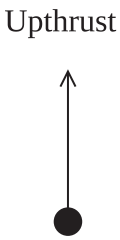
1 Kite surfing is the sport of riding on a small surfboard, propelled forwards across water by a large kite. The surfer holds onto a bar that is attached to the lines. As the air moves over the kite an upwards and forwards force is produced, causing a tension in the lines of the kite.

Consider the board and the surfer to be a single object and the lines of the kite to be equivalent to a single line.

(a) (i) Complete the free body diagram for the forces acting on the surfer at the instant he starts to move along the water.

(2)



(ii) At maximum speed, the angle of the kite to the horizontal is 40° and the total tension in the lines is 1100 N.

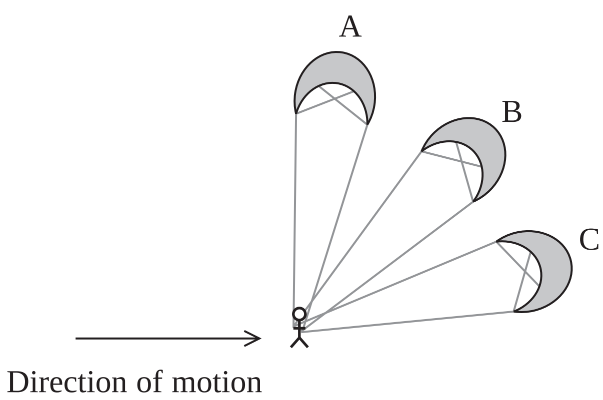
Show that the horizontal force from the kite on the surfer is about 800 N.

(2)

(iii) By considering the vertical forces acting on the surfer, explain why the mass of the surfer must be at least 72 kg.

(3)

*(b) The diagram shows three positions of the kite when pulling the surfer along.



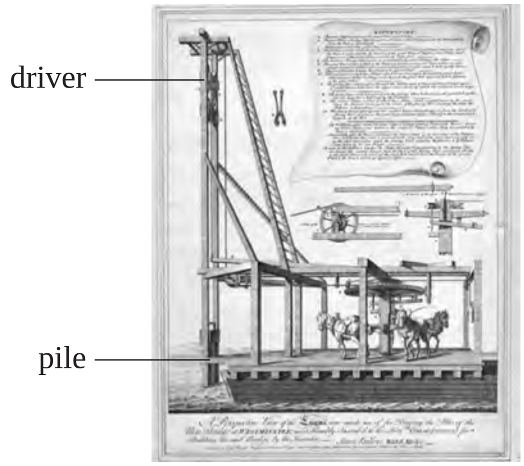
State and explain which position of the kite would supply the most power to the surfer. Assume that the tension in the kite lines is the same in each position.

(4)

(Total for Question = 11 marks)

2 Pile drivers have been used for centuries to push piles into the ground for use as foundations of buildings and other structures. A large mass (the driver) is raised and then dropped onto an object (the pile) which is pushed into the ground.

The picture shows the pile driver that was used to build a London bridge in the 17th century.



(a) (i) The driver on the pile driver above had a mass of 810 kg and could be dropped a maximum distance of 6.0 m onto the pile.

Show that the energy transferred from the driver is about 50 kJ.

(2)

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(ii) In one instance, 40% of this energy is used usefully to drive in the pile. The pile moves 0.20 m into the ground.

Determine the average resistive force acting on the pile as it moves through the ground.

(3)

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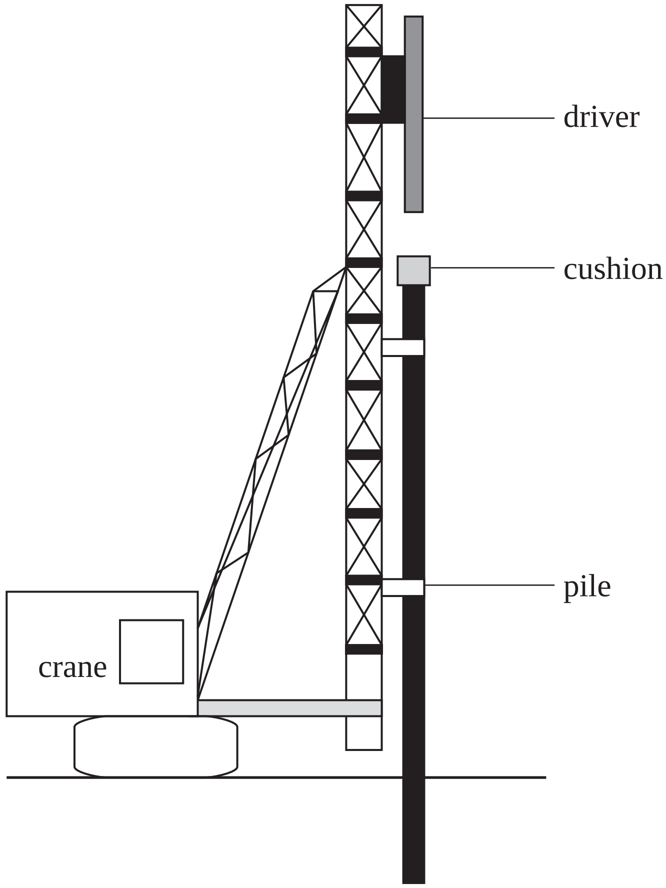
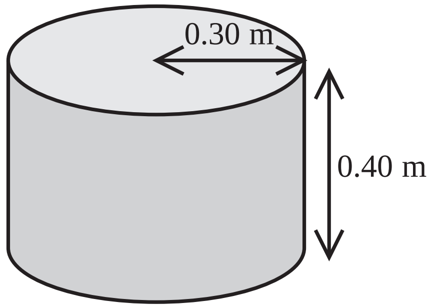
Average resistive force =

(b) In order to protect the driver on modern pile drivers, a cushion made of wood is placed on the pile.



The cushion is a cylindrical piece of wood of Young modulus = 120 MPa



The cushion is compressed when hit by the driver.

(i) The maximum compressive force applied to the wood during impact is 7.0×10^5 N. Show that the compression of the cushion is about 0.01 m.

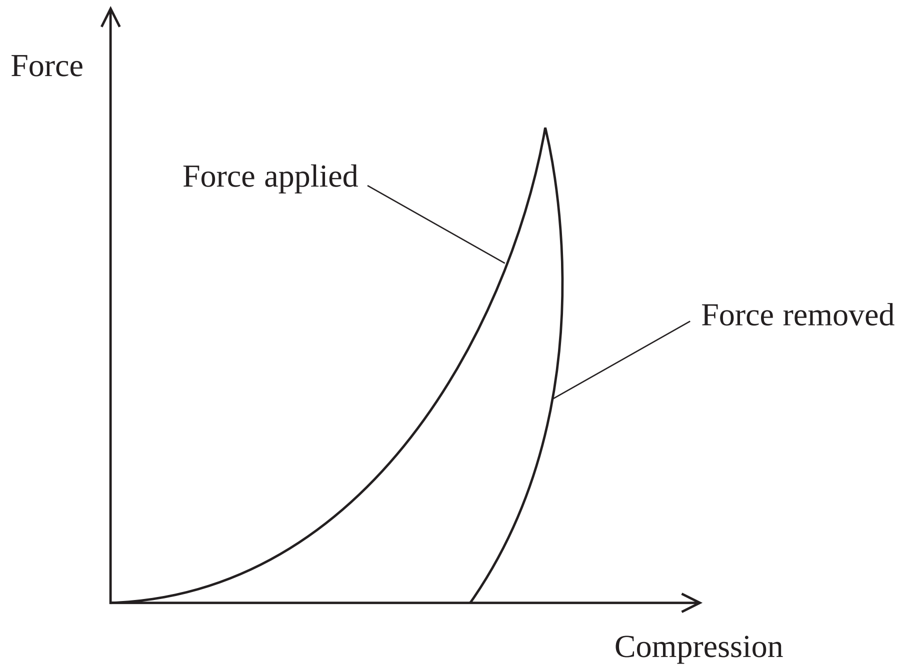
(3)

(ii) Calculate the energy stored in the cushion under compression.

(2)

Energy stored =

*(iii) The graph shows how the compression of the wooden cushion varies with force, as the force is applied and removed during an impact.



Use the graph to explain the following:

1. the wooden cushion has to be replaced after a few hundred impacts,

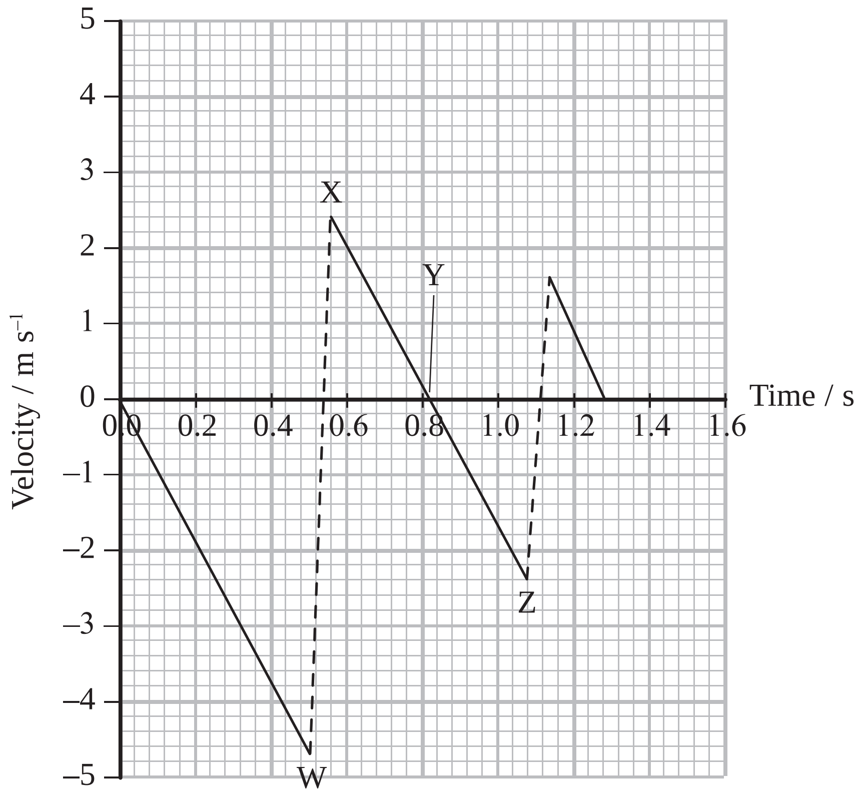
(2)

2. with each impact the temperature of the wooden cushion rises slightly.

(1)

(Total for Question = 13 marks)

3 A basketball is dropped vertically onto the horizontal ground and bounces twice before being caught. The graph shows how the velocity of the basketball varies with time.



(a) Suggest why the downward sloping lines are all parallel.

(1)

(b) (i) State the reason for the upwardly sloping dotted lines.

(1)

(ii) Describe how the gradient of the dotted lines would change if the basketball was not fully inflated.

(1)

(c) Calculate the initial height through which the basketball fell.

(2)

Height =

(d) (i) Show that the kinetic energy of the basketball at X is about 1 J.

mass of ball = 0.4 kg

(2)

(ii) Hence calculate the height of the basketball at Y.

(2)

Height =

(e) The velocity of the basketball on impact at W is greater than the velocity on impact at Z.

State a reason for the difference in velocities at W and Z.

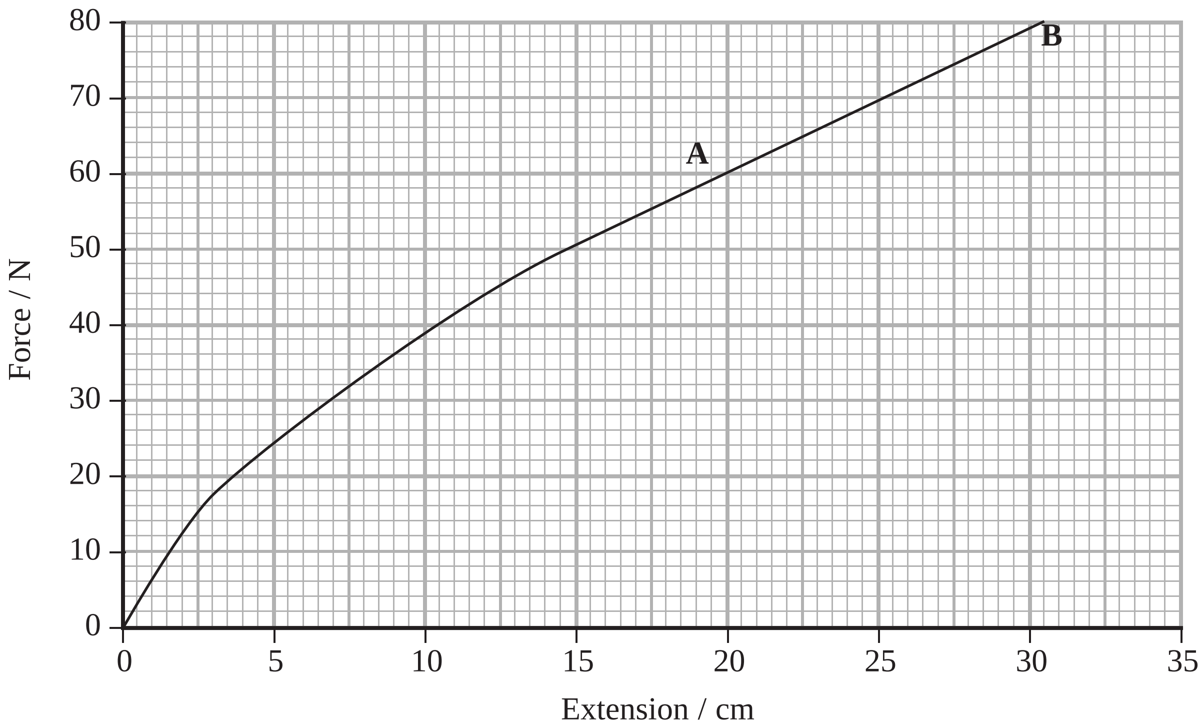
(1)

(Total for Question = 10 marks)

4 The photographs show an exercise device and someone using it. The device contains two rubber cords which are extended when the device is used.

A student investigates the properties of the device by hanging weights on it and measuring the extension.

The student obtains the following graph for her results.



(a) The student notices that her graph is a straight line between A and B and concludes that the device obeys Hooke's law.

Comment on this conclusion.

(2)

(b) (i) Describe how the student could use the graph to obtain an estimate of the total work done.

(2)

(ii) The student sets up a spreadsheet to investigate the work done in stretching the device each time a weight is added.

	A	B	C	D
1	Total stretching force / N	Extension / cm	Change in extension / m	Work done (force × change in extension) / J
2	0	0.0	0.000	0.00
3	10	1.6	0.016	0.16
4	20	3.5	0.019	0.38
5	30	7.0	0.035	1.05
6	40	10.5	0.035	1.40
7	50	14.5	0.040	2.00
8	60	20.0	0.055	3.30
9	70	25.2	0.052	3.64
10	80	30.5	0.053	4.24
11			Total work done	16.17

Explain why this spreadsheet results in an over-estimate for the total work done.

(2)

(c) The student eats a packet of crisps and then uses the exercise device. The energy content in a packet of crisps is 540 kJ. During exercise this energy is converted and 25% of it is transferred to mechanical work.

The student extends the device fully 15 times in 1 minute. An accurate value for the work done in fully extending the device is 14.7 J.

Calculate the time it would take the student, working at this rate, to transfer 25% of the energy from the crisps to mechanical work.

(3)

Time =

(d) Explain whether more or less work would be done applying the same maximum total stretching force to a similar exercise device with rubber cords of twice the cross-sectional area.

(2)

(Total for Question = 11 marks)

5 Metrology is the science of measurement and World Metrology Day is May 20th. In 2010, the day was used to celebrate the 50th anniversary of the SI system.

A metrologist from the National Physical Laboratory said on a radio programme that the SI system uses units that everyone can understand. He stated the following example.

> "If you hold an apple in your hand it's about a *newton*, if you raise it through one metre that's about a *joule* and if you do it in one second that's about a *watt*."

Assuming that the apple has a mass of 100 g, explain and justify the statements made about the three words in italics.

(6)

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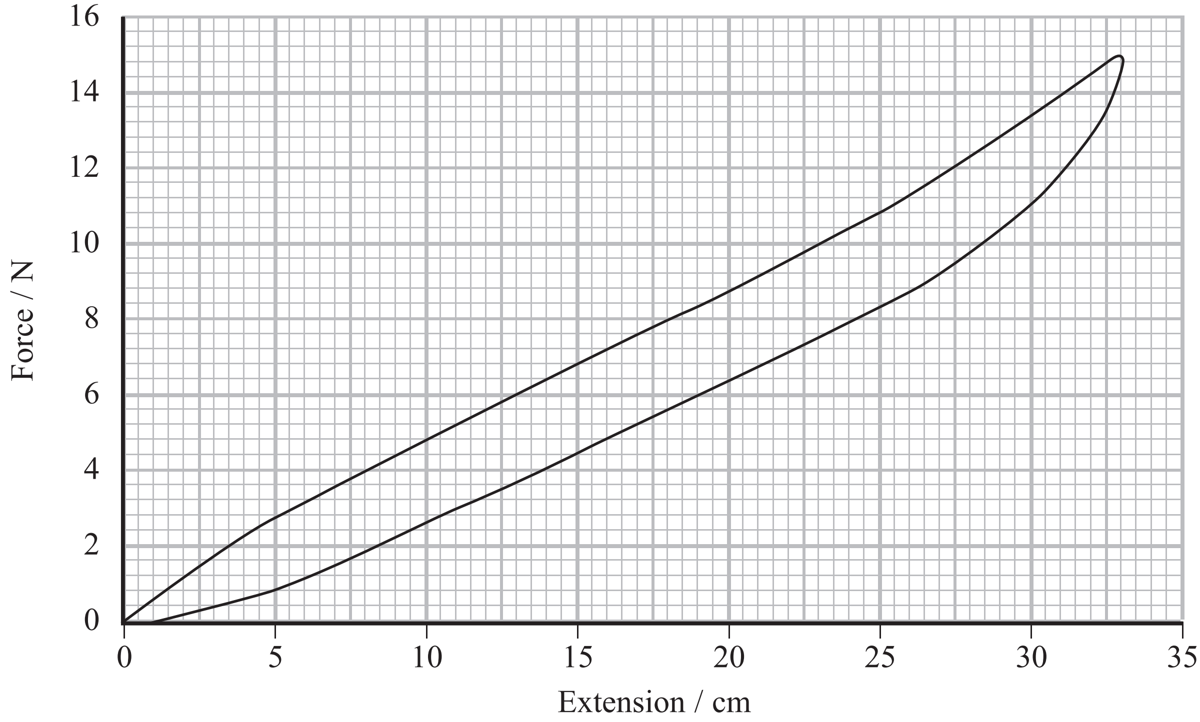
(Total for Question 6 marks)

6 A student investigates the effect of varying the stretching force applied to the elastic waistband of some trousers.



The graph produced by the student shows the stretching force against extension for the elastic waistband. The top line was recorded as the force increased and the lower line as the force decreased.

(a) Explain whether the elastic waistband obeys Hooke's law.

(2)

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(b) Show that, in this investigation, the work done on the elastic waistband in stretching it is less than 3 J.

(2)

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(c) Suggest how the elastic properties of the waistband help in keeping the trousers in place.

(2)

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(d) The line for the decreasing force is lower than the line for the increasing force.

Explain the significance of this.

(2)

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(Total for Question 8 marks)