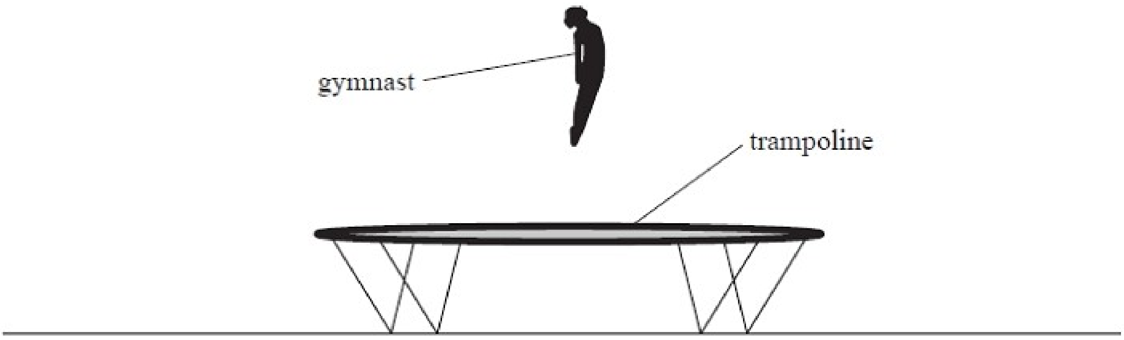
Questions

Q2. A gymnast bounces on a trampoline.

For part of each bounce, the gymnast is in contact with the trampoline. For the rest of each bounce the gymnast is in the air, as shown.



(a) The trampoline gives the gymnast a maximum upward acceleration of 14.2 m s^{-2}.

Calculate the maximum upward force of the trampoline on the gymnast.
mass of gymnast = 58 kg

(4)

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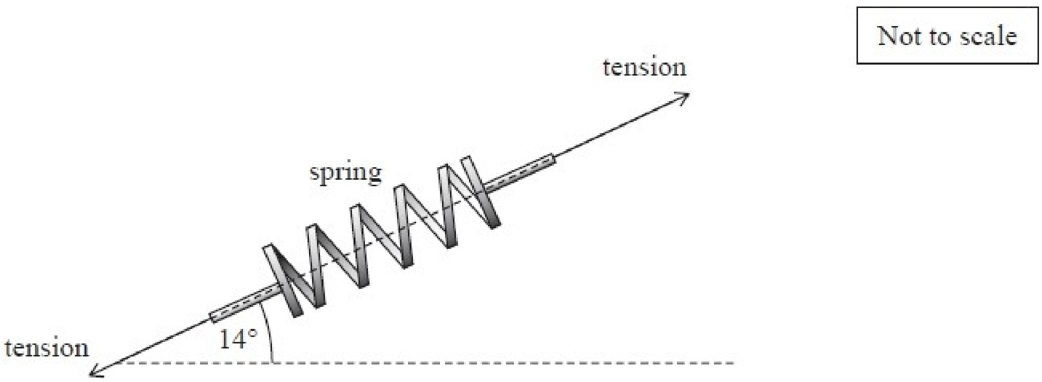
Maximum upward force = ...

(b) The trampoline is made of a sheet of material attached to a frame by springs.

The vertical components of the tension in the springs provide the upward force on the gymnast.
The vertical component of the tension in one spring is 68 N when the spring makes an angle to the horizontal of 14°, as shown below.



(i) Show that the tension in the spring is about 300 N.

(2)

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(ii) The extension of the spring was 4.6×10^{-2} m.
Calculate the stiffness of the spring.

(2)

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Stiffness = ...

*(c) The vertical acceleration of the gymnast varies while she is in contact with the trampoline.

Explain how the forces on the gymnast affect the vertical acceleration while she is in contact with the trampoline.
Your answer should identify the forces acting on the gymnast and the directions of the forces. Ignore air resistance.

(6)

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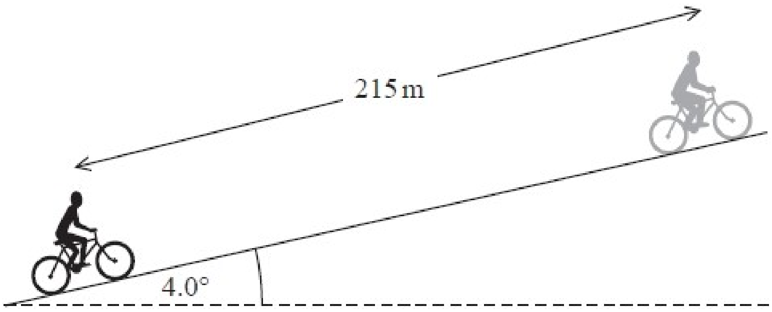
Q3. A cyclist is moving up a slope at a constant speed. The angle of the slope to the horizontal is 4.0°, as shown.



As the cyclist pedals, there is a constant forward force on the bicycle of 150 N. The cyclist travels 215 m along the slope.

(a) Show that the work done by the cyclist is about 3×10^4 J.

(2)

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(b) The cyclist must do work against the force of gravity and air resistance.

(i) Calculate the work done by the cyclist against air resistance.
mass of cyclist and bicycle = 90 kg

(4)

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Work done against air resistance = ...

(ii) State one assumption that must be made when calculating the work done against air resistance.

(1)

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(c) At the top of the slope, the road becomes horizontal. The cyclist continues to pedal with the same force.

Explain how the speed of the cyclist changes as the road becomes horizontal.

(2)

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Q4. A toy car is released from rest and rolls down a slope, as shown.

mass of car = 0.160 kg
speed of car at bottom of slope = 2.6 m s^{-1}

(a) Calculate the increase in kinetic energy of the car as it accelerates down the slope.

(2)

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Increase in kinetic energy = ...

(b) As the car accelerates down the slope, the work done against frictional forces is 0.26 J.

Calculate the vertical displacement of the car.

(2)

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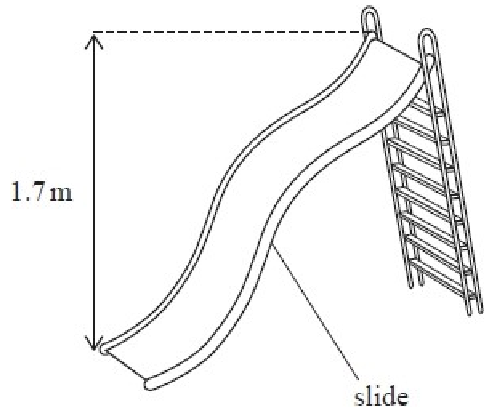
Vertical displacement of car = ...

(Total for question = 4 marks)

Q5. A child's slide has a vertical height of 1.7 m as shown.



(a) A child starts from rest at the top of the slide and moves down the slide.

The resistive forces acting on the child can be ignored.

(i) Explain why the equations of motion should **not** be used to determine the maximum speed of the child.

You should consider the shape of the slide.

(3)

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(ii) The child has a mass of 24 kg.

Determine the maximum speed v of the child on the slide.

(3)

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v = ...

(b) Two slides, X and Y, have the same height.

Slide X is longer than slide Y, as shown.

A child moves from rest down slide X and reaches a maximum speed v_X.

A second child moves from rest down slide Y and reaches a maximum speed v_Y.

The child on slide Y has a greater mass than the child on slide X.
The resistive forces acting on both children can be ignored.
Explain how v_X compares with v_Y.

(3)

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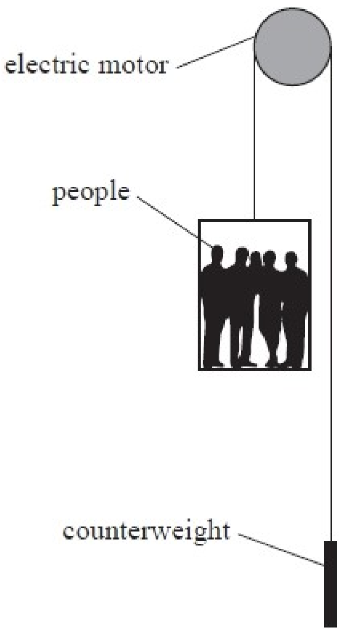
(Total for question = 9 marks)

Q6.

The diagram shows a lift system for moving people up and down a tall building. There is a counterweight to balance the weight of the lift. An electric motor is used to raise and lower the lift.



(a) Explain how the counterweight affects the amount of work required from the electric motor to raise the lift.

(2)

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(b) The electric motor raises the lift through a height of 40.0 m in a time of 30.0 s.

Show that the output power of the electric motor is about 12 kW.
total mass of lift and people = 2 250 kg
mass of counterweight = 1 300 kg

(4)

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(c) The electric motor dissipates energy to the surroundings at a rate of 3 600 W.

Determine the efficiency of the electric motor.

(2)

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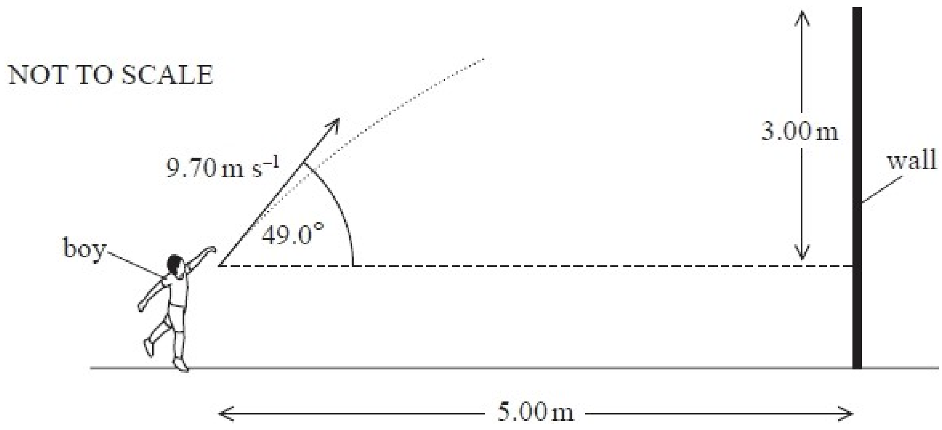
Efficiency = ...

(Total for question = 8 marks)

Q7. A boy was throwing a ball towards a wall. The wall was 5.00 m from the boy. The top of the wall was 3.00 m above the point where the boy released the ball.

The boy tried to throw the ball over the wall but sometimes the ball hit the wall.

In one attempt, the boy threw the ball with an initial velocity of 9.70 m s^{-1} at an angle to the horizontal of 49.0°, as shown.



(a) Show that the ball travelled the distance to the wall in about 0.8 s.

(3)

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(b) Deduce whether or not the ball went over the wall for this attempt.

(4)

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(Total for question = 7 marks)

Mark Scheme

Q1.

Question Number	Answer		Mark
(a)	Use of $\rho = \frac{m}{V}$	(1)	
	Use of $\Delta E = mc\Delta\theta$	(1)	
	Use of $P = \frac{\Delta E}{\Delta t}$	(1)	
	$P = 1630$ (W) [at least 3 sig fig required] [rounded data may give 1640 W] [If reverse calculation shown then MAX 3 marks] [Do not allow intermediate rounding to less than 3 sig figs for m or ΔE]	(1)	4
	Example of calculation $m = 4.25 \times 10^{-4}\ \text{m}^3 \times 998\ \text{kg m}^{-3} = 0.424\ \text{kg}$ $\Delta E = 0.424\ \text{kg} \times 4190\ \text{J kg}^{-1}\text{K}^{-1} \times (100 - 22)\ \text{K} = 1.386 \times 10^5\ \text{J}$ $P = \frac{1.386 \times 10^5\ \text{J}}{85\ \text{s}} = 1631\ \text{W}$		
(b)	Use of $\Delta E = L\Delta m$	(1)	
	Use of $P = \frac{\Delta E}{\Delta t}$	(1)	
	$t = 440$ s (ecf from (a)) [show that value for P gives 449 s]	(1)	3
	Example of calculation $\Delta E = 0.75 \times 0.424\ \text{kg} \times 2.26 \times 10^6\ \text{J kg}^{-1} = 7.19 \times 10^5\ \text{J}$ $t = \frac{7.19 \times 10^5\ \text{J}}{1630\ \text{W}} = 441\ \text{s}$		
	Total for question		7

Q2.

Question Number	Answer		Mark
(a)	Use of $W = m\,g$	(1)	
	Use of resultant force = push from trampoline – weight of gymnast	(1)	
	Use of $\Sigma F = m\,a$	(1)	
	$P = 1.4 \times 10^3$ N	(1)	4
	Example of calculation $\Sigma F = P - W$ $m\,a = T - m\,g$ $58 \text{ kg} \times 14.2 \text{ m s}^{-2} = P - 58 \text{ kg} \times 9.81 \text{ N kg}^{-1}$ $P = 58 \text{ kg} \times (14.2 + 9.81) \text{ m s}^{-2} = 1.39 \times 10^3 \text{ N}$		
(b)(i)	$T = 68 \text{ N} \div \sin 14°$ **Or** $68 \text{ N} \div \cos 76°$	(1)	
	$T = 280$ (N)	(1)	2
	Example of calculation $T = 68 \text{ N} \div \sin(14°) = 281 \text{ N}$		
(b)(ii)	Use of $F = k\,\Delta x$	(1)	
	$k = 6.1 \times 10^3 \text{ N m}^{-1}$ (allow ecf from (b)(i))	(1)	2
	Example of calculation $F = 2.81 \times 10^2 \text{ N} = k \times 4.6 \times 10^{-2} \text{ m}$ $k = 2.81 \times 10^2 \text{ N} \div 4.60 \times 10^{-2} \text{ m} = 6.11 \times 10^3 \text{ N m}^{-1}$		

(c)*

This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content and lines of reasoning.

IC points	IC mark	Max linkage mark available	Max final mark
6	4	2	**6**
5	3	2	**5**
4	3	1	**4**
3	2	1	**3**
2	2	0	**2**
1	1	0	**1**
0	0	0	**0**

	Marks
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

	Indicative content: • The weight (of the gymnast) acts downwards on the gymnast • The normal contact force (from trampoline) acts upwards • The normal contact force decreases as she moves upwards **Or** The normal contact force increases as she moves downwards • The normal contact force is zero when gymnast makes/loses contact with trampoline **Or** The normal contact force is maximum at bottom of bounce • Resultant/net force is the difference between weight and normal contact force • When the normal contact force is less than the weight the acceleration is downwards **Or** When the normal contact force is greater than the weight the acceleration is upwards	6
	Total for question	**14**

Q3.

Question Number	Answer		Mark
(a)	Use of $\Delta W = F\,\Delta x$ [allow any dimensionally correct variation, *e.g.* involving trig] $\Delta W = 3.2 \times 10^4$ (J) [do not allow if cos 4° used in MP1, gives 3.217].] <u>Example of calculation</u> $\Delta W = 150\ \text{N} \times 215\ \text{m} = 3.23 \times 10^4\ \text{J}$	(1) (1)	2
(b)(i)	Use of correct trigonometry to calculate Δh **Or** Use of correct trigonometry to calculate component of *g* along slope, [61.6 (N)] Use of $\Delta E_{grav} = m\,g\,\Delta h$ [$\Delta E_{grav} = 90\ \text{kg} \times 9.81 \times 215\ \text{m} \times \sin 4.0°$ scores MP1&2] Total work done = work done against gravity + work done against air resistance Work against air resistance = 2.0×10^4 J (allow ecf from (a)) ["show that" value gives 1.68×10^4 J] <u>Example of calculation</u> $\Delta h = 215\ \text{m} \times \sin 4.0° = 15.0\ \text{m}$ $\Delta E_{grav} = 90\ \text{kg} \times 9.81 \times 15.0 = 1.32 \times 10^4\ \text{J}$ $W = 3.20 \times 10^4\ \text{J} - 1.32 \times 10^4\ \text{J} = 1.88 \times 10^4\ \text{J}$	(1) (1) (1) (1)	4
(b)(ii)	Force of gravity and air resistance are the only significant forces acting (to oppose the motion of the bicycle) **Or** Frictional forces (in the bearings of the bicycle) are negligible [accept zero, do not accept friction between bicycle and slope/ground] **Or** Work done against frictional forces (in the bearings of the bicycle) is negligible [accept zero]	(1)	1
(c)	No work done against (force of) gravity **Or** All work done against air resistance **Or** No backward force due to gravity so resultant force acts Speed increases [MP2 dependent on MP1]	 (1) (1)	2
	Total for question		9

Q4.

Question Number	Answer		Mark
(a)	Use of $E_k = ½ m v^2$	**(1)**	
	$E_k = 0.54$ J	**(1)**	**2**
	Example of calculation $E_k = 0.5 \times 0.16 \text{ kg} \times (2.6 \text{ m s}^{-1})^2 = 0.541$ J		
(b)	Use of $E_{grav} = m\,g\,\Delta h$	**(1)**	
	$\Delta h = 0.51$ m	**(1)**	**2**
	(allow ecf from (a))		
	Example of calculation Decrease in GPE = 0.54 J + 0.26 J = 0.8 J $\Delta h = 0.8 \text{ J} / (0.16 \text{ kg} \times 9.81 \text{ m s}^{-2}) = 0.51$ m		
	Total for question		**4**

Q5.

Question Number	Answer		Mark
(a)(i)	The gradient / steepness of the slide varies	(1)	
	(So) the acceleration (of the child) varies	(1)	
	The equations of motion require a constant acceleration	(1)	3
(a)(ii)	Use of $\Delta E_{grav} = mgh$	(1)	
	Use of $\Delta E_k = \frac{1}{2}mv^2$	(1)	
	$v = 5.8 \text{ m s}^{-1}$	(1)	3
	Do not accept use of equations of motion.		
	Example of calculation $\Delta E_{grav} = 24 \text{ kg} \times 9.81 \text{ N kg}^{-1} \times 1.7 \text{ m} = 400 \text{ J}$ $400 \text{ J} = 0.5 \times 24 \text{ kg} \times v^2$ $v = \sqrt{\frac{2 \times 400}{24}} = 5.77 \text{ m s}^{-1}$		
(b)	$v_X = v_Y$	(1)	
	Maximum 2 from:		
	$\Delta E_{grav} = \Delta E_k$ and mass is in both equations	(1)	
	(Maximum) speed of child = $\sqrt{2g\Delta h}$ (and g is constant)	(1)	
	(Maximum) speed does not depend on mass of child **Or** (Maximum) speed is (only) dependent on Δh	(1)	3
	Total for question		**9**

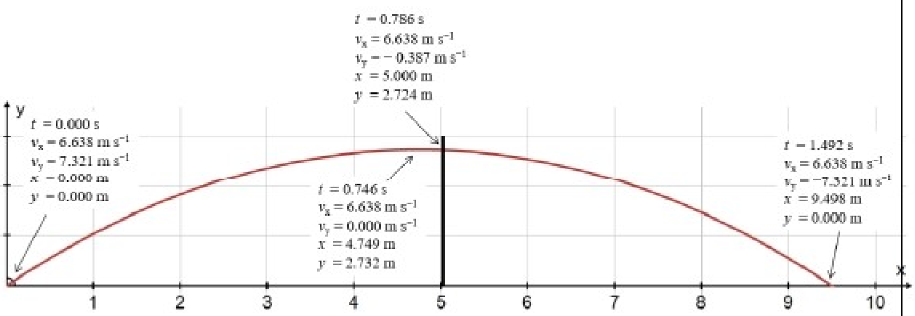
Q6.

Question Number	Answer		Mark
(a)	Amount of work from the electric motor is reduced	(1)	2
	Because there is energy transfer between the counterweight and the lift **Or** Because counterweight contributes to total work done (on lift cage) **Or** Because the counterweight reduces the force required from the motor **Or** Because total work done (on lift cage) is sum of work done by counterweight/gravity and by the motor.	(1)	

Question Number	Answer		Mark
(b)	Use of $\Delta W = F\Delta x$ **or** $\Delta E_{grav} = mg\Delta h$	(1)	4
	Use of conservation of energy	(1)	
	Use of $P = W / t$	(1)	
	$P = 12.4$ (kW)	(1)	
	Or		
	Calculates resultant force	(1)	
	Use of $\Delta W = F\Delta x$	(1)	
	Use of $P = W / t$	(1)	
	$P = 12.4$ (kW)	(1)	
	<u>Example of calculation</u> For counterweight $\Delta E_{grav} = mg\Delta h$ $= 1300 \text{ kg} \times 9.81 \text{ ms}^{-2} \times 40.0 \text{ m} = 5.101 \times 10^5 \text{ J}$ For lift $\Delta E_{grav} = mg\Delta h$ $= 2250 \text{ kg} \times 9.81 \text{ ms}^{-2} \times 40.0 \text{ m} = 8.829 \times 10^5 \text{ J}$ Energy required $= 8.829 \times 10^5 \text{ J} - 5.101 \times 10^5 \text{ J} = 3.728 \times 10^5 \text{ J}$ $P = 3.728 \times 10^5 \text{ J} \div 30 \text{ s} = 1.243 \times 10^4 \text{ W}$		
(c)	Use of efficiency = useful power output ÷ total power input	(1)	2
	Efficiency = 0.78 (ecf from (b))	(1)	
	<u>Example of calculation</u> Efficiency = 12.4 kW÷ (12.4 + 3.6) kW = 0.775		
	Total for question		**8**

Q7.

Question Number	Answer		Mark
(a)	Use of correct trigonometry to calculate horizontal component [9.7 cos 49° or 9.7 sin 41° seen] Use of $s = u\,t + ½\,a\,t^2$ with $a = 0$ [*i.e.* use of $s = v\,t$] $t = 0.79$ (s) [NB reverse argument scores 2 marks (Rule 4.2)] <u>Example of calculation</u> $v_H = 9.70 \text{ m s}^{-1} \times \cos 49° = 6.36 \text{ m s}^{-1}$ $t = 5.00 \text{ m} \div 6.36 \text{ m s}^{-1} = 0.786 \text{ s}$	(1) (1) (1)	3

(b)	Use of correct trigonometry to calculate vertical component [9.7 sin 49° or 9.7 cos 41° seen] Use of $s = u\,t + ½\,a\,t^2$ $s = 2.7$ m (ecf from (a)) ["show that" value also gives 2.72 m] Correct conclusion from valid comparison using student's calculated value **Or** Use of $v^2 = u^2 + 2\,a\,s$ Max height = 2.7 m [no ecf] Correct conclusion from valid comparison using student's calculated value [allow any valid *suvat* method, allow ecf if method involves t from (a)] <u>Example of calculation</u> $v_V = 9.70 \text{ m s}^{-1} \times \sin 49° = 7.32 \text{ m s}^{-1}$ $s = 7.32 \text{m s}^{-1} \times 0.79 \text{ s} - 0.5 \times 9.81 \text{ m s}^{-2} \times (0.79 \text{ s})^2 = 2.72 \text{ m}$ 2.72 m < 3.00 m so ball does not go over the wall [Significant moments …  	(1) (1) (1) (1) (1) (1) (1)	 4
	Total for question		7