1 A lead ball of mass 0.25 kg is swung round on the end of a string so that the ball moves in a horizontal circle of radius 1.5 m. The ball travels at a constant speed of 8.6 m s^{-1}.

(a) (i) Calculate the angle, in degrees, through which the string turns in 0.40 s.

angle ____________________ degree

(3)

(ii) Calculate the tension in the string.
You may assume that the string is horizontal.

tension ____________________ N

(2)

(b) The string will break when the tension exceeds 60 N.
Calculate the number of revolutions that the ball makes in one second when the tension is 60 N.

number of revolutions ____________________

(2)

(c) Discuss the motion of the ball in terms of the forces that act on it. In your answer you should:

- explain how Newton's three laws of motion apply to its motion in a circle
- explain why, in practice, the string will not be horizontal.

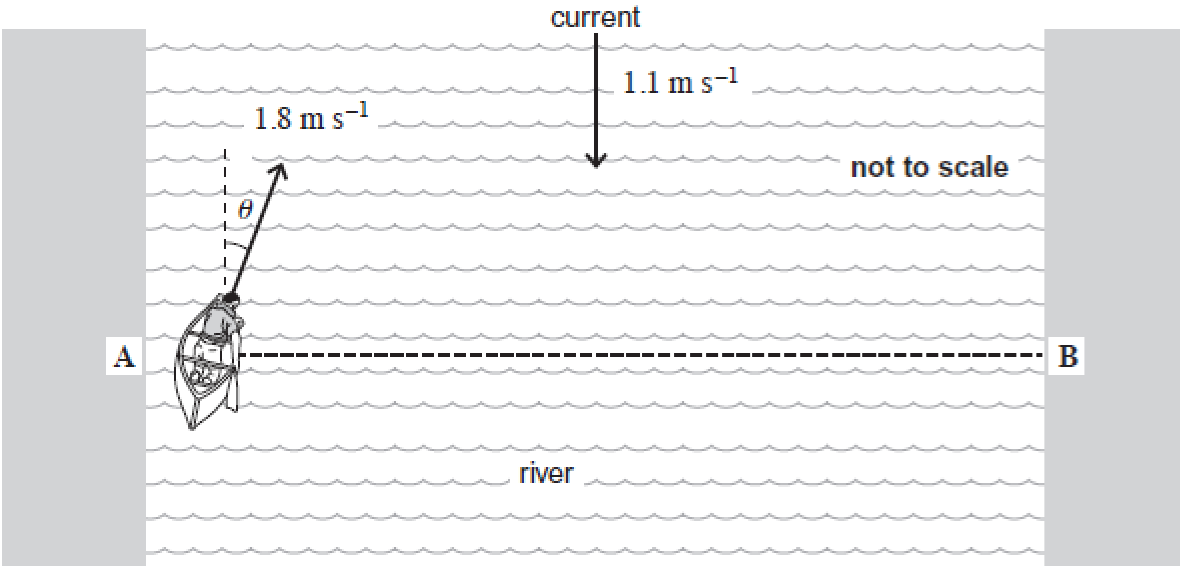
You may wish to draw a diagram to clarify your answer.

The quality of your written communication will be assessed in your answer.

(6)

(Total 13 marks)

2 A canoeist wishes to cross a river in a straight line between two points labelled **A** and **B** as shown in the diagram below.
The canoeist can paddle the canoe at a speed of 1.8 m s^{-1} in still water.
The current in the river has a speed of 1.1 m s^{-1}.



To cross from **A** to **B** the canoeist has to paddle at an angle θ to the direction of the current, as shown above.

Determine θ using a scale drawing.

angle θ ____________________ degrees

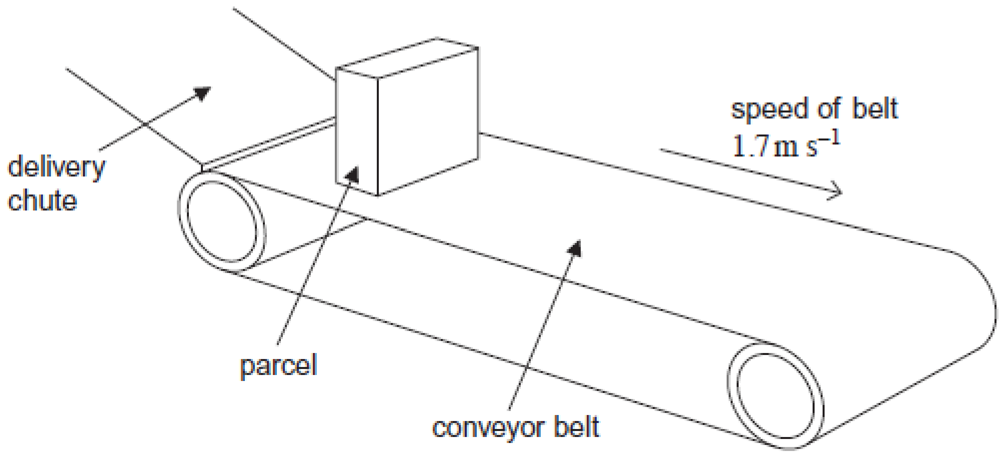
(Total 3 marks)

3 (a) A parcel of mass 15 kg drops from a delivery chute onto a conveyor belt as shown in **Figure 1**.

The belt is moving at a steady speed of 1.7 m s^{-1}.

The parcel lands on the moving belt with negligible speed and initially starts to slip. It takes 0.82 s for the parcel to gain enough speed to stop slipping and move at the same speed as the conveyor belt.

Figure 1



(i) Calculate the change in kinetic energy of the parcel during the first 0.82 s.

change in kinetic energy ____________________ J

(2)

(ii) The average horizontal force acting on the parcel during the first 0.82 s is 31 N.

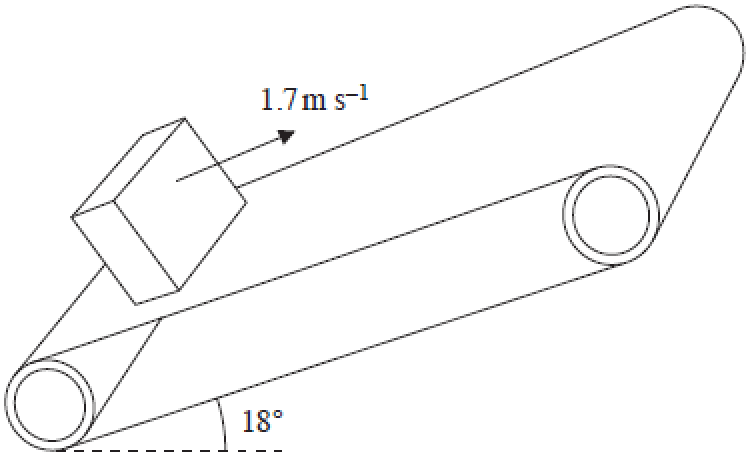
Calculate the horizontal distance between the parcel and the end of the delivery chute 0.82 s after the parcel lands on the conveyor belt. Assume that the parcel does not reach the end of the conveyor belt.

horizontal distance ____________________ m

(2)

(b) At a later stage the parcel is being raised by another conveyor belt as shown in **Figure 2**.

Figure 2



This conveyor belt is angled at 18° to the horizontal and the parcel moves at a steady speed of 1.7 m s^{-1} without slipping.

Calculate the rate at which work is done on the parcel.

rate at which work is done ____________________ W

(3)

(Total 7 marks)

4 (a) State the principle of moments.

____

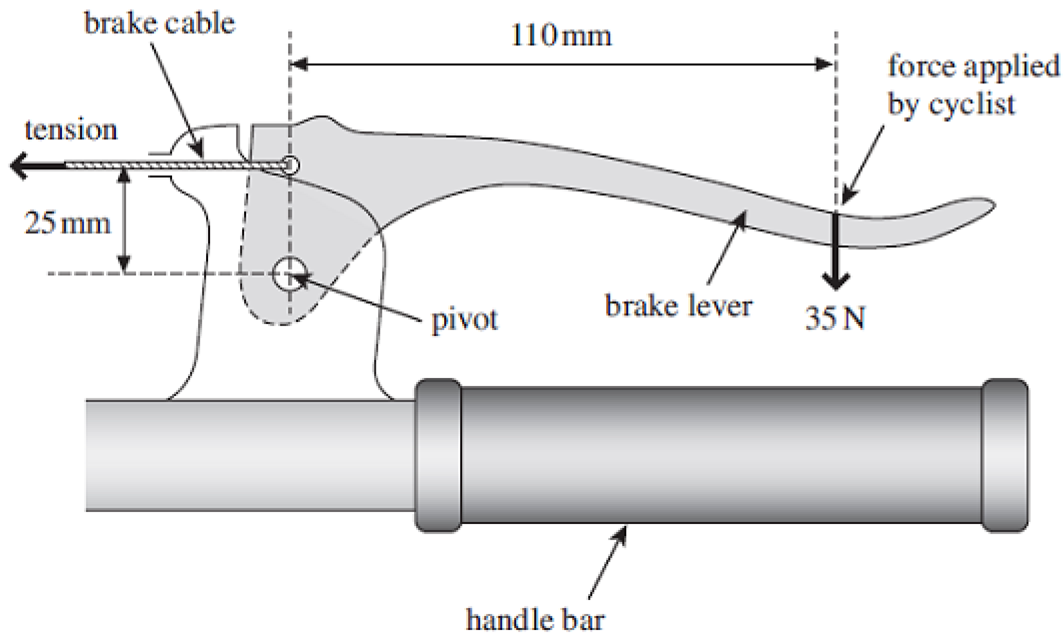
____

____

____

(3)

(b) The diagram below shows a bicycle brake lever that has been pulled with a 35 N force to apply the brake.



(i) Calculate the moment of the force applied by the cyclist about the pivot. State an appropriate unit.

moment = ____________________ unit __________

(3)

(ii) Calculate the tension in the brake cable. Assume the weight of the lever is negligible.

tension = ____________________ N

(3)

(c) In order to maintain a constant velocity of 15 ms^{-1} downhill, the cyclist applies the brake. The power developed by the braking force is 2.8 kW.

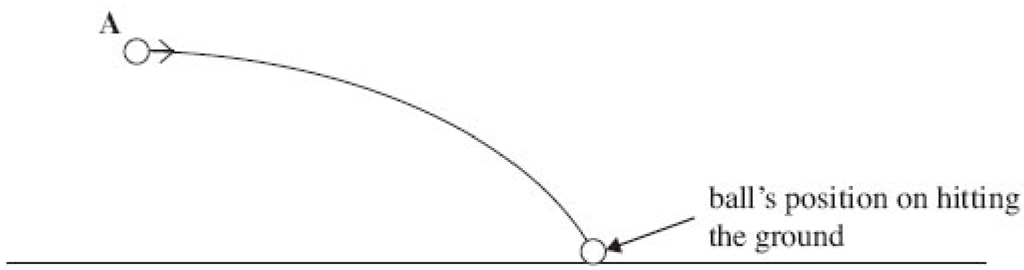
Calculate the total average frictional force between the brake blocks and the wheel rim.

frictional force = ____________________ N

(2)

(Total 11 marks)

5 The figure below shows the path that a tennis ball would follow in the absence of air resistance, after being hit horizontally at **A**.



(a) Explain why the path of the ball is curved in this way.

____

____

____

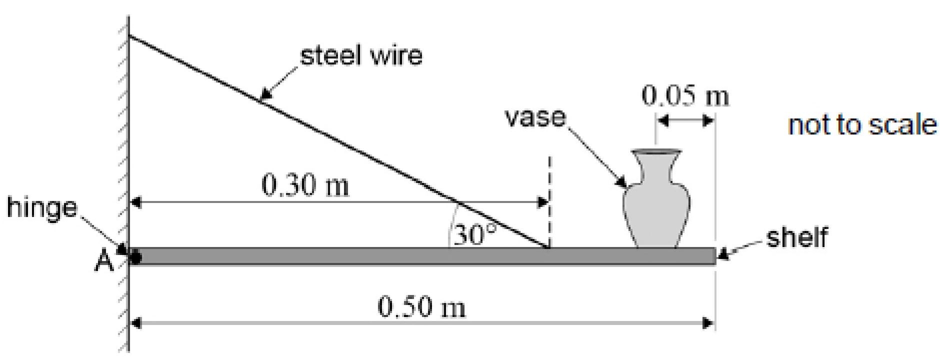
(2)

(b) Draw onto the figure the path of a ball, hit in the same way at **A**, that is affected by air resistance.

(1)

(Total 3 marks)

6 The diagram below shows a vase placed on a uniform shelf that is supported by a steel wire.



The mass of the vase is 0.65 kg and the mass of the shelf is 2.0 kg. The shelf is hinged at A. The steel wire is attached to the shelf 0.30 m from A and is at an angle of 30° to the shelf. The other end of the steel wire is attached to the wall.

(a) State the principle of moments.

____

____

____

____

____

(2)

(b) Show, by taking moments about A, that the tension in the steel wire is about 50 N.

(4)

(c) The cross-sectional area of the steel wire is 7.8×10^{-7} m^2. The steel has a Young modulus of 180 GPa.

Calculate the tensile strain of the steel wire when it is holding up the shelf and the vase.

tensile strain = ____________________

(2)

(Total 8 marks)

7 A car is designed to break the land speed record. The thrust exerted on the car is 230 kN at one instant of its motion. The mass of the car at this instant is 11 000 kg.

(a) The acceleration of the car at this instant is 2.9 m s^{-2}.

Calculate the air resistance acting on the car.

air resistance = ____________________ N

(3)

(b) The thrust on the car remains constant as the speed increases.

Explain why the acceleration decreases and eventually reaches zero.

____

____

____

____

____

(2)

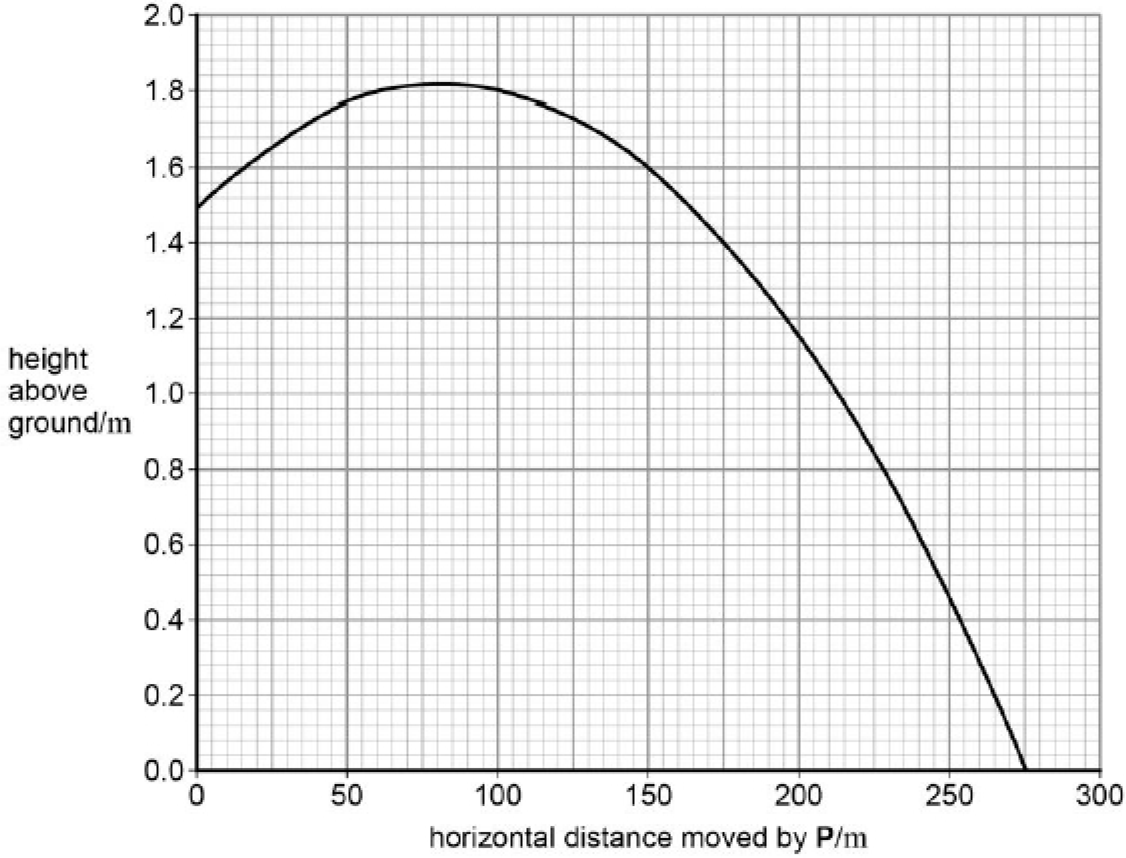
(c) A supersonic car is attempting to break the land speed record on a horizontal track. When it is travelling at 320 m s^{-1}, a small part **P** that is 1.5 m above the ground becomes detached from the car. The initial vertical velocity of **P** is 2.5 m s^{-1} in the upwards direction.

Calculate the time taken for the small part **P** to reach the ground.
Assume that air resistance has a negligible effect on the vertical motion.

time = ________________________ s

(3)

(d) The graph below shows the path that **P** would follow from the instant that it became detached if there were no air resistance in the horizontal direction.



In practice, air resistance is not negligible in the horizontal direction.

Draw, on the graph, a line to show the path that **P** would follow assuming that air resistance only affects motion in the horizontal direction.

(2)

(e) Explain your answer to part **(d)**, including the reason why air resistance is negligible in the vertical direction.

____

____

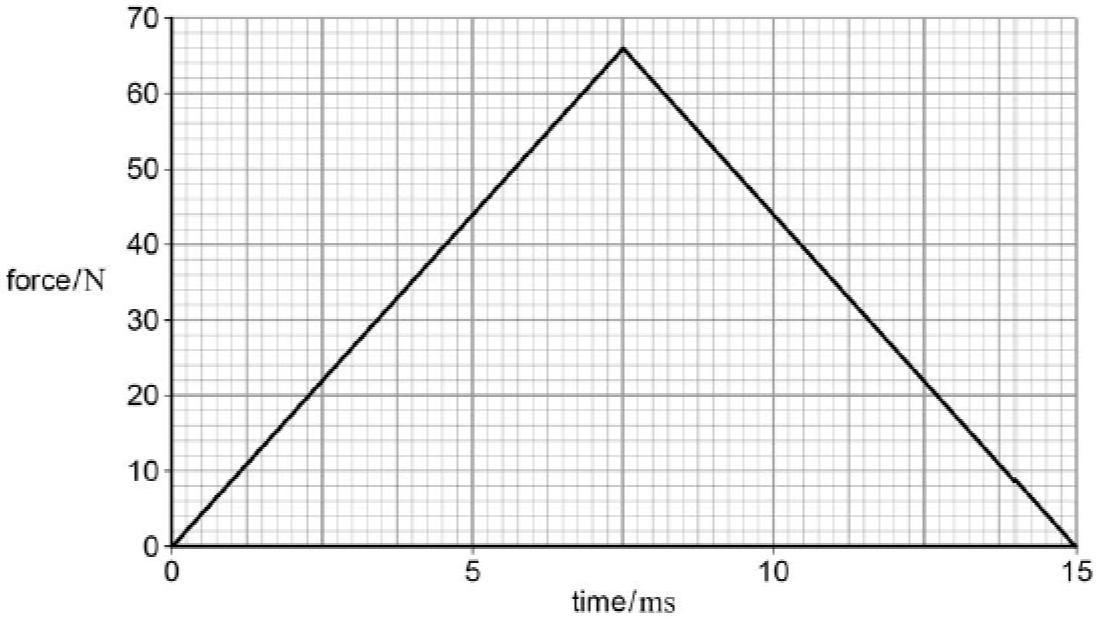
____

____

____

(2)
(Total 12 marks)

8 A golf ball is raised from the ground and dropped onto a hard plate to test the properties of the ball. A sensor measures the force exerted by the plate on the ball during its collision with the plate. The graph below shows the variation of force exerted on the golf ball with time.



(a) Show that the change in momentum of the golf ball during the collision is about 0.5 N s.

(2)

(b) The ball strikes the plate with a speed of 7.1 m s^{-1} and has a mass of 45 g. It leaves the plate with a speed of 3.9 m s^{-1}.

Show that this is consistent with a change in momentum of about 0.5 N s.

(3)

(c) The ball continues to bounce, each time losing the same fraction of its energy when it strikes the plate. Air resistance is negligible.

Determine the percentage of the original gravitational potential energy of the ball that remains when it reaches its maximum height after bouncing three times.

gravitational potential energy remaining = ____________________ %

(4)

(d) Explain, with reference to the conservation of momentum, the effect that the motion of the golf ball has on the motion of the Earth from the instant it is released until it bounces at the plate.

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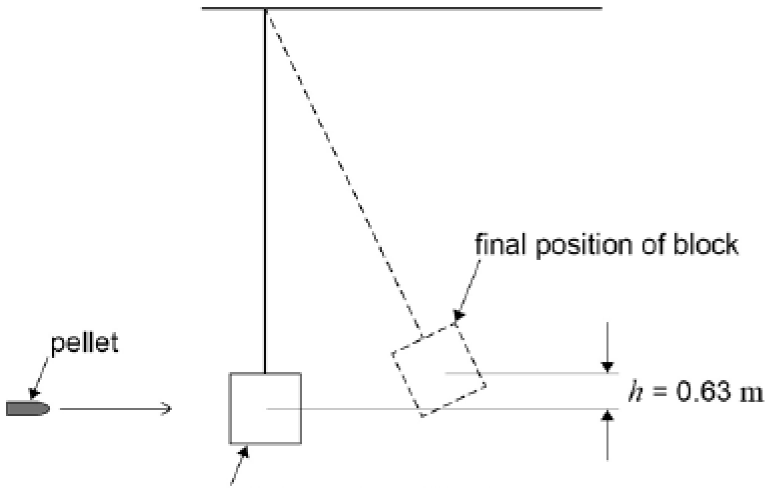
(3)

(Total 12 marks)

9 The speed of an air rifle pellet is measured by firing it into a wooden block suspended from a rigid support.
The wooden block can swing freely at the end of a light inextensible string as shown in the figure below.



A pellet of mass 8.80 g strikes a stationary wooden block and is completely embedded in it. The centre of mass of the block rises by 0.63 m. The wooden block has a mass of 450 g.

(a) Determine the speed of the pellet when it strikes the wooden block.

speed = ____________________ m s^{-1}

(4)

(b) The wooden block is replaced by a steel block of the same mass.
The experiment is repeated with the steel block and an identical pellet. The pellet rebounds after striking the block.

Discuss how the height the steel block reaches compares with the height of 0.63 m reached by the wooden block. In your answer compare the energy and momentum changes that occur in the two experiments.

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(4)

(c) Discuss which experiment is likely to give the more accurate value for the velocity of the pellet.

___

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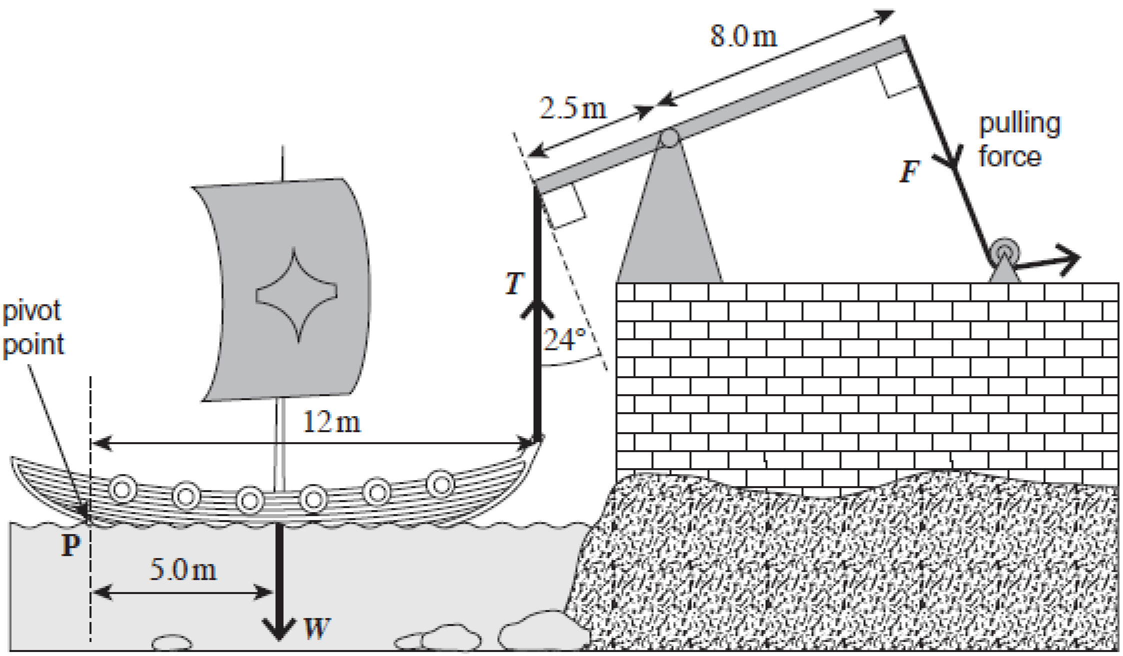
___

___

(2)
(Total 10 marks)

10 It is said that Archimedes used huge levers to sink Roman ships invading the city of Syracuse. A possible system is shown in the following figure where a rope is hooked on to the front of the ship and the lever is pulled by several men.



(a) (i) Calculate the mass of the ship if its weight was 3.4×10^4 N.

mass ____________________ kg

(1)

(ii) Calculate the moment of the ship's weight about point **P**. State an appropriate unit for your answer.

moment ____________________ unit __________

(2)

(iii) Calculate the minimum vertical force, T, required to start to raise the front of the ship. Assume the ship pivots about point **P**.

minimum vertical force ____________________ N

(2)

(iv) Calculate the minimum force, F, that must be exerted to start to raise the front of the ship.

force ____________________ N

(3)

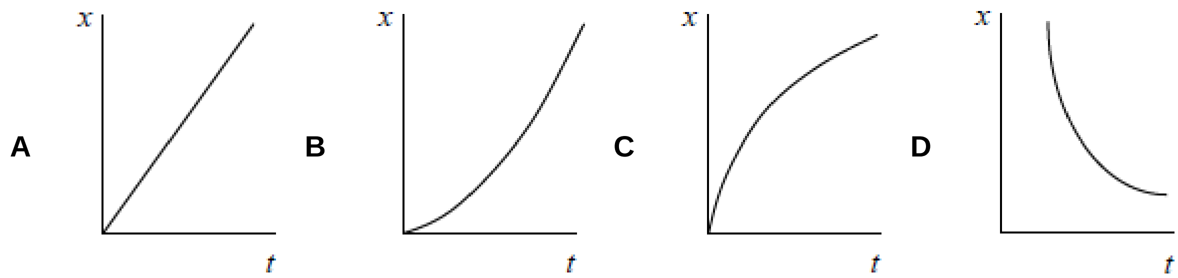
(Total 8 marks)

11 Which of the following is **not** a unit of power?

A	$N\ m\ s^{-1}$	⬭
B	$kg\ m^2\ s^{-3}$	⬭
C	$J\ s^{-1}$	⬭
D	$kg\ m^{-1}\ s^{-1}$	⬭

(Total 1 mark)

12 A car accelerates uniformly from rest along a straight road. Which graph shows the variation of displacement *x* of the car with time *t*?



A ☐

B ☐

C ☐

D ☐

(Total 1 mark)

13 Which of the following statements is correct?

The force acting on an object is equivalent to

A its change of momentum. ☐

B the impulse it receives per second. ☐

C the energy it gains per second. ☐

D its acceleration per metre. ☐

(Total 1 mark)

14 Two forces of 6 N and 10 N act at a point. Which of the following could **not** be the magnitude of the result?

A 16 N ☐

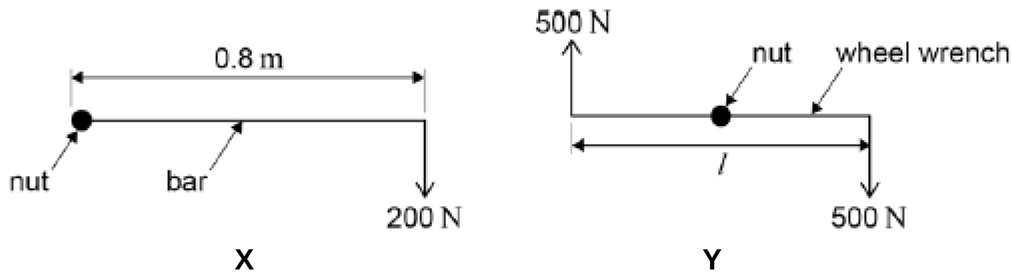
B 8 N ☐

C 5 N ☐

D 3 N ☐

(Total 1 mark)

15 A car wheel nut can be loosened by applying a force of 200 N on the end of a bar of length 0.8 m as in **X**. A car mechanic is capable of applying forces of 500 N simultaneously in opposite directions on the ends of a wheel wrench as in **Y**.



What is the minimum length l of the wrench which would be needed for him to loosen the nut?

A 0.16 m

B 0.32 m

C 0.48 m

D 0.64 m

(Total 1 mark)

16 A ballbearing **X** of mass 2*m* is projected vertically upwards with speed *u*. A ballbearing **Y** of mass *m* is projected at 30° to the horizontal with speed 2*u* at the same time. Air resistance is negligible. Which of the following statements is correct?

A The horizontal component of **Y**'s velocity is *u*.

B The maximum height reached by **Y** is half that reached by **X**

C **X** and **Y** reach the ground at the same time.

D **X** reaches the ground first.

(Total 1 mark)

17 What is the relationship between the distance y travelled by an object falling freely from rest and the time x the object has been falling?

A y is proportional to x^2 ☐

B y is proportional to $\sqrt{x}$ ☐

C y is proportional to $\frac{1}{x}$ ☐

D y is proportional to $\frac{1}{x^2}$ ☐

(Total 1 mark)

18 A car exerts a driving force of 500 N when travelling at a constant speed of 72 km h^{-1} on a level track. What is the work done in 5 minutes?

A 3.0×10^6 J ☐

B 2.0×10^6 J ☐

C 2.0×10^5 J ☐

D 1.1×10^5 J ☐

(Total 1 mark)

Mark schemes

1

(a) (i) $\omega\left(=\frac{v}{r}\right) = \frac{8.6}{1.5}$ (= 5.73 rad s^{-1}) ✓

$\theta(= \omega t)$ = 5.73 × 0.40 = 2.3 (2.29) (rad) ✓

$= \frac{2.29}{2\pi}$ × 360 = 130 (131) (degrees) ✓

[**or** $s((= vt)$ = 8.6 × 0.40 (= 3.44 m) ✓

$\theta = \frac{3.44}{2\pi \times 1.5}$ × 360 ✓ = 130 (131) (degrees) ✓]

Award full marks for any solution which arrives at the correct answer by valid physics.

3

(ii) tension $F(=m\omega^2 r)$ = 0.25 × 5.73^2 × 1.5 ✓ = 12(.3) (N) ✓

[**or** $F\left(=\frac{mv^2}{r}\right) = \frac{0.25 \times 8.6^2}{1.5}$ ✓ = 12(.3) (N) ✓]

Estimate because rope is not horizontal.

2

(b) maximum $\omega\left(=\sqrt{\frac{F}{mr}}\right) = \sqrt{\frac{60}{0.25 \times 1.5}}$ (= 12.6) (rad s^{-1}) ✓

maximum $f\left(=\frac{\omega}{2\pi}\right) = \frac{12.6}{2\pi}$ = 2.01 (rev s^{-1}) ✓

[**or** maximum $v = \sqrt{\frac{Fr}{m}} = \sqrt{\frac{60 \times 1.5}{0.25}}$ (= 19.0) (m s^{-1}) ✓

maximum $f\left(=\frac{v}{2\pi r}\right) = \frac{19.0}{2\pi \times 1.5}$ = 2.01 (rev s^{-1}) ✓]

Allow 2 (rev s^{-1}) for 2^{nd} mark.
Ignore any units given in final answer.

2

(c) **The student's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**

The student's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

High Level (Good to excellent): 5 or 6 marks

The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

The student appreciates that the velocity of the ball is not constant and that this implies that it is accelerating. There is a comprehensive and logical account of how Newton's laws apply to the ball's circular motion: how the first law indicates that an inward force must be acting, the second law shows that this force must cause an acceleration towards the centre and (if referred to) the third law shows that an equal outward force must act on the point of support at the centre. The student also understands that the rope is not horizontal and states that the weight of the ball is supported by the vertical component of the tension.

> *A **high level** answer must give a reasonable explanation of the application of at least two of Newton's laws, and an appreciation of why the rope will not be horizontal.*

Intermediate Level (Modest to adequate): 3 or 4 marks

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

The student appreciates that the velocity of the ball is not constant. The answer indicates how at least one of Newton's laws applies to the circular motion. The student's understanding of how the weight of the ball is supported is more superficial, the student possibly failing to appreciate that the rope would not be horizontal and omitting any reference to components of the tension.

> *An **intermediate level** answer must show a reasonable understanding of how at least one of Newton's laws applies to the swinging ball.*

Low Level (Poor to limited): 1 or 2 marks

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

The student has a much weaker knowledge of how Newton's laws apply, but shows some understanding of at least one of them in this situation. The answer coveys little understanding of how the ball is supported vertically.

> *A **low level** answer must show familiarity with at least one of Newton's laws, but may not show good understanding of how it applies to this situation.*
>
> *References to the effects of air resistance, and/or the need to keep supplying energy to the system would increase the value of an answer.*

The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.

- *First law:* ball does not travel in a straight line, so a force must be acting on it
- although the ball has a constant speed its velocity is not constant because its direction changes constantly
- because its velocity is changing it is accelerating
- *Second law*: the force on the ball causes the ball to accelerate (or changes the momentum of it) in the direction of the force
- the acceleration (or change in momentum) is in the same direction as the force
- the force is centripetal: it acts towards the centre of the circle
- *Third law*: the ball must pull on the central point of support with a force that is equal and opposite to the force pulling on the ball from the centre
- the force acting on the point of support acts outwards
- *Support of ball*: the ball is supported because the rope is not horizontal
- there is equilibrium (or no resultant force) in the vertical direction
- the weight of the ball, mg, is supported by the vertical component of the tension, $F \cos \theta$, where θ is the angle between the rope and the vertical and F is the tension
- the horizontal component of the tension, $F \sin \theta$, provides the centripetal force $m \omega^2 r$

Credit may be given for any of these points which are described by reference to an appropriate labelled diagram.

A reference to Newton's 3 rd law is not essential in an answer considered to be a high level response. 6 marks may be awarded when there is no reference to the 3rd law.

max 6

[13]

2 Right-angled triangle, nose-to-tail with arrows

M1

Appropriate scale (fills half the space minimum)

A1

52 ± 1 (degrees)

1 mark for 52.3° by calculation

B1

[3]

3 (a) (i) Use of $KE = \frac{1}{2} m v^2$

C1

21.7 (J)

A1

2

(ii) Use of $W = Fs$

Allow 1 mark for use of suvat or F=ma

C1

0.70 (m)

A1

2

(b) Use of $\Delta E_p = mg\Delta h$

C1

Correct sub for *h* (1.7 sin 18°)

C1

77.3 (W)
OR
Use of $P=Fv$
Correct sub for *F* (*mg* sin 18°) or v (1.7 sin 18°)
77.3 (W)

A1

3

[7]

4 (a) (sum of) clockwise moment(s) = (sum of) anticlockwise moment(s) ✓
sum of clockwise moment **s** = **sum of** anticlockwise moment **s** (about any given point) ✓
(for a system in) equilibrium ✓ allow 'balanced'

third mark depends upon the first
Don't allow references to 'forces' being balanced.
Don't allow 'stationary'.
Allow 'total', etc instead of sum
Ignore definitions of moment

3

(b) (i) 35 × 110 (×10^{-3}) ✓
(= 3.85) = 3.9 (or 3.8) ✓

allow 4 or 3.90 but not 4.0

(3.9) **Nm** / allow (3850, 3900) **Nmm** ✓ don't allow nm, NM

unit must match answer

3

(ii) 3.85 = T × 25 (×10^{-3}) ✓ ecf from (bi)

Correct answer with no working gets 2 out of three.

T = 3.85 / 25 (×10^{-3}) = 0.150 (×10^{3}) ✓ ecf

Allow 156 (160) N from rounding error

= 150 (154 N) ✓

3

(c) *(P = Fv , F = P / v)*
= 2.8(× 10^{3}) / 15 ✓
= 190 (186.7 N) ✓

2

[11]

5 (a) constant horizontal (component of) velocity/no horizontal force or acceleration

B1

accelerates vertically/increasing vertical (component) of velocity

B1

2

(b) appropriate curve starting at same place with shorter trajectory

B1

1

[3]

6 (a) Sum of / total clockwise <u>moments</u> = sum of / total anticlockwise <u>moments</u>✓

<u>For a body in equilibrium</u>✓

2

(b) Clockwise moments = 2.0 × 9.81 × 0.25 + 0.65 × 9.81 × 0.45

= 7.77 (N m)✓

Anticlockwise moments = Tsin30 × 0.3✓

Tsin30 × 0.3 = 7.77 or T = 7.77/(sin30 × 0.3) ✓

T = 52.0 (N) ✓

First mark for clockwise moments, workings or correct answer.
Second mark for anticlockwise moments.
Third mark for equating clockwise and anticlockwise moments.
Fourth mark for correct answer.

4

(c) tensile stress = 52.0/(7.8 × 10^{-7}) = 6.6 × 10^{7} ✓

tensile strain = 6.6 × 10^{7}/(180 × 10^{9})= 3.7 × 10^{-4} ✓

2

[8]

7 (a) resultant force = 11 000 × 2.9 = 31900 (N) ✓

resultant force = thrust − air resistance

OR

31 900 = 230 000 – air resistance✓

198 000 (N) ✓

3

(b) Air resistance increases with speed so resultant force decreases with speed ✓

Eventually air resistance = thrust (so no acceleration)✓

2

(c) Time to reach maximum height = 2.5/9.8=0.255 s✓

maximum height = 1.5 + 4.9 × 0.255^2 = 1.82 m✓

Time to reach ground from maximum height = 0.61 s giving total time = 0.87 s✓

OR

$-1.5 = 2.5t - 0.5 \times 9.8 \times t^2$✓

rearrange quadratic gives $4.9t^2 - 2.5t - 1.5 = 0$ and

solution $t = \dfrac{2.5 \pm \sqrt{2.5^2 + 4 \times 4.9 \times 1.5}}{2 \times 4.9}$ ✓

Giving solutions 0.86 or − 0.35 hence time = 0.86 s✓

Allow credit for alternative routes

3

(d) Starts at 2.5 m s^{-1} and maximum height same but reached earlier✓

Maximum range no more than 175 m✓

2

(e) Motion unchanged vertically / maximum height of P is unchanged: air resistance decelerates P horizontally so less distance travelled. (both points needed) ✓

Air resistance increases with speed: speed is low vertically but very high horizontally (both points needed) ✓

2

[12]

8 (a) Attempt to determine area under graph or statement that area under needed or 0.5 × 15 × 10^{-3} x 66 ✓

0.495 (N s)✓

condone power of 10 error

2

(b) Momentum before = 0.045 × 7.1 = 0.320 (N s) down✓

Momentum after = 0.045 × 3.9 = 0.175 (N s) upwards✓

Change = 0.495 (N s) ✓

3

(c) Initial KE on impact = $0.5 \times 0.045 \times 7.1^2 = 1.13$ (J) or Ke after impact = 0.342 (J)✓

Fractional change ke after / ke before = 0.30✓

Use of their fractional change cubed✓

Percentage change after 3 bounces = $0.3^3 \times 100$ (%) = 2.7%✓

4

(d) As ball falls momentum of ball toward the Earth (always) = momentum of Earth toward the ball✓

On impact the momentum of both ball and Earth become zero✓

After impact momentum of ball away from Earth = momentum of Earth in opposite direction✓

3

[12]

9 (a) Max GPE of block = $Mgh = 0.46 \times 9.81 \times 0.63 = 2.84$ J ✓

The first mark is for working out the GPE of the block

1

Initial KE of block = $\frac{1}{2} Mv^2 = 2.84$ J

Initial speed of block $v^2 = (2 \times 2.84) / 0.46$

$v = 3.51\ ms^{-1}$ ✓

The second mark is for working out the speed of the block initially

1

momentum lost by pellet = momentum gained by block

$= Mv = 0.46 \times 3.51 = 1.61\ kg\ m\ s^{-1}$ ✓

The third mark is for working out the momentum of the block (and therefore pellet)

1

Speed of pellet = $1.58 / m = 1.58 / 8.8 \times 10^{-3} = 180\ ms^{-1}$ (183) ✓

The final mark is for the speed of the pellet

1

At each step the mark is for the method rather than the calculated answer

Allow one consequential error in the final answer

(b) As pellet rebounds, change in momentum of pellet greater and therefore the change in momentum of the block is greater ✓

Ignore any discussion of air resistance

1

Initial speed of block is greater ✓

1

(Mass stays the same)

Initial KE of block greater ✓

1

Therefore height reached by steel block is greater than with wooden block ✓

1

(c) Calculation of steel method will need to assume that collision is elastic so that change of momentum can be calculated ✓

1

This is unlikely due to deformation of bullet, production of sound etc. ✓

1

And therefore steel method unlikely to produce accurate results.

[10]

10 (a) (i) $m = W / g)$

(3.4×10^4 / 9.81 =) 3500 (3466 kg) ✓

Allow use of g = 10

1

(ii) (moment = 34 000 × 5.0) = 1.7×10^5 ✓ (Nm)

Nm ✓ do not allow NM \ nM etc

allow in words

2

(iii) 170 000 = T x 12 OR T = 170 000 / 12 ✓ ecf aii

= $1.4(167) \times 10^4$ ✓ (N)

2

(iv) (component of T perpendicular to lever) = T cos 24 **OR** 14 167 × 0.9135 **OR** 12942 (N) ✓ ecf aiii allow 2.5cos24 × T

(12942) × 2.5 = **F** × 8.0

OR F = ((12942) × 2.5) / 8.0 ✓ ecf for incorrect component of T or T on its own

F = 4000 (N) ✓ (4044) ecf for incorrect component of T or T on its own

allow 4100 for use of 14 200 (4054)

Some working required for full marks. Correct answer only gets 2

Failure to find component of T is max 2 (4400 N)

3

[8]

11 D **[1]**

12 B **[1]**

13 B **[1]**

14 D **[1]**

15 B **[1]**

16 C **[1]**

17 A **[1]**

18 A **[1]**

Examiner reports

1 The rubric for the paper requires students to show their working and it is generally wise for a student to do so since otherwise credit cannot be given when an incorrect answer is obtained. This usually involves showing any equation used and the substitution of numerical values into it. When these steps are not shown, marks may not be gained even when the final answer is numerically correct and this led to some of the more careless students failing to gain some of the marks in part (a). There were several successful routes to the answer in part (i), using angular speed, linear speed and / or time period or frequency. The main causes of weaker answers were thinking that an answer in radians was the final answer in degrees, or not showing how a conversion from radians to degrees had been carried out.

The majority of answers for the tension in part (a)(ii) were correct, arrived at by the use of either $m\omega^2 r$ or mv^2 / r. Part (b), the maximum frequency of rotation, was also usually addressed successfully.

The final part of the question required an explanation of the mechanics of the rotated ball in terms of Newton's laws and an explanation of why the supporting string would not be horizontal. This part was used to assess the quality of the students' written communication by applying a standard 6-mark scheme. The understanding of circular motion traditionally presents difficulties for many, and the students in 2015 were no exception. It was at least satisfying to see a greater proportion of them attempting to address the bullet points than has often been the case previously. In order to achieve an intermediate level grading (3-4 marks) it was necessary for the answer to show knowledge and understanding of how at least one of Newton's laws applies. For a high level grading (5-6 marks) this was required for at least two of the laws, together with some understanding of the non-horizontal string. On the whole the students showed some familiarity with Newton's laws, particularly the second law and the third law. How they apply to circular motion was more demanding. Fundamental to any satisfactory explanation is the observation that although the speed of the ball is constant its velocity is not. It is therefore accelerated at right angles to the path and this requires a force to act in this same direction. Common misconceptions were that the ball continues at constant *speed* because no overall force acts on it (supposedly Newton I), or that the ball is in equilibrium in an orbit of constant radius because equal and opposite radial forces are acting (supposedly Newton III). The most able students were able to apply all of the laws correctly to the rotated ball and to explain the non-horizontal string by considering the weight of the ball being balanced by the vertical component of the tension.

2 The technical demand of this question meant very few candidates scored full marks. Lines in vector diagrams often failed to have arrow-heads or were not drawn using most of the available space on the page. A significant majority of candidates gained 1 mark by correctly calculating the angle using trigonometry.

3 Most candidates dealt with the simple calculation in part (a)(i) but many lost a mark by simply forgetting to square the velocity.

Part (a)(ii) gave the average horizontal force with no indication that the force, and therefore acceleration, was constant. Therefore, candidates who used suvat equations, apart from $s = \frac{1}{2}(u+v)t$, were awarded only 1 mark. Just under 20% of candidates got the answer using a valid method, with most opting to equate the work done to the change in kinetic energy.

Part (b) proved to be the most challenging question in the paper with barely one-sixth of candidates gaining any marks at all. The majority of candidates failed to see that a sin component of either displacement or velocity was required and instead used $W=F.s(\cos\theta)$ when dealing with the angle.

4 (b) (i) Most candidates got this correct. Only a few dropped a mark for the unit, e.g. with N / m rather than Nm.

(ii) A very large number of candidates thought that $W = Fs\cos\theta$ had to be used and needlessly multiplied by cos25.

(iii) This tended to be 3 marks or zero. Some lost marks due to errors in the powers of ten. Other than that, a large number didn't know how to do a simple moments calculation.

(c) The majority were very successful on this question.

5 Although many candidates referred to the independence of the horizontal and vertical components, only around half mentioned that there was a constant horizontal component and vertical acceleration caused by gravity. Almost all candidates that attempted part (b) correctly did so. It seems likely that those who did not attempt it had not noticed the question.

10 (a) Most candidates were successful on this one but a few divided by 9.81 rather than multiply.

(b) There was significant use of mass rather than weight for this moment calculation and 12 m was occasionally used rather than 5 m.

Incorrect units were often seen. Nm^{-1} and NM being the most common errors.

(c) Most candidates got this one right but a few attempted to use trigonometry to resolve the weight of the ship. A few used a distance of $12 - 5 = 7$ m, perhaps thinking the pivot was at the centre of mass.

(d) Quite a few candidates did not attempt to resolve T and did $2.5 \times T = 8.0 \times F$, but nearly all had a correct moments equation, which was credited.