all* GPE at A *is converted to KE at B which is converted to back to an equal amount of GPE* at C. Some students explained that GPE transfers to KE but then failed to mention the conversion back to GPE. eg 'all the GPE is converted to KE at B, so it gets to the same height at C'. Often the law of energy conservation was quoted but they did not explicitly state that there were no energy 'losses' due to no friction or drag.

In part (b) there was some carelessness in the positioning of the label for B. Many students had a significant straight section at the start and showed the ball decelerating after point X.

In part (c) students often stated that the speed was constant but did not point out that the ball would move in a straight line. They often explained the motion in terms of there being 'no forces' acting on the ball rather than 'balanced forces'.

8 This question proved difficult for a good number of the students. Less than half of the students achieved all three marks. Successful students had set their working out clearly and confidently dealt with the calculation. Many students were able to find the vertical component of either the drag or the tension but incorrectly thought that this component was the weight of the parascender.

9 Part (a) was correctly done by most candidates. In part (b), a large number of candidates could make no progress towards a correct parallelogram or triangle of forces.

10 This question produced many high marks. The usual error was failing to calculate the area correctly in m^2, usually through multiplying by 10^3 instead of 10^6. Only the very best candidates realised in part (ii) that the centre of gravity of the water dropped by 5 m and not 10 m. In part (iii) most candidates knew how to calculate the average loss of gravitational potential energy per second and how to use the efficiency correctly.

11 This question had been used in a previous examination, when the facility was 51%; this time the facility improved to 80%. The most common incorrect response was distractor C, 7.5 m s^{-1}, which would have been correct if the resultant force had been 15 N throughout instead of 5 N for half of the time and 15 N for the remainder.

12 This question, about the physical quantities that are conserved in an elastic collision, was answered correctly by 86% of the students. A question that turns out as easy as this becomes ineffective as a discriminator between the most successful and least successful students, and this question was the poorest discriminator in this test. 7% of the students thought that kinetic energy would *not* be conserved (distractor C).

13 This proved to be a very demanding question with only 29% of students giving the correct answer, although it proved to be quite discriminating. Students were required to calculate the kinetic energy of the car, and divide this by the distance to find the average decelerating force. The same answer could be obtained by calculating the acceleration using the suvat equations, and using F = ma. Slightly more students gave the answer C than gave the correct answer, perhaps neglecting to square the speed when calculating the kinetic energy.

14 This calculation proved to be very accessible, with 84% of students giving the correct answer. It should be noted that, in a written paper, students who use the suvat equations would not get the same credit as those who correctly equate GPE and KE, despite the two approaches giving the same answer.

15 Collisions between dynamics trolleys of similar mass, the basis of this question, are often studied when considering the conservation of momentum. This was an elastic collision, and so kinetic energy would be conserved as well as momentum. Four out of five students decided that the moving trolley would stop and pass all of its momentum on to the other trolley.

16 This question was a simple conservation of momentum calculation involving a collision between two trucks. 63% of the candidates selected the correct response by finding v to be 1.0 m s^{-1} from $8000 \times 2.5 + 0 = (8000 + 12000)\,v$, and then finding the change in momentum from $8000 \times (2.5 - 1.0)$.

22% of the candidates chose distractor C, which was the total momentum of the coalesced trucks, and 11% chose distractor A, which was the final momentum of the 8000 kg truck.