St. Mary's Anglican Girls' School

Semester I Exam

2009 Question/Answer Booklet

PHYSICS 12

(Questions marked with a * are for the pre 2010 course)
(Stars have not been placed in the answer key only in the blank question paper)

<u>TIME ALLOWED FOR THIS PAPER</u>

Reading time before commencing work:	10 minutes
Working time for paper:	2 ½ hours

<u>MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER</u>

TO BE PROVIDED BY THE SUPERVISOR
This Question/Answer Booklet.
Physical Formulae and Constants sheet.

TO BE PROVIDED BY THE CANDIDATE
<u>Standard Items</u>
Pens, pencils, eraser or correction fluid, ruler.
<u>Special Items</u>
Physical formulae and constants sheet, drawing implements, templates and calculators satisfying the conditions set by the Curriculum Council.

<u>IMPORTANT NOTE TO CANDIDATES</u>

No other items may be taken into the examination room.

It is your responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. Please check carefully and if you have any unauthorised material with you hand it in to the supervisor BEFORE reading any further.

NAME: ______________________________

	Short Answer	Problem Solving	Comprehension	%
Out of				

	/48	/84	/35	/167
% Weighting	/30	/50	/20	/100

STRUCTURE OF THE PAPER

Section	No of questions	No of marks out of 167	Proportion of exam total
A: Short Answers	12	48	30%
B: Problem Solving	7	84	50%
C: Comprehension and Interpretation	1	35	20%

INSTRUCTIONS TO CANDIDATES

Write your answers in the spaces provided beneath each question in sections A and B
The value of each question in section A is four marks.

Note that (where appropriate) answers should be given numerically and they should be evaluated **and not left in fractional or radical form**. Give all numerical **answers to three significant figures** except in the cases for which estimates are required.

Questions containing specific instructions to **show working** should be answered with a complete, logical, clear sequence of reasoning showing how the final answer was arrived at; **correct answers which do not show working out will not be awarded full marks**.

Questions containing the instruction **estimate** may give insufficient numerical data for their solution. Candidates should provide appropriate figures to enable an approximate solution to be obtained.

Candidates should remember that when descriptive answers are required, they should be used to display understanding of the aims and objectives of the Physics 12 course. A descriptive answer, which addresses the context of a question without displaying an understanding of physics principles, will not attract marks.

Despite an incorrect final result, credit may be obtained for method and working, provided these are **clearly and legibly set out**.

SECTION A : Short Answers - 48 Marks (30%)

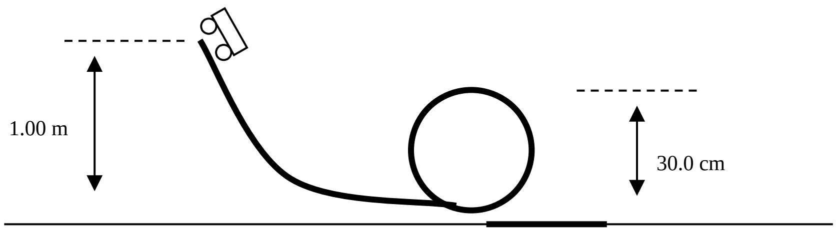
Attempt ALL 12 questions in this section.
Show all working out. (4 marks each)

A1. A person is throwing horse shoes at an iron rod that has been driven into the ground. If the horse shoe hits and stays on the iron rod, you win the game. The horse shoe is thrown from a height of 1.10m above the ground and is 6.00 m from the iron rod. If the horse shoe is to hit the rod where it touches the ground and the horse shoe is thrown purely horizontally initially, at what speed is it thrown?

A2. Two balls of identical volume and surface area but very different mass are dropped from a height of 1000 m above the ground through the earth's atmosphere. Which ball hits the ground first? Explain why.

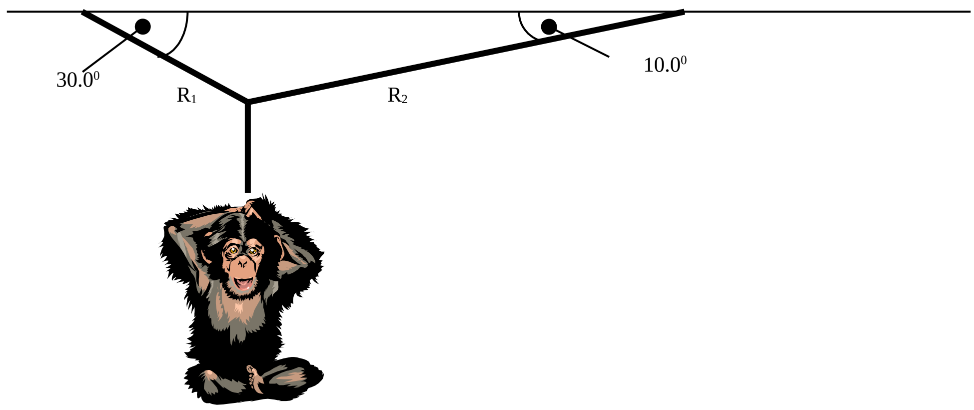
A3. A 1000.0 kg car is driving around a corner at 30.0 km/h on a flat level wet road. Calculate the minimum radius of curvature the driver can use without the car slipping if the maximum value of friction between the car and the road is 4900.0 N?

***A4.** A 4 year old child is dropping matchbox cars down a track and then through a vertical loop the loop. What is the speed of the car at the top of the loop if the loop has a diameter of 30.0 cm and the car is dropped from a height of 1.00 m?

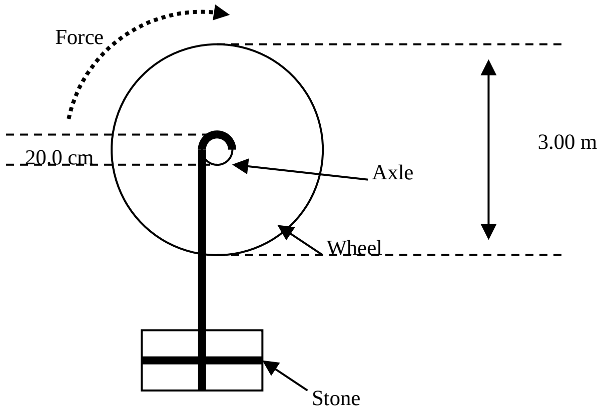


A5. Estimate the weight of an egg on the surface of Neptune, if Neptune has a mass of 9.99×10^{25} kg and a radius of 2.48×10^{7} m.

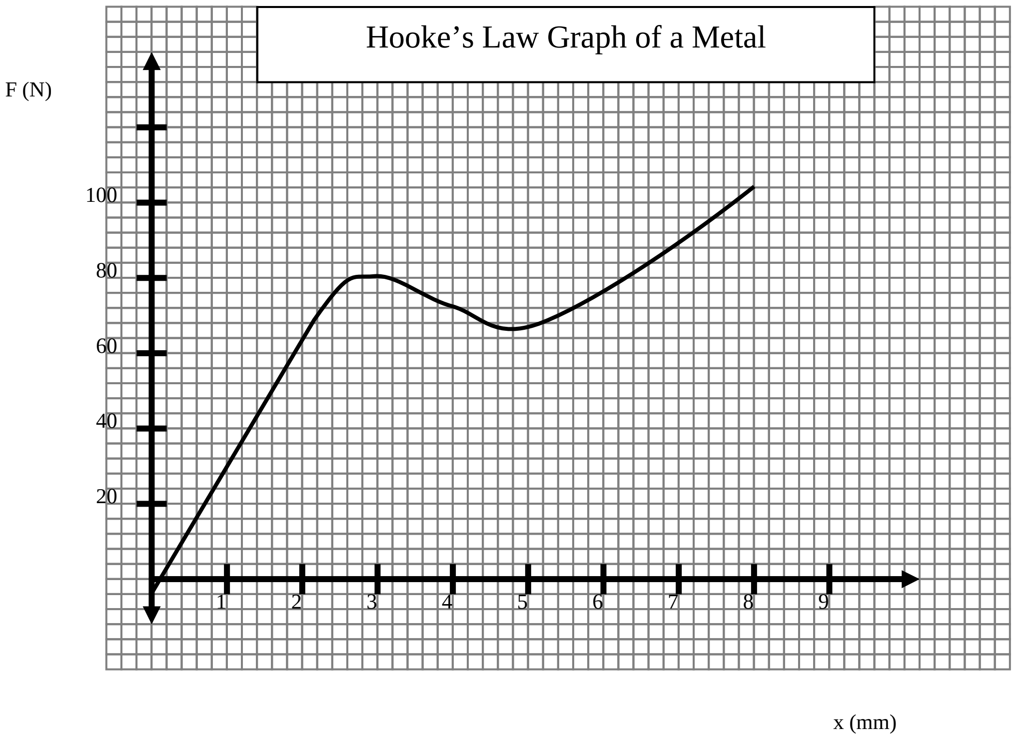
A6. Some physics students stow away on a biology excursion to the Perth Zoo. They see a very cute 40.0 kg baby orangutan hanging from a rope. What is the tension in rope 1 and rope 2?



A7. In ancient Egypt a Hebrew is lifting a 110.0 kg stone using a wheel and axle. The rope wraps itself around a 20.0 cm diameter axle. A wheel attached to the axle has a diameter of 3.00 m. What is the minimum force applied to the wheel to lift the stone (assuming no friction)?



***A8**.



a) From the graph what is the spring constant "k"?

(2 marks)

b) What is the ratio of energy stored at 60 N compared to 20 N?

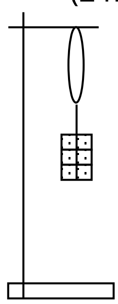
(2 marks)

***A9.** A dog has a mass of 15 kg and is standing on 4 legs. If the mass of the dog is evenly supported by each of its four legs, and each leg bone has a cross sectional radius of 1.50 cm, what is the stress on each leg?

***A10.** A CSIRO scientist has invented some identical elastic bands that stretch uniformly under an increasing or decreasing load. She decides to test them. An unstrained elastic band has a length of 8.00 cm. When a mass of 150.0 g is hung from the elastic band, it stretches to a new length of 9.50 cm.

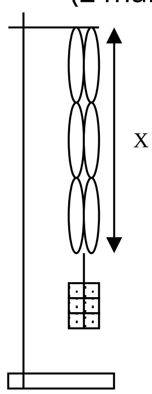
a) What is the strain on the band?

(2 marks)



b) She now joins 6 elastic bands as shown in the diagram below and re-hangs the 150.0 g mass. What is the distance marked X in the diagram?

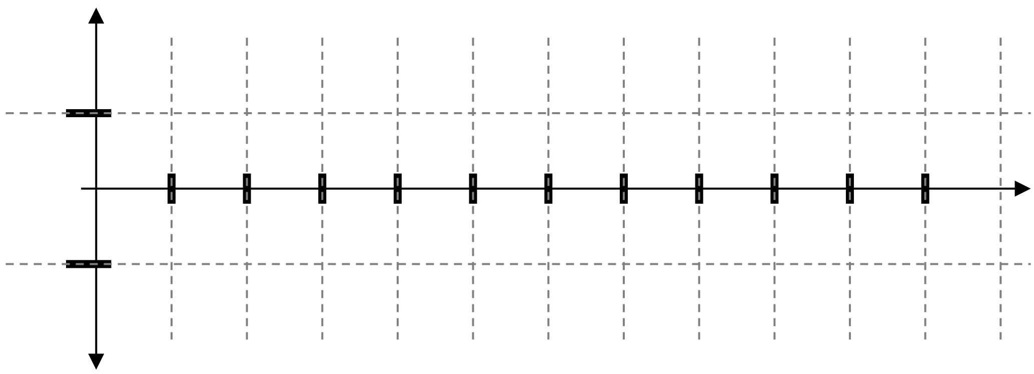
(2 marks)



A11. What does the human ear hear as a sound is altered in the following ways from 2000 Hz?

Change	Perception
Wavelength increases	
Frequency increases	
Amplitude increases	

A12. A sound is travelling in air at 340 m/s. The frequency of the sound is 1000 Hz. Draw and label a transverse graph of a single air particle oscillating with an amplitude of 0.5 cm. Be sure to show one complete cycle.



SECTION B : Problem Solving - 84 Marks (50%)

Attempt ALL 7 questions.

B1. (Total = 12 marks)

An astronaut is playing golf on the moon. She strikes the ball with a club and gets the ball into the hole with no bounces. For the purposes of this calculation the gravity on the moon is 1/6th that on earth. The moon has no atmosphere. A golf ball is struck at 15.0 m/s at an angle of 10.0^{0} above the horizontal. The ball lands at the same height from which it was struck.

a) What is the final velocity of the golf ball just before it enters the hole?

(1 mark)

b) What is the maximum height of the golf ball?

(3 marks)

c) What is the time of flight of the golf ball to the hole from takeoff?

(3 marks)

d) What is the velocity of the golf ball at its maximum height?

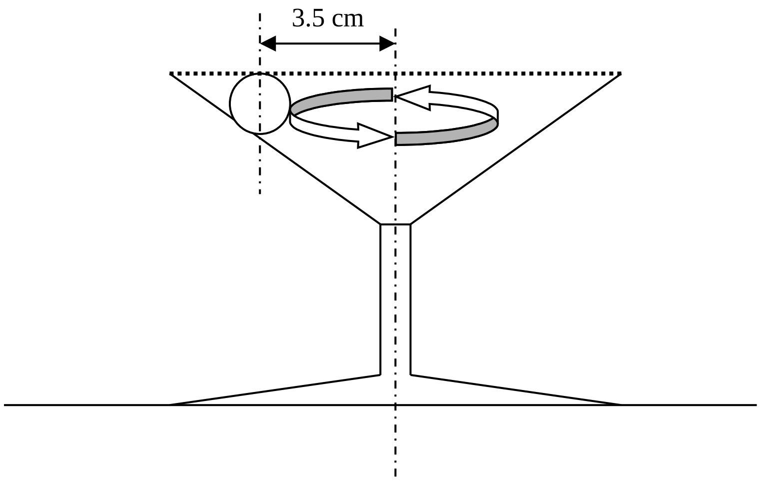
(3 marks)

e) Estimate the force of the club on the ball if the collision between club and ball takes 0.02 seconds.

(2 marks)

B2. (Total = 12 marks)

A perfectly circular 5.00g olive is rolling around the side of a martini glass at 0.530 m s^{-1} as shown in the diagram below. The side of the glass is slippery and exerts no fictional force on the olive.



a) Draw a labeled free body diagram of the forces acting on the olive on the diagram above.

(2 marks)

b) What is the centripetal force acting on the olive?

(3 marks)

c) What is the size of the force that that the side of the glass exerts on the olive?

(3 marks)

d) Is the olive accelerating? Explain.

(2 marks)

e) Despite the olive being perfectly round and the sides of the glass being perfectly slippery, will the olive continue to roll in a circle for ever? Explain.

(2 marks)

B3. (Total = 12 marks)

a) A spacecraft is taking astronauts to the moon from the earth. At what height above the surface of the earth will a 78.0 kg astronaut weigh half his weight on the surface of the earth?

(4 marks)

When man first walked on the moon they had to land in a special landing craft. The landing craft was sent from a second space craft orbiting directly above the landing position. This means that the second space craft is “geostationary” (lunostationary) above the moon. The period of rotation of the moon is quite slow (27.32 days).

b) What is the height of the second space craft above the surface of the moon in its “geostationary” orbit above the surface of the moon?

(3 marks)

c) Explain why the special landing craft had to land on the <u>equator</u> of the moon.

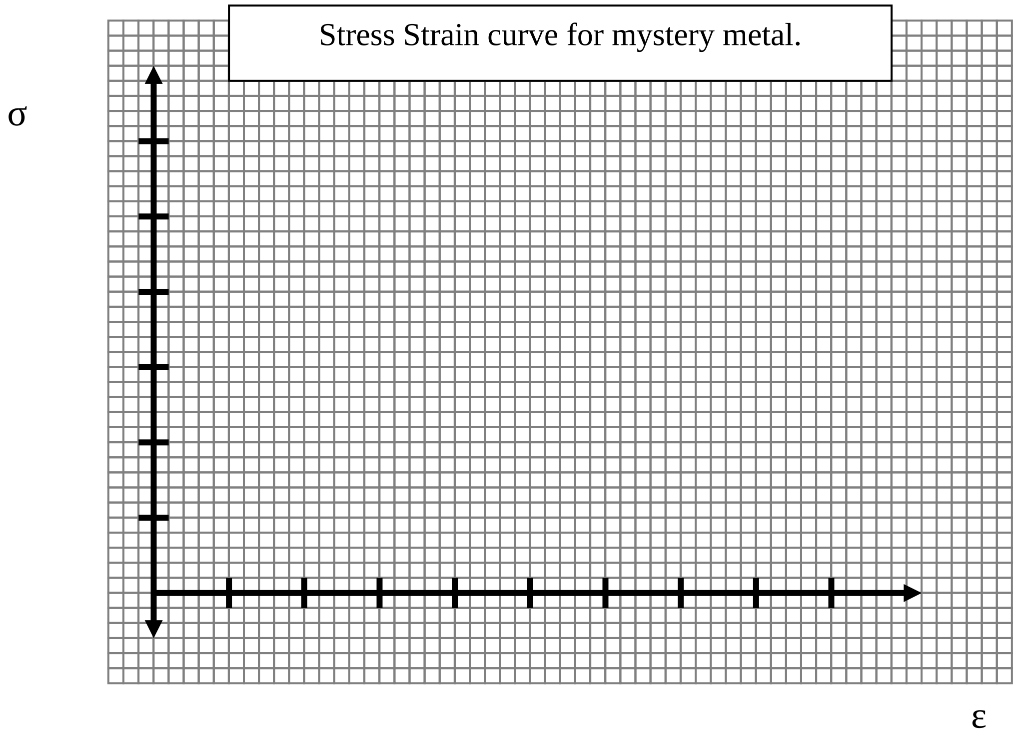
(2 marks)

d) Calculate the distance (point in space) from the centre of the moon at which the pull of the moon on a spacecraft equals the pull of the earth on the space craft.

(3 marks)

***B4. (Total = 12 marks)**

Onto the axes below place the following data points for a pure metal wire.



a) Proportional limit of 14.0×10^8 N m^{-2} at a strain of 0.0034 strain.

(1 mark)

b) Elastic limit of 16.0×10^8 N m^{-2} at a strain of 0.0044 strain.

(1 mark)

c) Join these points with a suitable curve.

(1 mark)

d) Using the Young's Modulus table on your constants sheet suggest which metal this graph is describing, with the support of calculations on the graph.

(1 mark)

e) What is the Hooke's law constant for this material if the metal has an original length of 4 m and a cross sectional area of 6×10^{-6} m^2

(3 marks)

f) What is the load on the wire when the wire contains 1.24 J of conservative energy?

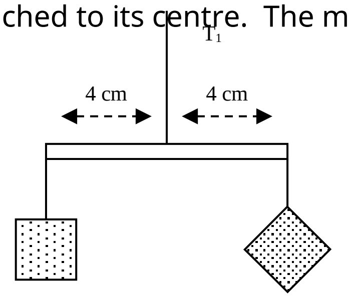
(3 marks)

g) Why is it impossible to plot the point at which the wire brakes (ultimate strength from constants sheet) on the graph? Explain.

(2 marks)

B5. (Total = 12 marks)

A toy maker is manufacturing a children's mobile to be hung above a baby's cot. The mobile hangs coloured squares of plastic from weightless threads off uniform wooden rods. Each square of plastic has a mass of 0.025 kg. The rod had a mass of 0.003 kg / cm. The first part of the mobile uses an 8 cm rod and two pieces of plastic. The rod is suspended from a thread attached to its centre. The mobile looks like this…



a) What is the mass of the rod?

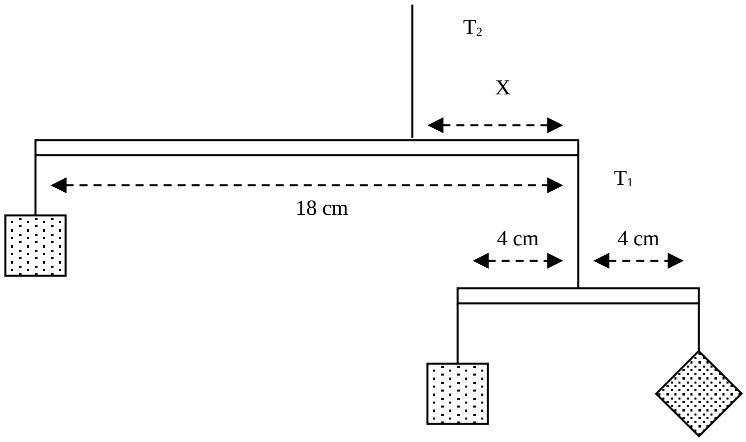
(1 mark)

b) What is the tension in the thread T_1?

(3 marks)

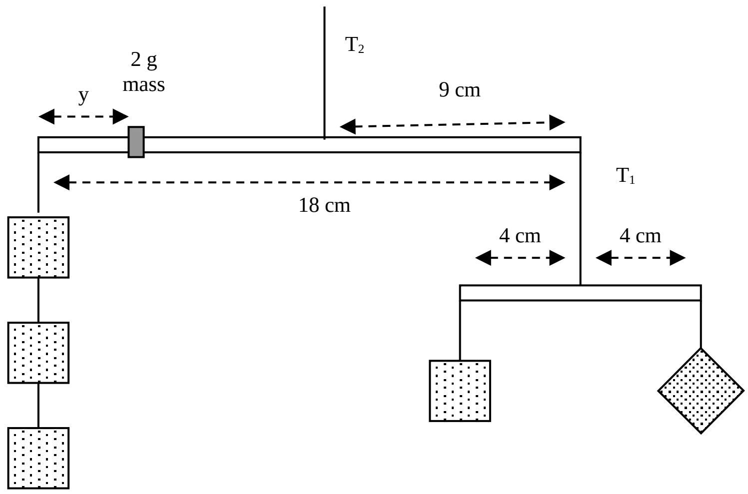
c) The mobile above is now hung from the right end of another 18.0 cm rod and a single piece of 0.025 kg plastic is hung from the left end as shown below. At what distance "X" should the supporting thread T_2 be attached if the 18.0 cm rod is to hang horizontal?

(4 marks)



d) A late design change is made and two extra 0.025 kg pieces of plastic are added to the left end of the rod to make a total of 3 pieces of plastic on the left end. The vertical supporting thread is placed at the centre of the 18 cm rod. A small 2 .00 g mass will need to be added to the 18 cm rod to make it hang horizontal. Where should this mass be added?

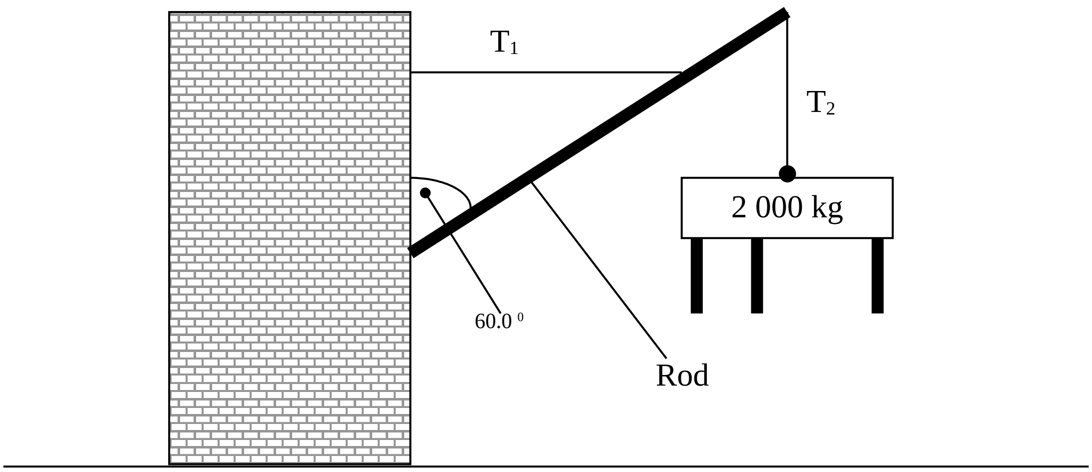
(4 marks)



***B6. (Total = 12 marks)**

(this contains non perpendicular forces but you should be able to manage it.

A grand piano is being loaded onto a truck using the primitive crane below. The rod is 3.00 m long. The rope T_1 is attached to the wall at right angles and attached to the rod 1.00 m from its top end. The rope T_2 is attached to the end of the rod. The rod is uniform and has a mass of 30 kg.



a) Draw and label clearly all of the forces acting on the rod.

(2 marks)

b) What is the tension in rope T_2?

(1 mark)

c) What is the tension in rope T_1?

(4 marks)

d) What is the size and direction of the force of the rod on the wall?

(4 marks)

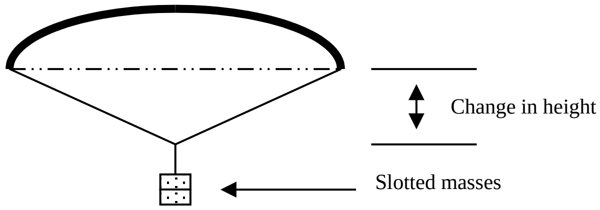
e) If the rope T_2 is lengthened as the piano is lowered, what will happen to the tension in T_1?

(1 mark)

B7. (Total = 12 marks)

(you can manage this but it is based on old syllabus)

A student who is interested in archery is doing an experiment with an archery bow. The student hangs slotted masses on the bow string of the bow and measures how much the string bends away from horizontal.



a) The following results were obtained. Convert the mass to weight and the height to S.I. units.

(1 mark)

Mass	**(g)**	50	100	200	300	400	500
Δ of Height	**(mm)**	2	3	11	10	13	17

b) Write a hypothesis as to the relationship between change in height and weight.

____ (1 mark)

c) What is the independent variable? ____________________

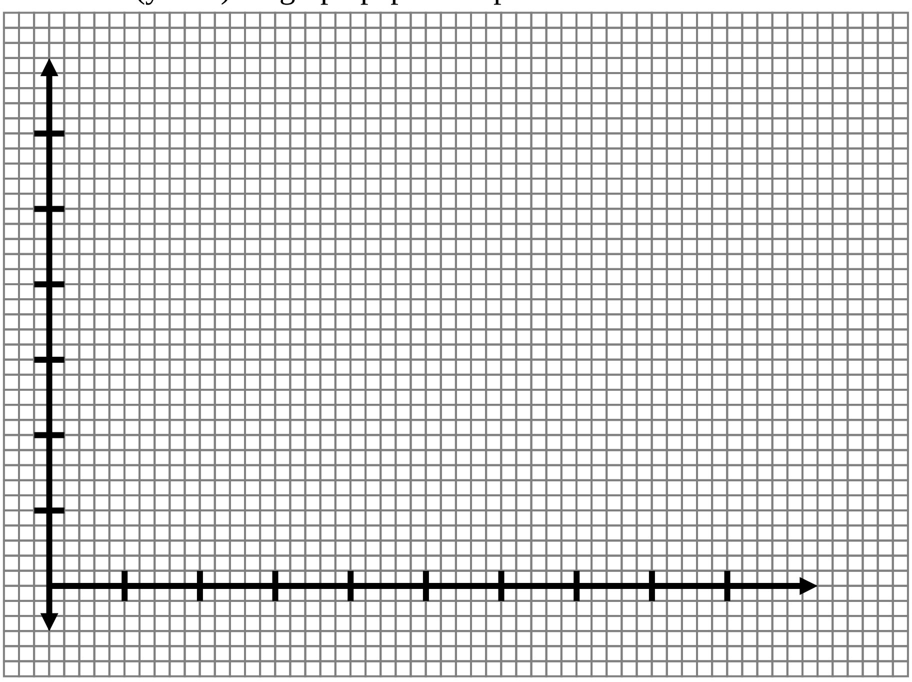
(1 mark)

d) What is the dependant variable? ____________________

(1 mark)

e) Manually graph the independent variable (x axis) against the dependant variable (y axis) on graph paper and put in a line of best fit.

(3 marks)



f) Calculate the slope of the line on the graph paper.

(1 mark)

g) State the mathematical relationship for the graph?

(1 mark)

h) What is the work done on the bow string when 350.0 g is hung from the string? (Work = mg Δh)

(1 mark)

i) Explain why the data is or is not reliable.

(1 mark)

j) Explain why the hypothesis is or is not valid.

(1 mark)

SECTION C : Comprehension and Interpretation - 35 Marks (20%)

Read the passage below carefully and answer all of the questions at the end of the passage. Candidates are reminded of the need for correct English and clear and precise presentation of answers.

Show all working out for questions requiring numerical answers.

***1. (Total = 17 marks)**

Ropes

Ropes and tethers are designed to support tensile loads; either stationary loads as for a suspension bridge, or dynamic loads as for a falling rock climber.

What is a rope?

A rope is a bundle of fibres/threads/wires twisted together. So why not just use a thicker single strand? While a single strand should have the same strength as a rope of the same cross sectional area there are several reasons why a rope is often a better solution.

- If one fibre fails the rope remains intact - whereas a rope made of a single large fibre would fail catastrophically.
- Thin fibres often have higher strength than thick ones made from the same material. Glass fibres are a good example of fibres which are strong in tension when thin because they are unlikely to contain a strength limiting defect. Drawn polymer fibres have much better mechanical properties than polymer products made by ordinary polymer processing, but such fibres can only be made in small diameters.
- A multi-stranded rope is more flexible than a single strand of the same diameter - for example multi-stranded copper 13A cable is much easier to bend than the single strand copper wire of the same diameter used in ring-main cables.

	Suspension cable	**Climbing rope**
Required strength	high	medium
Allowable weight	low	low
Stretch Requirements	high Young's modulus	high elongation
Flexibility	little required	great
Impact toughness	medium	high
Creep resistance	high	low
Notes	Since these are used to suspend bridges the most important criterion is strength in tension. Because it is important that the bridge does not flex too greatly under strong winds or during the passing of large lorries, the stiffness (Young's modulus) must also be high. In addition, for very large span bridges the weight of the cables themselves is also important. For this reason a specific stiffness - specific strength chart (below) is useful for identifying suitable materials - the chart shows a selection of materials available as fibres. Until recently steel cables have been used for bridge type applications. **Steel wire** such as that used inside pianos (patented steel wire) can have a very high tensile strength, but it is quite heavy. Recently very high specific stiffness and strengths have been recorded for **synthetic fibres**. These are now used in suspension bridges by incorporating fibres into a matrix to form a composite bundle. This is then twisted with others to form a rope. Creep properties (the gradual extension over time under a tensile load) are	Unlike suspension cables, climbing ropes are not designed to be continuously under load. This means that creep is much less of an issue. Climbing ropes are primarily used in the event of a fall. If a climber should fall, then the rope must be able to stop the fall without breaking, but also without too rapid a deceleration (the opposite of acceleration) since this can also cause injury. This design constraint is met by requiring materials with a large elastic elongation before failure (see below). The weight of the material is also important - partly as a lead climber has the weight of the rope hanging below them, but also because climbing gear is often carried for large distances. Original climbing ropes were made of **hemp** - a natural fibre that is similar to **cotton**. Modern ropes are made of **nylon**, or combine a fibre core with a protective textile sheath (using nylon and **rubber**).

	also very important.	

Good performance at low weight?

Ranking candidate materials

Two important material characteristics needed to satisfy the design requirements for climbing ropes are:

i. the elastic elongation to failure, and
ii. how much energy the rope can absorb by elastic stretching before breaking.

These quantities are not separate material properties, but depend on two familiar properties - strength and Young's modulus - as follows:

elastic strain at failure = strength/Young's modulus

elastic energy stored at failure (per unit volume) = ½ x strength x elastic strain at failure

	Young's modulus (GPa)	Density (kg/m^3)	Ultimate Strength (MPa)
Cotton	7.9	1,540	225
Hemp	32	1,490	300
Bulk Polyester	2.9	1,300	50
Bulk Nylon	2.5	1,090	63
Carbon Fibre	300	1,770	3,430
Aramid Fibre	124	1,450	3,930
Polyester Fibre	13.2	1,390	784
Nylon Fibre	3.9	1,140	616
Alloy Steel	210	7,800	1,330

Safety factors in design

For parachute lines and climbing ropes, where safety is the most important requirement, designers apply what is called a "safety factor". If you design a product that has to be strong and design it to survive to 5 times the expected maximum load, this is a safety factor of 5.

Extracted on 23/4/2009 from
http://www-materials.eng.cam.ac.uk/mpsite/short/OCR/ropes/default.html

1. Why do suspension cables for suspension bridges need to be light?

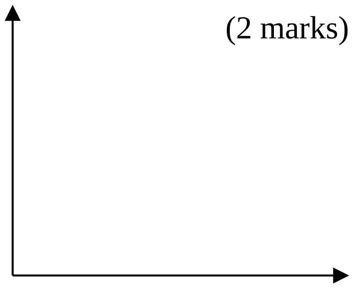
(2 marks)

2. What type of Young's modulus does a mountain climber require? Explain.
(2 marks)

3. What is the advantage of a rope made from multiple fibres compared to a rope made from a single fibre?
(1 mark)

4. Using the table above, give an example of a material that would make a good mountain climbing rope? Explain with reference to the all the numbers in the table.
(4 marks)

5. Why do ropes have a safety factor "built" into them? Explain with reference to a Young's modulus graph drawn by you.
(2 marks)



6. What is the elastic strain at failure of a hemp rope? Explain any assumptions present in your calculation.
(3 marks)

7. What is the elastic energy (per unit volume) stored at failure in a nylon fibre rope?
(2 marks)

8. What is creep?
(1 mark)

2. (Total = 18 marks)

Crashing a Drag Racer.

(Paragraph 1)
My first two runs got me acclimatised to the sheer power delivered by the jet engine and the technique needed to keep the car straight – Colin advised me that to counter the camber and the cross wind, I had to apply a constant 30 degrees of steering input. On the third run, the after burner failed to ignite properly. But the next time, the car exploded into action – a manic, violent thing. Just 23 seconds after hitting that little (afterburner) switch, the run was finished. I'd ridden a wave of power that ten Formula One cars together would struggle to achieve.

(Paragraph 2)
I was ecstatic. Colin and the crew knew from the onboard telemetry (but didn't tell me) that I'd hit 314.4 mph (506 kmh), faster than the official British land-speed record.

There was time for one more run.

(Paragraph 3)
(t = 0 secs, v = 0 kmh)
Colin begins the start procedure. The noise builds to the whine of a jet as Colin gives the all-clear. The power dial is set to 125%. I hit the switch and release the brake. In under eight seconds we're doing 200 mph (320 kmh).

(Paragraph 4)
(t = 14.25 secs, v = 464 kmh)
By the time my senses have sped up enough to keep pace with what's going on, I realise that something is wrong. This is not the usual push and pull of the steering as the front end scrabbles to keep the one-tonne car and its passenger heading in a straight line.

(Paragraph 5)
(t = 14.64 secs, v = 459 kmh)
I am counter steering now and battling something. Unknown to me, the front right tyre has suffered a catastrophic and total failure. On video footage, the front of the car leaps high enough with the (tyre) explosion to lift the other front wheel clear off the ground.

(Paragraph 6)
(t = 15.00 secs, v = 449 kmh)
The car veers off to the right. My foot hits the brake – instinctively but useless. I am still fighting. But I am losing.

(Paragraph 7)
(t = 15.71secs, v = 373 kmh)
I know I'm going to crash. I remember the parachute lever. I pull it. The car does not stop and begins to roll over. The next thing to happen, I am quietly convinced, is that I die. I am not scared, my life does not flash before my eyes: there is just a calm resignation. And I pass out as the g-forces generated by the crash exceed those at which I can maintain consciousness.

(Paragraph 8)
The roll bars protect my head, but they dig into the grass, slowing the car from 373 kmh to 307 kmh in just 0.46 seconds. My brain is thrown forward, distorted; its shape elongated, hitting the front of my skull. The force my brain experiences, overstretches some of the nerves and causes them to break. The resulting injuries could leave me paralysed, deaf, blind, or wipe out my personality – the person I recognise as me.

This article is extracted from Australian Readers Digest – March 2008
"The day I died at 449 km h" by Top Gear's Richard Hammond p123 – 137

1. What 2 things are wrong with the article's use of the units "kmh" from a physicist perspective?

(2 marks)

2. Mathematically derive the relationship that converts "mph" (miles per hour) to "kmh" (kilometres per hour) using the numbers in paragraph 2, if 0.00 mile / h equals 0.00 km/h (Note the relationship is linear).

(3 marks)

3. What is the acceleration of the drag racer if it accelerates to "320 kmh in 8 seconds"? (Paragraph 2)

(3 marks)

4. Why does the car begin to turn upwards into the air when the tyre explodes? (Paragraph 5)

(2 marks)

5. How does deploying a parachute behind a fighter aircraft or drag racer cause the vehicle to slow? (Paragraph 7)

(2 marks)

6. Why does strong acceleration cause a person to black out? (Paragraph 7)

(2 marks)

7. If the driver has a mass of 70.0 kg what is the magnitude and direction of the force on the driver if the driver (and car's) velocity change from "from 373 kmh to 307 kmh in just 0.46 seconds". (Paragraph 8)

(3 marks)

8. Why is the driver's brain thrown forward even though the seat belt acting on the driver is causing the driver's body to stop? (Paragraph 8)

(1 mark)

End of Exam

St. Mary's Anglican Girls' School

Semester I Exam

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PHYSICS 12

Answers

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The value of each question in section A is four marks.

Note that (where appropriate) answers should be given numerically and they should be evaluated **and not left in fractional or radical form**. Give all numerical **answers to three significant figures** except in the cases for which estimates are required.

Questions containing specific instructions to **show working** should be answered with a complete, logical, clear sequence of reasoning showing how the final answer was arrived at; **correct answers which do not show working out will not be awarded full marks**.

Questions containing the instruction **estimate** may give insufficient numerical data for their solution. Candidates should provide appropriate figures to enable an approximate solution to be obtained.

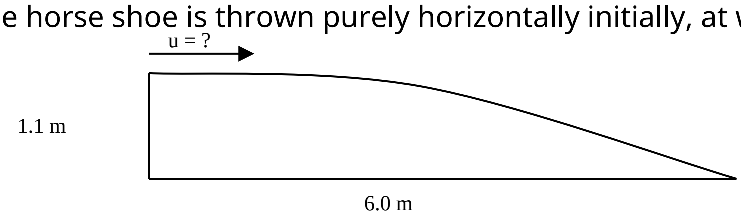
Candidates should remember that when descriptive answers are required, they should be used to display understanding of the aims and objectives of the Physics 12 course. A descriptive answer, which addresses the context of a question without displaying an understanding of physics principles, will not attract marks.

Despite an incorrect final result, credit may be obtained for method and working, provided these are **clearly and legibly set out**.

SECTION A : Short Answers - 48 Marks (30%)

Attempt ALL 12 questions in this section.
Show all working out. (4 marks each)

A1. A person is throwing horse shoes at an iron rod that has been driven into the ground. If the horse shoe hits and stays on the iron rod, you win the game. The horse shoe is thrown from a height of 1.10m above the ground and is 6.00 m from the iron rod. If the horse shoe is to hit the rod where it touches the ground and the horse shoe is thrown purely horizontally initially, at what speed is it thrown?



V	H
u = 0	u = ?
s = ut + ½ at	
$-1.1 = 0 + ½ \times -9.8 \times t^2$	
t = 0.474 s	
	u = s / t
	u = 6 / 0.474
	u = 12.7 m s^{-1}
	(Note - horizontally not req.)

A2. Two balls of identical volume and surface area but very different mass are dropped from a height of 1000 m above the ground through the earth's atmosphere. Which ball hits the ground first? Explain why.

The heavy ball hits the ground first.

Air resistance on both balls is the same (a function of surface area)

Weight is different

Resultant accelerating force on the object with more mass is larger than the small mass causing big mass to reach ground first.

Small Mass	Large Mass
$(- mg) + F_f = ma$	$(- mg) + F_f = ma$
Big small = big acceleration	Small + small = small acceleration

A3. A 1000.0 kg car is driving around a corner at 30.0 km/h on a flat level wet road. Calculate the minimum radius of curvature the driver can use without the car slipping if the maximum value of friction between the car and the road is 4900.0 N?

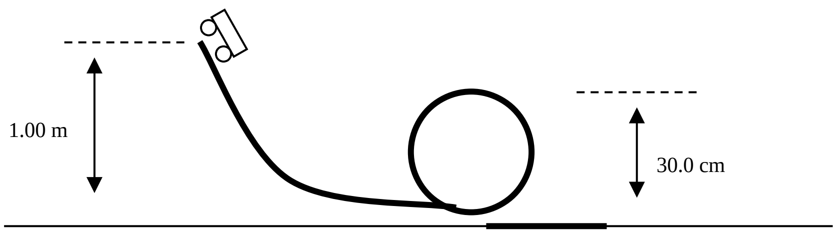
v = 30 / 3.6 = 8.33 m/s

$F_c = mv^2 / r$

$4900 = 1000 \times 8.33^2 / r$

r = 14.2 m

A4. A 4 year old child is dropping matchbox cars down a track and then through a vertical loop the loop. What is the speed of the car at the top of the loop if the loop has a diameter of 30.0 cm and the car is dropped from a height of 1.00 m?



Energy before		= Energy after		
mgh	=	mgh	+	$\frac{1}{2} mv^2$
gh	=	gh	+	$\frac{1}{2} v^2$
9.8 x 1	=	9.8 x 0.3	+	$\frac{1}{2} v^2$
9.8	=	2.94	+	$\frac{1}{2} v^2$

$(9.8 - 2.94) \times 2 = v^2$

v = 3.70 m/s

A5. Estimate the weight of an egg on the surface of Neptune, if Neptune has a mass of 9.99×10^{25} kg and a radius of 2.48×10^{7} m.

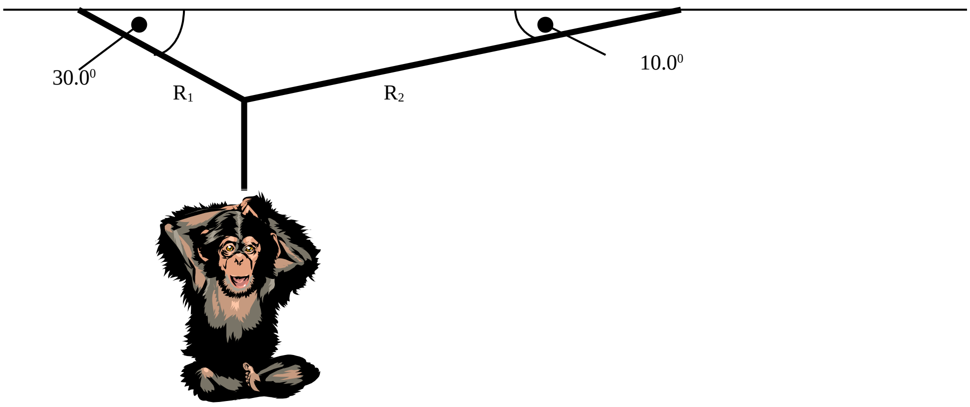
$m_{egg} = 50$ g = 0.05 kg

$F = G\, m_1 m_2 / r^2$

$F = 6.67 \times 10^{-11} \times 0.05 \times 9.99 \times 10^{25} / (2.48 \times 10^{7})^2$

$F = 5.42 \times 10^{-1}$ N down

A6. Some physics students stow away on a biology excursion to the Perth Zoo. They see a very cute 40.0 kg baby orangutan hanging from a rope. What is the tension in rope 1 and rope 2?



mg = 40 x 9.8 = **392 N**

$$\frac{392}{\sin 140^0} = \frac{R_1}{\sin 120^0} = \frac{R_2}{\sin 100^0}$$

$$\frac{392}{\sin 140^0} = \frac{R_1}{\sin 120^0}$$

$R_1 = 528$ N

$$\frac{392}{\sin 140^0} = \frac{R_2}{\sin 100^0}$$

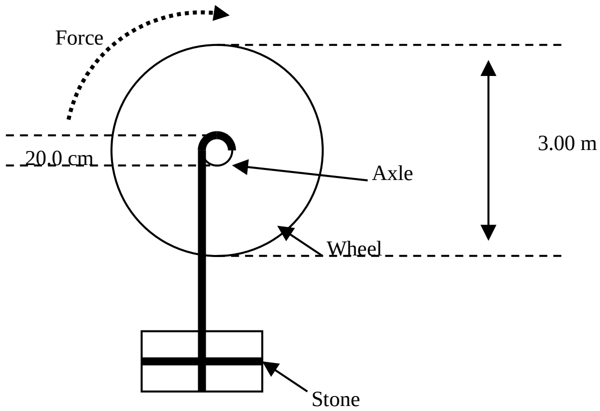
$R_2 = 601$ N

A7. In ancient Egypt a Hebrew is lifting a 110.0 kg stone using a wheel and axle. The rope wraps itself around a 20.0 cm diameter axle. A wheel attached to the axle has a diameter of 3.00 m. What is the minimum force applied to the wheel to lift the stone (assuming no friction)?

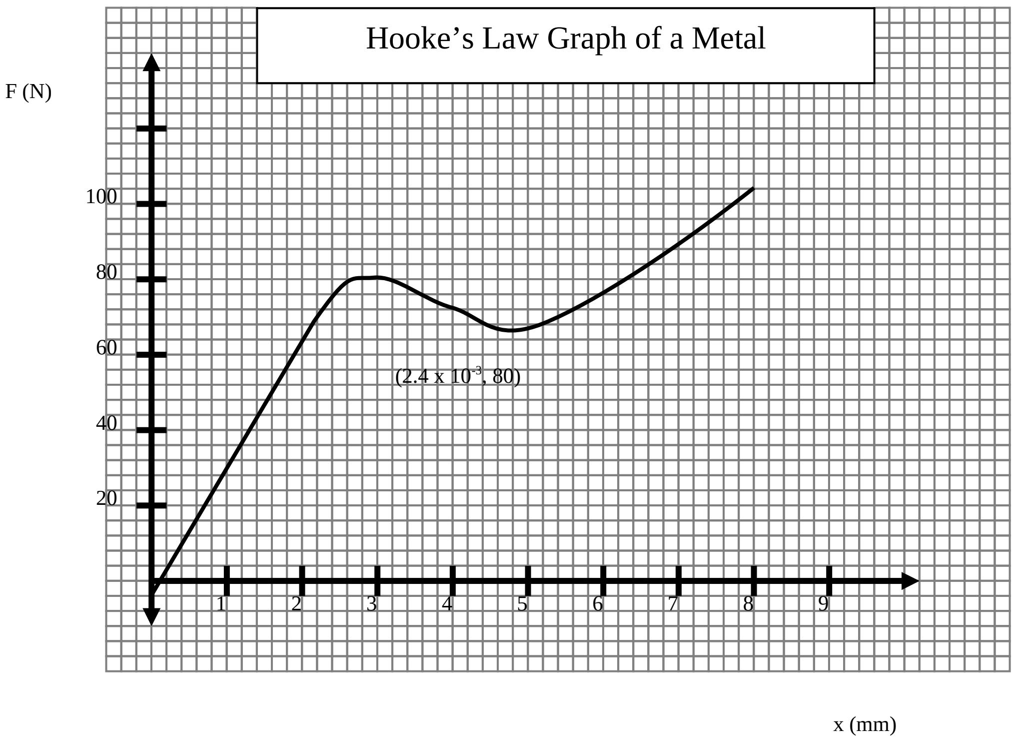
$r_{axle} = 0.1$ m
$r_{wheel} = 1.5$ m

$\Sigma M_c = \Sigma M_a$
$1.5 \times F = 0.1 \times 110 \times 9.8$
$1.5 \times F = 0.1 \times 1078$
$1.5 \times F = 107.8$

F = 71.9 N



A8.



a) From the graph what is the spring constant "k"?

(2 marks)

F = kx so k = F / x = rise / run
$k = (80 - 0) / (2.4 \times 10^{-3} - 0)$
$k = 80 / 2.4 \times 10^{-3}$
$k = 3.33 \times 10^{4}$ N m^{-1} (accept 3.1×10^{4} to 3.5×10^{4})

b) What is the ratio of energy stored at 60 N compared to 20 N?

(2 marks)

E = ½ Fx

Energy at 60	Energy at 20

$E = 0.5 \times 60 \times 1.8 \times 10^{-3}$ $E = 5.4 \times 10^{-2}$ J	$E = 0.5 \times 20 \times 0.6 \times 10^{-3}$ $E = 6 \times 10^{-3}$

Ratio = $5.4 \times 10^{-2} / 6 \times 10^{-3}$
Ratio = 9 : 1

A9. A dog has a mass of 15 kg and is standing on 4 legs. If the mass of the dog is evenly supported by each of its four legs, and each leg bone has a cross sectional radius of 1.50 cm, what is the stress on each leg?

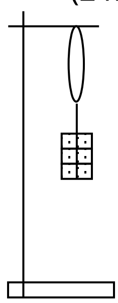
Stress = F / A

Method 1 = all force --- all legs	Method 2 = ¼ force --- one leg
Stress = 15 x 9.8 / 4 x pi x $(1.5 \times 10^{-2})^2$ Stress = 147 / 2.8278 x 10^{-3} **Stress = 5.20 x 10^4 N m^{-2}**	Stress = ¼ x 15 x 9.8 / pi x $(1.5 \times 10^{-2})^2$ Stress = 36.75 / 7.0695 x 10^{-4} **Stress = 5.20 x 10^4 N m^{-2}**

A10. A CSIRO scientist has invented some identical elastic bands that stretch uniformly under an increasing or decreasing load. She decides to test them. An unstrained elastic band has a length of 8.00 cm. When a mass of 150.0 g is hung from the elastic band, it stretches to a new length of 9.50 cm.

a) What is the strain on the band?

(2 marks)



Strain = $\Delta l / l_0$

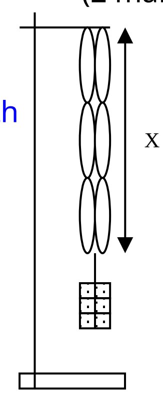
Strain = (9.5 – 8.0) x 10^{-2} / 8 x 10^{-2}

Strain = (1.5) x 10^{-2} / 8 x 10^{-2}

Strain = 1.88 x 10^{-1} Strain

b) She now joins 6 elastic bands as shown in the diagram below and re-hangs the 150.0 g mass. What is the distance marked X in the diagram?

(2 marks)



Method 1 (series / parallel)

Original change in length x series / parallel = new change in length

1.5 x 3 / 2 = 2.25 cm

add original lengths =0.0225 + (3 x 0.08) = 02.64 x 10^{-1} m

Method 2 – Young's modulus method.

One band	6 as shown
Y = $\frac{0.15 \times 9.8 \times 0.08}{(A \times 0.015)}$	Y = $\frac{0.15 \times 9.8 \times 0.24}{(2A \times \Delta l)}$

Set equal to each other

$$\frac{0.15 \times 9.8 \times 0.08}{(A \times 0.015)} = \frac{0.15 \times 9.8 \times 0.24}{(2A \times \Delta l)}$$

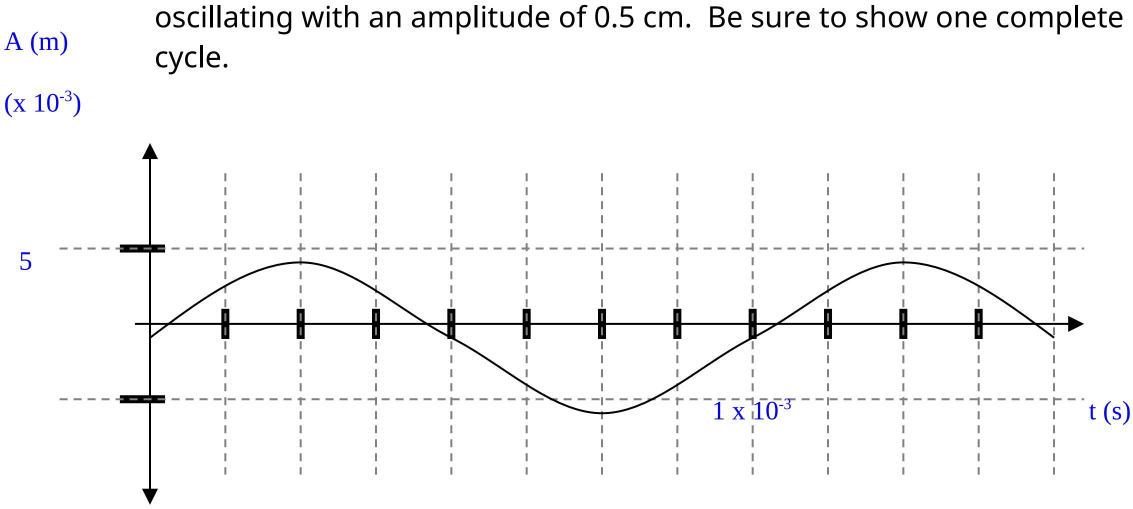
$\Delta l = 0.24 \times 0.015 / (0.08 \times 2) = 2.25 \times 10^{-2}$ m

$l = l_0 + \Delta l = (3 \times 0.08) + 2.25 \times 10^{-2} =$ **2.63×10^{-1} m**

A11. What does the human ear hear as a sound is altered in the following ways from 2000 Hz?

Change	Perception
Wavelength increases	Pitch Decreases (1) appears to get softer (½).
Frequency increases	Pitch increases (1) appears to get softer (½).
Amplitude increases	Appears to get louder. (1)

A12. A sound is travelling in air at 340 m/s. The frequency of the sound is 1000 Hz. Draw and label a transverse graph of a single air particle oscillating with an amplitude of 0.5 cm. Be sure to show one complete cycle.

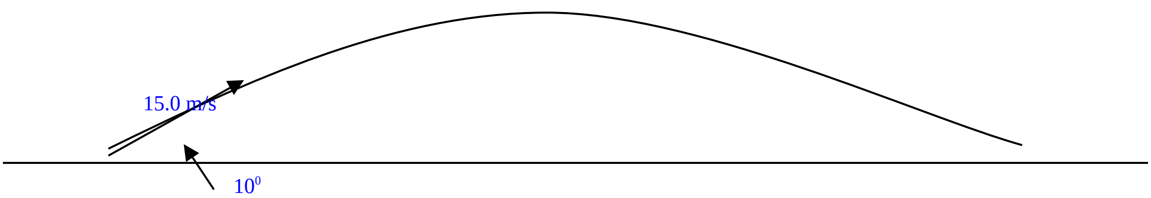


SECTION B : Problem Solving - 84 Marks (50%)

Attempt ALL 7 questions.

B1. (Total = 12 marks)

An astronaut is playing golf on the moon. She strikes the ball with a club and gets the ball into the hole with no bounces. For the purposes of this calculation the gravity on the moon is 1/6th that on earth. The moon has no atmosphere. A golf ball is struck at 15.0 m/s at an angle of 10.0^0 above the horizontal. The ball lands at the same height from which it was struck.



a) What is the final velocity of the golf ball just before it enters the hole?

(1 mark)

15 m/s at 10^0 below the horizontal

b) What is the maximum height of the golf ball?

(3 marks)

V	H
$u_v = 15 \text{ Sin } (10)$ $v_v = 0$ $v^2 = u^2 + 2as$ $0 = 15 \text{ Sin } (10)^2 + 2 \times (-9.8/6) \times s$ **s = 2.08 m**	

c) What is the time of flight of the golf ball to the hole from takeoff?

(3 marks)

V	H
$u_v = 15 \text{ Sin } (10)$ $v_v = -15 \text{ Sin } (10)$ $v = u + at$	

-15 Sin (10) = 15 Sin (10) + (-9.8/6) x t **t = 3.19 s**	

d) What is the velocity of the golf ball at its maximum height?

(3 marks)

$\frac{1}{2} m v^2 = mgh + \frac{1}{2} mv^2$

$0.5 \times 15^2 = ((9.8 / 6) \times 2.08) + 0.5 \times v^2$

$(112.5 – 20.38) \times 2 = v^2$

v = 14.8 m/s horizontally

e) Estimate the force of the club on the ball if the collision between club and ball takes 0.02 seconds.

(2 marks)

$F = m (v – u) / t$

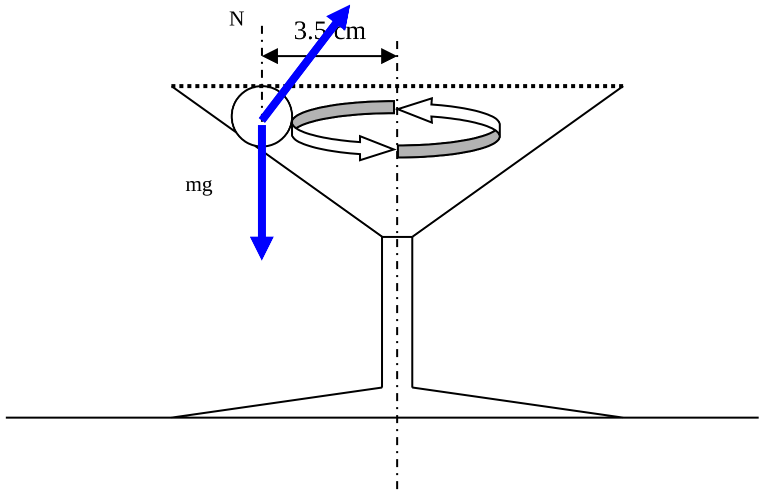
$m_{(ball)} = 0.05$ kg (estimate) (range = 70.0 g to 20.0 g)

$F = 0.05 (15 – 0) / 0.02$

F = 37.5 N

B2. (Total = 12 marks)

A perfectly circular 5.00g olive is rolling around the side of a martini glass at 0.530 m s^{-1} as shown in the diagram below. The side of the glass is slippery and exerts no fictional force on the olive.



a) Draw a labeled free body diagram of the forces acting on the olive on the diagram above.

(2 marks)

b) What is the centripetal force acting on the olive?

(3 marks)

$Fc = m\ v^2 / r$

$Fc = 3 \times 10^{-3} \times 0.53^2 / 3.5 \times 10^{-2}$

$Fc = 4.01 \times 10^{-2}$ N

c) What is the size of the force that that the side of the glass exerts on the olive?

(3 marks)

V	H
$-mg + N_v = 0$ $Nv = mg = 5 \times 10^{-3} \times 9.8$ $N_v = 4.9 \times 10^{-2}$ N	$N_h = F_c =$ **4.01×10^{-2} N**

$N^2 = N_v^2 + N_h^2 = (4.9 \times 10^{-2})^2 + (4.01 \times 10^{-2})^2$

$N = 6.33 \times 10^{-2}$ N

d) Is the olive accelerating? Explain.

(2 marks)

Yes.

The olive is moving in a circle. Its direction is constantly changing and so its velocity is not constant.

Consequently it is accelerating (centripetal force towards the center of the circle.

e) Despite the olive being perfectly round and the sides of the glass being perfectly slippery, will the olive continue to roll in a circle for ever? Explain.

(2 marks)

No

Air resistance *will exert a force on the olive causing it to lose velocity.*

or

Loss of ***energy*** *due to work done on olive by air resistance.*

B3. (Total = 12 marks)

a) A spacecraft is taking astronauts to the moon from the earth. At what height above the surface of the earth will a 78.0 kg astronaut weigh half his weight on the surface of the earth?

(4 marks)

$F = G\ m_1\ m_2 / r^2$

$½\ mg = G\ m_1\ m_2 / r^2$

$½\ g = G\ m_1 / r^2$

$r^2 = G\ m_e / (½\ g)$

$r^2 = 6.67 \times 10^{-11} \times 5.98 \times 10^{24} / 4.9$

$r = 9.02 \times 10^6$ m

$h = 9.02 \times 10^6 - 6.37 \times 10^6 =$ **2.65×10^6 m**

When man first walked on the moon they had to land in a special landing craft. The landing craft was sent from a second space craft orbiting directly above the landing position. This means that the second space craft is "geostationary" (lunostationary) above the moon. The period of rotation of the moon is quite slow (27.32 days).

b) What is the height of the second space craft above the surface of the moon in its "geostationary" orbit above the surface of the moon?

(3 marks)

$r^3 / T^2 = Gm_m / 4\ pi^2$

$r^3 = 6.67 \times 10^{-11} \times 7.35 \times 10^{22} \times (27.32 \times 24 \times (3600))^2 / (4\ pi^2)$

$r^3 = 6.91718985 \times 10^{23}$

$r = 8.84 \times 10^7$ m

$h = 8.84 \times 10^7 - 1.74 \times 10^6 =$ **8.67×10^7 m**

c) Explain why the special landing craft had to land on the <u>equator</u> of the moon.

(2 marks)

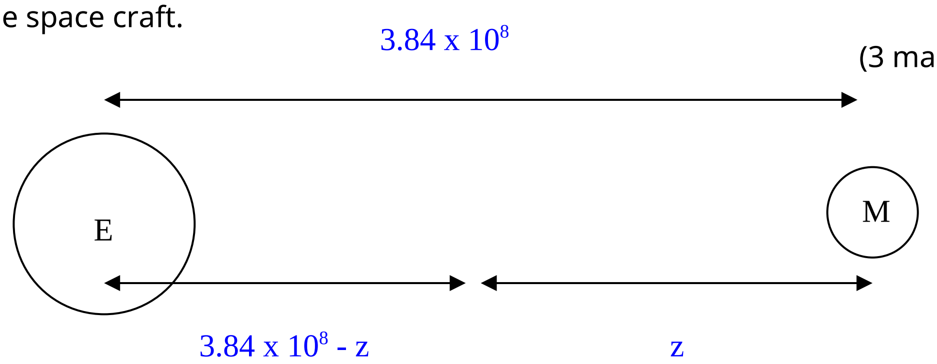
The satellite has to orbit the center of the moon.

If it is to remain directly above it will have to orbit above the equator.

a diagram is useful.

d) Calculate the distance (point in space) from the centre of the moon at which the pull of the moon on a spacecraft equals the pull of the earth on the space craft.

(3 marks)



F	F
$g = G\,m_1 / r^2$ $= 6.67 \times 10^{-11} \times 5.98 \times 10^{24} / (3.84 \times 10^8 - z)^2$	$g = G\,m_1 / r^2$ $= 6.67 \times 10^{-11} \times 7.35 \times 10^{22} / z^2$

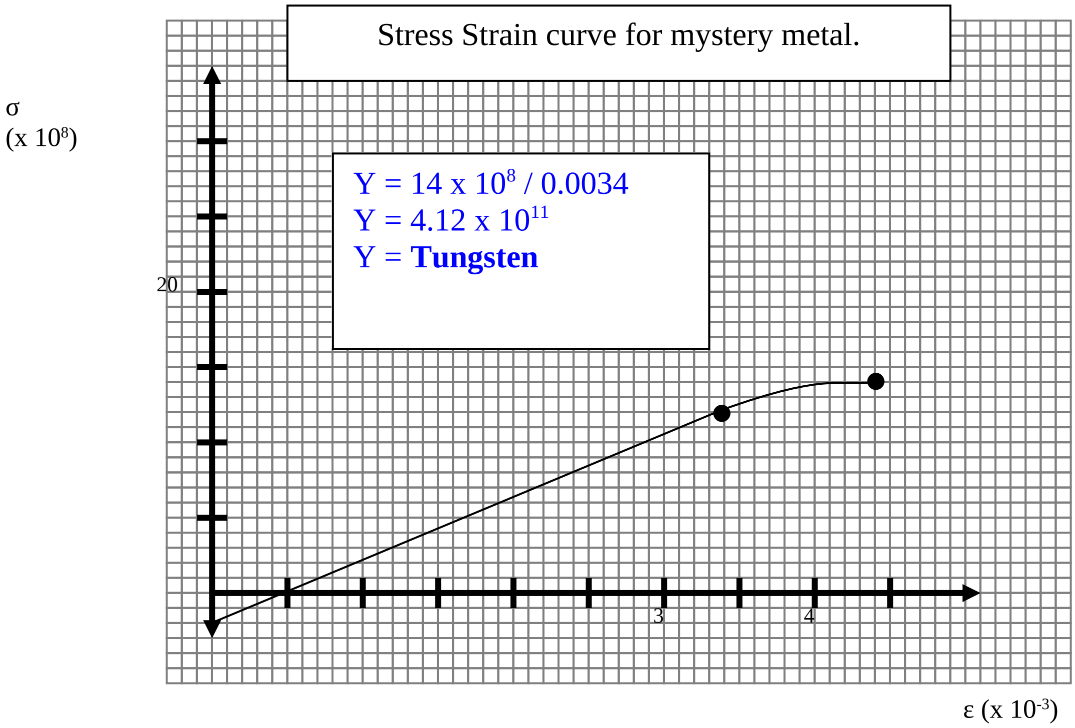
Set the 2 equations = to each other and use solve mode.

$5.98 \times 10^{24} \times z^2 = 7.35 \times 10^{22} \times (3.84 \times 10^8 - z)^2$

$z = 3.83 \times 10^7$ m

B4. **(Total = 12 marks)**

Onto the axes below place the following data points for a pure metal wire.



a) Proportional limit of 14.0 x 10^8 N m^{-2} at a strain of 0.0034 strain.

(1 mark)

b) Elastic limit of 16.0 x 10^8 N m^{-2} at a strain of 0.0044 strain.

(1 mark)

c) Join these points with a suitable curve.

(1 mark)

d) Using the Young's Modulus table on your constants sheet suggest which metal this graph is describing, with the support of calculations on the graph.

(1 mark)

e) What is the Hooke's law constant for this material if the metal has an original length of 4 m and a cross sectional area of 6 x 10^{-6} m^2

(3 marks)

$k = Y A / l_o$

$k = 4.12 \times 10^{11} \times 6 \times 10^{-6} / 4$

$k = 6.18 \times 10^5$ N m^{-1}

f) What is the load on the wire when the wire contains 1.24 J of conservative energy?

(3 marks)

$E = ½ k x^2$

$1.24 = 0.5 \times 6.18 \times 10^5 . x^2$

$x = 2.00 \times 10^{-3}$ m

$F = k x$

$F = \mathbf{6.18 \times 10^5} \times \mathbf{2.00 \times 10^{-3}}$

$F = 1.24 \times 10^3$ N

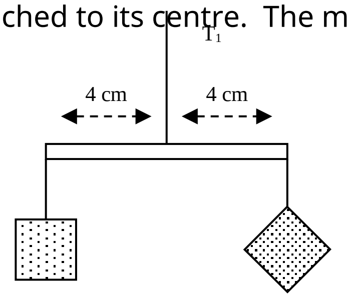
g) Why is it impossible to plot the point at which the wire brakes (ultimate strength from constants sheet) on the graph? Explain.

(2 marks)

The wire is plastic and there is no **strain** listed or rule for the strain at the plastic limit.

B5. (Total = 12 marks)

A toy maker is manufacturing a children's mobile to be hung above a baby's cot. The mobile hangs coloured squares of plastic from weightless threads off uniform wooden rods. Each square of plastic has a mass of 0.025 kg. The rod had a mass of 0.003 kg / cm. The first part of the mobile uses an 8 cm rod and two pieces of plastic. The rod is suspended from a thread attached to its centre. The mobile looks like this…



a) What is the mass of the rod?

(1 mark)

= 8 x 0.003 = **2.40 x 10^{-2}kg**

b) What is the tension in the thread T_1?

(3 marks)

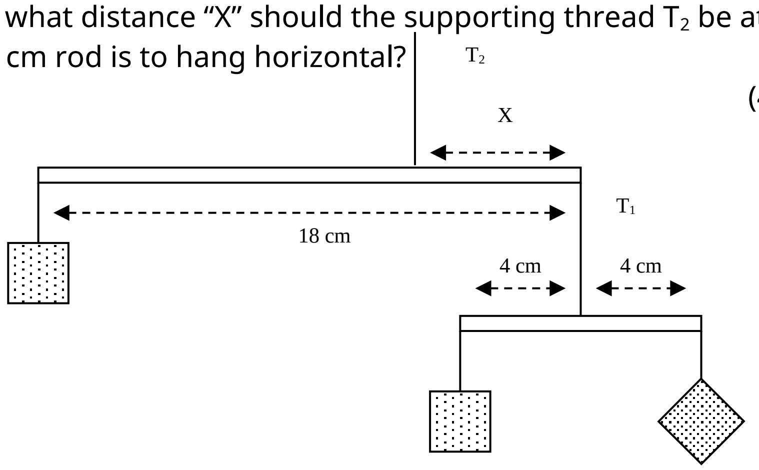
T = mg

T = (2.4 x 10^{-2} x 9.8) + (2 x 0.025 x 9.8) = 0.2352 + 0.2450

T = 7.25 x 10^{-1} N

c) The mobile above is now hung from the right end of another 18.0 cm rod and a single piece of 0.025 kg plastic is hung from the left end as shown below. At what distance "X" should the supporting thread T_2 be attached if the 18.0 cm rod is to hang horizontal?

(4 marks)



Take moments about left hand end

T = (0.025 x 9.8) + (18 x 0.003) x 9.8 + (7.25 x 10^{-1})

T = (2.45 x 10^{-1}) + (5.292 x 10^{-1}) + (7.25 x 10^{-1})

T = 1.4992 N

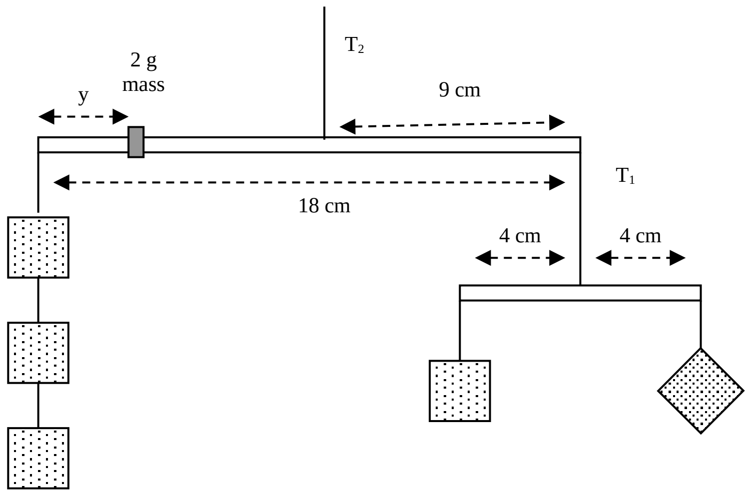
Mc = Ma

(0.18 x 7.25 x 10^{-1}) + (0.09 x (18 x 0.003 x 9.8)) = ((0.18 – X) x **1.4992**)

$1.305 \times 10^{-1} + 4.762 \times 10^{-2} = (0.18 - X) \times$ **1.4992**
$0.1188 = (0.18 - X)$
$X = 0.18 - 0.1188 =$ **6.12×10^{-2} m**

d) A late design change is made and two extra 0.025 kg pieces of plastic are added to the left end of the rod to make a total of 3 pieces of plastic on the left end. The vertical supporting thread is placed at the centre of the 18 cm rod. A small 2 .00 g mass will need to be added to the 18 cm rod to make it hang horizontal. Where should this mass be added?

(4 marks)



Take moments about T_2

$(0.09 \times 0.025 \times 3 \times 9.8) + (y \times 0.002 \times 9.8) = (0.09 \times \mathbf{7.25 \times 10^{-1}})$

$6.615 \times 10^{-2} + y \times 1.96 \times 10^{-2} = 6.525 \times 10^{-2}$

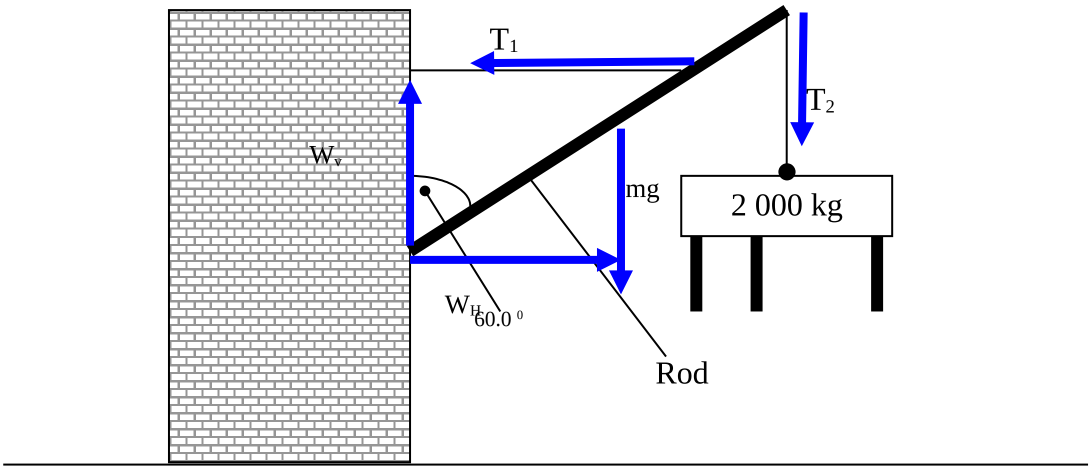
$y = (6.525 \times 10^{-2} - 6.615 \times 10^{-2}) / 1.96 \times 10^{-2}$

$y = -4.59 \times 10^{-2}$

$y = 0.09 + 4.59 \times 10^{-2} = \mathbf{13.6 \times 10^{-2}\ m}$

B6. **(Total = 12 marks)**

A grand piano is being loaded onto a truck using the primitive crane below. The rod is 3.00 m long. The rope T_1 is attached to the wall at right angles and attached to the rod 1.00 m from its top end. The rope T_2 is attached to the end of the rod. The rod is uniform and has a mass of 30 kg.



a) Draw and label clearly all of the forces acting on the rod.

(2 marks)

b) What is the tension in rope T_2?

(1 mark)

T_2 = mg = 2000 x 9.8 = **1.96 x 10^4 N**

c) What is the tension in rope T_1?

(4 marks)

Method 2

Mc = Ma

(30 x 9.8 x 1.5 cos 30) +(2000 x 9.8 x 3 cos 30) = T_1 x 2 x (Cos 60)

(3.819 x 10^2 + 5.09 x 10^4) / 1 = T_1

T_1 = 5.12 x 10^4 N

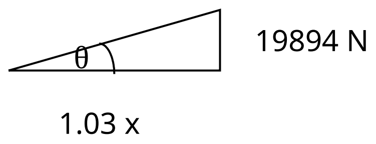
d) What is the size and direction of the force of the rod on the wall?

(4 marks)

V	H
Wv = ? F up = F down Wv + mg + T_2 Wv = 30 x 9.8 + 2000 x 9.8 Wv = 294 + 19600 Wv = **1.99 x 10^4 N**	**Wh = ?** F left = F right Wh = T_1 Wh **= = 5.12 x 10^4 N**

Pythagorus

W^2 = (**1.99 x 10^4**)^2 + (**5.12 x 10^4**)^2
W = 5.48 x 10^4 N



Angle

Tan θ = (**1.99 x 10^4** / **5.12 x 10^4**)

θ = **21.2^0**

Force of wall on rod

5.48 x 10^4 N Right 21.2^0 Up

By Newton's third law.

Force of rod on wall

5.48 x 10^4 N Left 21.2^0 Down

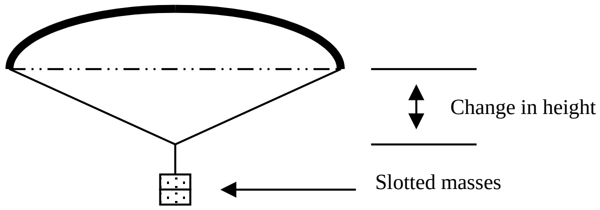
e) If the rope T_2 is lengthened as the piano is lowered, what will happen to the tension in T_1?

(1 mark)

It will not change.

B7. **(Total = 12 marks)**

A student who is interested in archery is doing an experiment with an archery bow. The student hangs slotted masses on the bow string of the bow and measures how much the string bends away from horizontal.



a) The following results were obtained. Convert the mass to weight and the height to S.I. units.

(1 mark)

Mass	**(g)**	50	100	200	300	400	500
weight		0.49	0.98	1.96	2.94	3.92	4.90
Δ of Height	**(mm)**	2	3	11	10	13	17
Δ of Height	m	0.002	0.003	0.011	0.01	0.013	0.017

b) Write a hypothesis as to the relationship between change in height and weight.

linear (1 mark)

c) What is the independent variable? mass or weight

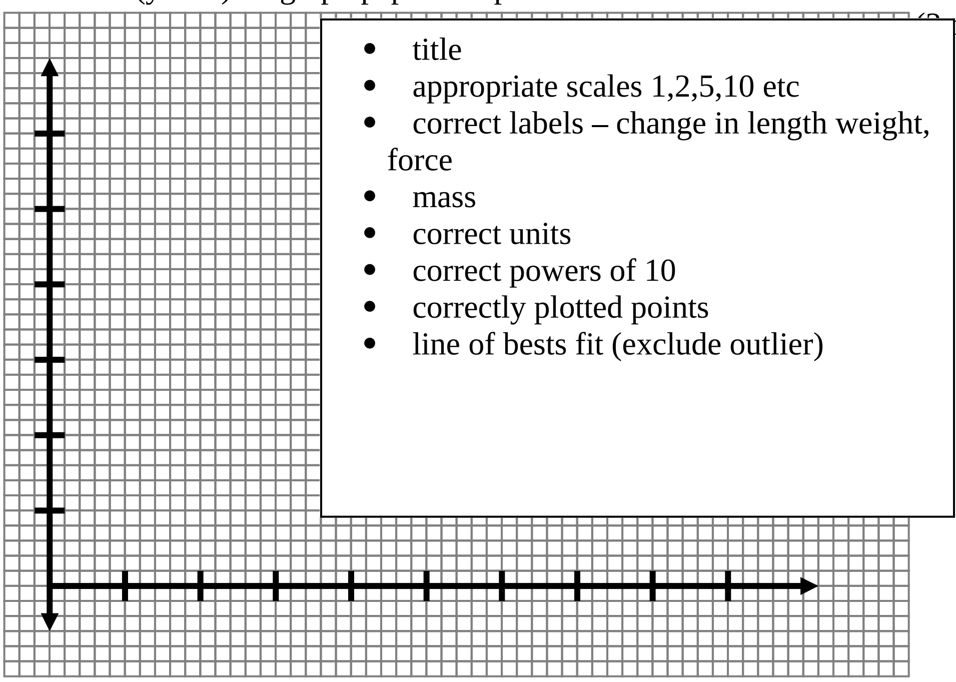
(1 mark)

d) What is the dependant variable? height

(1 mark)

e) Manually graph the independent variable (x axis) against the dependant variable (y axis) on graph paper and put in a line of best fit.

marks)



- title
- appropriate scales 1,2,5,10 etc
- correct labels – change in length weight, force
- mass
- correct units
- correct powers of 10
- correctly plotted points
- line of bests fit (exclude outlier)

f) Calculate the slope of the line on the graph paper.

(1 mark)

The two points I chose are (0 N,0 m) and (3 N, 10×10^{-3} m)
slope = Rise / run
slope = $10 \times 10^{-3} / 3$
slope = 3.33×10^{-3} m / N

g) State the mathematical relationship for the graph?

(1 mark)

h = 3.33×10^{-3} x weight

h) What is the work done on the bow string when 350.0 g is hung from the string?

(1 mark)

E = ½ F x

E = $0.5 \times (0.350 \times 9.8) \times 1.143 \times 10^{-2}$

E = 1.96×10^{-2} J

i) Explain why the data is or is not reliable.

(1 mark)

Reliable = closely correlated.

j) Explain why the hypothesis is or is not valid.

(1 mark)

Valid if you said linear.

Not valid if you said something other than linear.

SECTION C : Comprehension and Interpretation - 35 Marks (20%)
Read the passage below carefully and answer all of the questions at the end of the passage. Candidates are reminded of the need for correct English and clear and precise presentation of answers.
Show all working out for questions requiring numerical answers.

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1. (Total = 17 marks)

Ropes

Ropes and tethers are designed to support tensile loads; either stationary loads as for a suspension bridge, or dynamic loads as for a falling rock climber.

What is a rope?

A rope is a bundle of fibres/threads/wires twisted together. So why not just use a thicker single strand? While a single strand should have the same strength as a rope of the same cross sectional area there are several reasons why a rope is often a better solution.

- If one fibre fails the rope remains intact - whereas a rope made of a single large fibre would fail catastrophically.
- Thin fibres often have higher strength than thick ones made from the same material. Glass fibres are a good example of fibres which are strong in tension when thin because they are unlikely to contain a strength limiting defect. Drawn polymer fibres have much better mechanical properties than polymer products made by ordinary polymer processing, but such fibres can only be made in small diameters.
- A multi-stranded rope is more flexible than a single strand of the same diameter - for example multi-stranded copper 13A cable is much easier to bend than the single strand copper wire of the same diameter used in ring-main cables.

	Suspension cable	Climbing rope
Required strength	high	medium
Allowable weight	low	low
Stretch Requirements	high Young's modulus	high elongation
Flexibility	little required	great
Impact toughness	medium	high
Creep resistance	high	low
Notes	Since these are used to suspend bridges the most important criterion is strength in tension. Because it is important that the bridge does not flex too greatly under strong winds or during the passing of large lorries, the stiffness (Young's modulus) must also be high. In addition, for very large span bridges the weight of the cables themselves is also important. For this reason a specific stiffness - specific strength chart (below) is useful for identifying suitable materials - the chart shows a selection of materials available as fibres. Until recently steel cables have been used for bridge type applications. **Steel wire** such as that used inside pianos (patented steel wire) can have a very high tensile strength, but it is quite heavy. Recently very high specific stiffness and strengths have been recorded for **synthetic fibres**. These are now used in suspension bridges by incorporating fibres into a matrix to form a composite bundle. This is then twisted with others to form a rope. Creep properties (the gradual extension over time under a tensile load) are	Unlike suspension cables, climbing ropes are not designed to be continuously under load. This means that creep is much less of an issue. Climbing ropes are primarily used in the event of a fall. If a climber should fall, then the rope must be able to stop the fall without breaking, but also without too rapid a deceleration (the opposite of acceleration) since this can also cause injury. This design constraint is met by requiring materials with a large elastic elongation before failure (see below). The weight of the material is also important - partly as a lead climber has the weight of the rope hanging below them, but also because climbing gear is often carried for large distances. Original climbing ropes were made of **hemp** - a natural fibre that is similar to **cotton**. Modern ropes are made of **nylon**, or combine a fibre core with a protective textile sheath (using nylon and **rubber**).

	also very important.	

Good performance at low weight?

Ranking candidate materials

Two important material characteristics needed to satisfy the design requirements for climbing ropes are:

iii. the elastic elongation to failure, and
iv. how much energy the rope can absorb by elastic stretching before breaking.

These quantities are not separate material properties, but depend on two familiar properties - strength and Young's modulus - as follows:

elastic strain at failure = strength/Young's modulus

elastic energy stored at failure (per unit volume) = ½ x strength x elastic strain at failure

	Young's modulus (GPa)	Density (kg/m^3)	Ultimate Strength (MPa)
Cotton	7.9	1,540	225
Hemp	32	1,490	300
Bulk Polyester	2.9	1,300	50
Bulk Nylon	2.5	1,090	63
Carbon Fibre	300	1,770	3,430
Aramid Fibre	124	1,450	3,930
Polyester Fibre	13.2	1,390	784
Nylon Fibre	3.9	1,140	616
Alloy Steel	210	7,800	1,330

Safety factors in design

For parachute lines and climbing ropes, where safety is the most important requirement, designers apply what is called a "safety factor". If you design a product that has to be strong and design it to survive to 5 times the expected maximum load, this is a safety factor of 5.
Extracted on 23/4/2009 from
http://www-materials.eng.cam.ac.uk/mpsite/short/OCR/ropes/default.html

1. Why do suspension cables for suspension bridges need to be light?

(2 marks)

So the bridge does not have to support the weight of the cables as well as the weight of the loads on the bridge

2. What type of Young's modulus does a mountain climber require? Explain.
(2 marks)

Low

Needs lots of stretch so that the mountain climber does not experience large impulsive forces

3. What is the advantage of a rope made from multiple fibres compared to a rope made from a single fibre?
(1 mark)

If one fibre snaps in a multi fibre rope then the other fibres will hold.

Thin fibres contain fewer impurities and so are stronger.

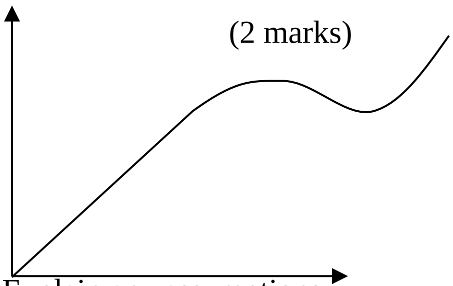
4. Using the table above, give an example of a material that would make a good mountain climbing rope? Explain with reference to the all the numbers in the table.
(4 marks)

Nylon Fibre

Low Young's Modulus, Low density, Ultimate Strength is high

5. Why do ropes have a safety factor "built" into them? Explain with reference to a Young's modulus graph drawn by you.
(2 marks)

The safety factor is there so that the ropes do not go into the plastic region.



6. What is the elastic strain at failure of a hemp rope? Explain any assumptions present in your calculation.
(3 marks)

$\varepsilon = \sigma / Y$
$\varepsilon = 300 \times 10^6 / 32 \times 10^9$
$\boldsymbol{\varepsilon = 9.38 \times 10^{-3}}$ **strain**
Assumes it stays proportional right to breaking point.

7. What is the elastic energy (per unit volume) stored at failure in a nylon fibre rope?
(2 marks)

$\frac{1}{2}\varepsilon\sigma = 1/2\ \sigma^2 / Y = 0.5 \times (616 \times 10^6)^2 / 3.9 \times 10^9 =$ $\mathbf{4.86 \times 10^7\ J / m^3}$

8. What is creep?
(1 mark)

When the rope stretches plastically even though it is in the elastic region over a long period of time.

2. (Total = 18 marks)

Crashing a Drag Racer.

(Paragraph 1)
My first two runs got me acclimatised to the sheer power delivered by the jet engine and the technique needed to keep the car straight – Colin advised me that to counter the camber and the cross wind, I had to apply a constant 30 degrees of steering input. On the third run, the after burner failed to ignite properly. But the next time, the car exploded into action – a manic, violent thing. Just 23 seconds after hitting that little (afterburner) switch, the run was finished. I'd ridden a wave of power that ten Formula One cars together would struggle to achieve.

(Paragraph 2)
I was ecstatic. Colin and the crew knew from the onboard telemetry (but didn't tell me) that I'd hit 314.4 mph (506 kmh), faster than the official British land-speed record.

There was time for one more run.

(Paragraph 3)
(t = 0 secs, v = 0 kmh)
Colin begins the start procedure. The noise builds to the whine of a jet as Colin gives the all-clear. The power dial is set to 125%. I hit the switch and release the brake. In under eight seconds we're doing 200 mph (320 kmh).

(Paragraph 4)
(t = 14.25 secs, v = 464 kmh)
By the time my senses have sped up enough to keep pace with what's going on, I realise that something is wrong. This is not the usual push and pull of the steering as the front end scrabbles to keep the one-tonne car and its passenger heading in a straight line.

(Paragraph 5)
(t = 14.64 secs, v = 459 kmh)
I am counter steering now and battling something. Unknown to me, the front right tyre has suffered a catastrophic and total failure. On video footage, the front of the car leaps high enough with the (tyre) explosion to lift the other front wheel clear off the ground.

(Paragraph 6)
(t = 15.00 secs, v = 449 kmh)
The car veers off to the right. My foot hits the brake – instinctively but useless. I am still fighting. But I am losing.

(Paragraph 7)
(t = 15.71secs, v = 373 kmh)
I know I'm going to crash. I remember the parachute lever. I pull it. The car does not stop and begins to roll over. The next thing to happen, I am quietly convinced, is that I die. I am not scared, my life does not flash before my eyes: there is just a calm resignation. And I pass out as the g-forces generated by the crash exceed those at which I can maintain consciousness.

(Paragraph 8)
The roll bars protect my head, but they dig into the grass, slowing the car from 373 kmh to 307 kmh in just 0.46 seconds. My brain is thrown forward, distorted; its shape elongated, hitting the front of my skull. The force my brain experiences, overstretches some of the nerves and causes them to break. The resulting injuries could leave me paralysed, deaf, blind, or wipe out my personality – the person I recognise as me.

This article is extracted from Australian Readers Digest – March 2008
"<u>The day I died at 449 km h</u>" by Top Gear's Richard Hammond p123 – 137

1. What 2 things are wrong with the article's use of the units "kmh" from a physicist perspective?

(2 marks)

a) it should be in m/s.
b) it should be km / h.

2. Mathematically derive the relationship that converts "mph" (miles per hour) to "kmh" (kilometres per hour) using the numbers in paragraph 2, if 0.00 mile / h equals 0.00 km/h (Note the relationship is linear).

(3 marks)

Rise / Run = 506 / 314.4 = 1.61

v (km/h) = 1.61 x v (miles / h)

3. What is the acceleration of the drag racer if it accelerates to "320 kmh in 8 seconds"? (Paragraph 2)

(3 marks)

$a = (v - u) / t$
$a = (320 / 3.6) / 8$
$\mathbf{a = 11.1\ m\ s^{-2}}$

4. Why does the car begin to turn upwards into the air when the tyre explodes? (Paragraph 5)

(2 marks)

The tyre exploding exerts a torque on the front of the drag racer.

5. How does deploying a parachute behind a fighter aircraft or drag racer cause the vehicle to slow? (Paragraph 7)

(2 marks)

Increases the cross sectional area of the car which increases air resistance.

6. Why does strong acceleration cause a person to black out? (Paragraph 7)

(2 marks)

The blood drains away from the brain due to inertia.

7. If the driver has a mass of 70.0 kg what is the magnitude and direction of the force on the driver if the driver (and car's) velocity change from "from 373 kmh to 307 kmh in just 0.46 seconds". (Paragraph 8)

(3 marks)

$F = m (v – u) / t$
$F = 70 (373 – 307) / 3.6 / 0.46$
$F = 2790$
$F = 2.79 \times 10^3$ N

8. Why is the driver's brain thrown forward even though the seat belt acting on the driver is causing the driver's body to stop? (Paragraph 8)

(1 mark)

Inertia
Force acts on the body but not on the brain. Brain continues until it experiences an unbalanced force (the skull).

End of Exam