



## Semester One Examination, 2010

### Question/Answer Booklet

## 3AB PHYSICS

Please place your student identification label in this box

Student Number: In figures

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In words

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### Time allowed for this paper

Reading time before commencing work: Ten minutes  
Working time for paper: Two hours thirty minutes

### Materials required/recommended for this paper

#### ***To be provided by the supervisor***

This Question/Answer Booklet  
Formulae and Constants Sheet

#### ***To be provided by the candidate***

Standard items: pens, pencils, eraser, correction fluid, ruler, highlighters

Special items: non-programmable calculators satisfying the conditions set by the Curriculum Council for this course

### Important note to candidates

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. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

	A	B	C	Total
Score				
Out of	45	75	30	150
%				

## Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Short response	12	12	45	45	30
Section Two: Problem-solving	7	7	75	75	50
Section Three: Comprehension	2	2	30	30	20
					100

## Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2010*. Sitting this examination implies that you agree to abide by these rules.
2. Write answers in this Question/Answer Booklet.
3. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.
4. Working or reasoning should be clearly shown when calculating or estimating answers.
5. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
  - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
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**Section One: Short response****30% (45 marks)**

This section has **12** questions. Answer **all** questions. Write your answers in the space provided.

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Suggested working time for this section is 45 minutes.

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**Question 1****(3 marks)**

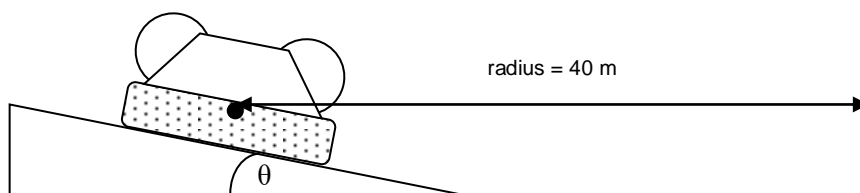
You are standing on a balcony of a building. Explain a procedure by which you can calculate the height of the balcony using only a ball and a stop watch.

**Question 2****(3 marks)**

A person with a parachute open arrives at the ground much later than a person whose parachute has failed to open. If both parachutists have the same mass and both parachutists fall at a constant (but very different) velocity from the same height. Explain the large difference in their terminal velocities.

**Question 3****(4 marks)**

A hovercraft is travelling around a banked curve (burr). The hovercraft is travelling at 50.0 km/h and the curve has a radius of 40.0 m. The hovercraft and driver have a combined mass of 200 kg. The hovercraft glides on a cushion of air and experiences no friction.



What is the angle for the burr?

**Question 4****(3 marks)**

A person is driving to the airport with their 40 kg suitcase in the back of a ute. When the ute goes around a wide corner at 60 km/h the bag in the back does not “slide around” in the back of the ute. When the ute goes around a tight corner at the same speed the bag does “slide around” in the back of the ute. Explain why the bag does or does not slide using example calculations.

**Question 5****(5 marks)**

- a) Gravity decreases linearly to zero when you travel inside the earth from the surface to the centre. Sketch a graph of this line showing the values for gravity at the centre and at the surface as a function of distance.

**(3 marks)**

- b) What is the mathematical equation for this line?

**(2 marks)****Question 6****(4 marks)**

- a) A new planet is discovered. It has a mass that is 384 times that of earth and a radius 8 times that of earth. What is the strength of its gravitational field?

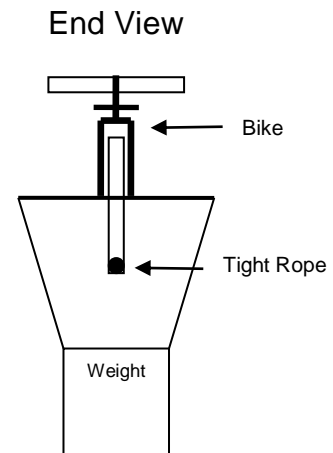
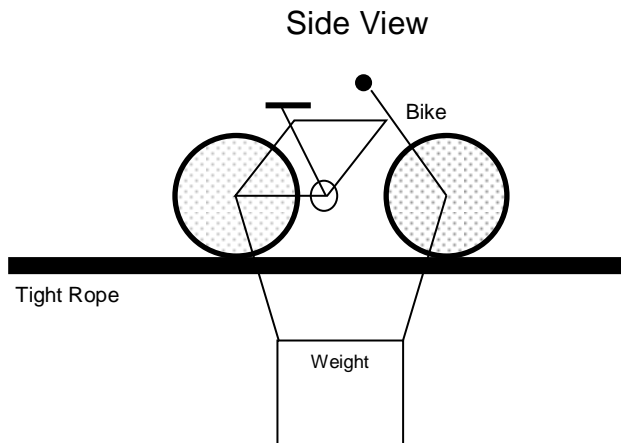
**(3 marks)**

- b) What is the ratio of the gravitational field strength on the surface of this planet as compared to earth?

**(1 mark)**

**Question 7****(4 marks)**

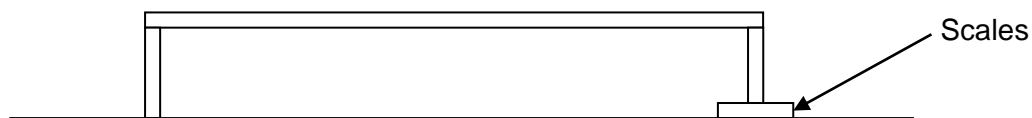
A bike with no tyres (just the metal rims) is stationary on a tightrope. The bike has axles that extend out sideways off which a large, heavy counter weight has been suspended below the tight rope.



- a) Is the situation shown above in mechanical or static equilibrium? (1 mark)
- mechanical**                      **static**                      (please circle one only)
- b) Explain why. (1 mark)
- c) Is the above situation in stable, unstable or neutral equilibrium? (please circle one only) (1 mark)
- stable**                      **unstable**                      **neutral?**                      (please circle one only)
- d) Explain why. (1 mark)

**Question 8****(4 marks)**

A boy wants to measure the weight of a park bench using a set of bathroom scales calibrated in newtons. He cannot fit the whole bench on the scales. He can only fit one complete end on the scales. The scales read 98 N. If the bench is uniform and level and nobody is sitting on it, what is the total weight of the bench?





**Question 9****(4 marks)**

Heidi is standing in front of a very large cliff. Heidi claps her hands while facing the cliff. Gertrude who is standing next to Heidi, uses a stopwatch to time how long it takes for the echo to return to them, having bounced off the cliff. It takes 4.74 seconds.

- a) How far are Heidi and Gertrude from the cliff?

(2 marks)

- b) What is the major source of error in this activity?

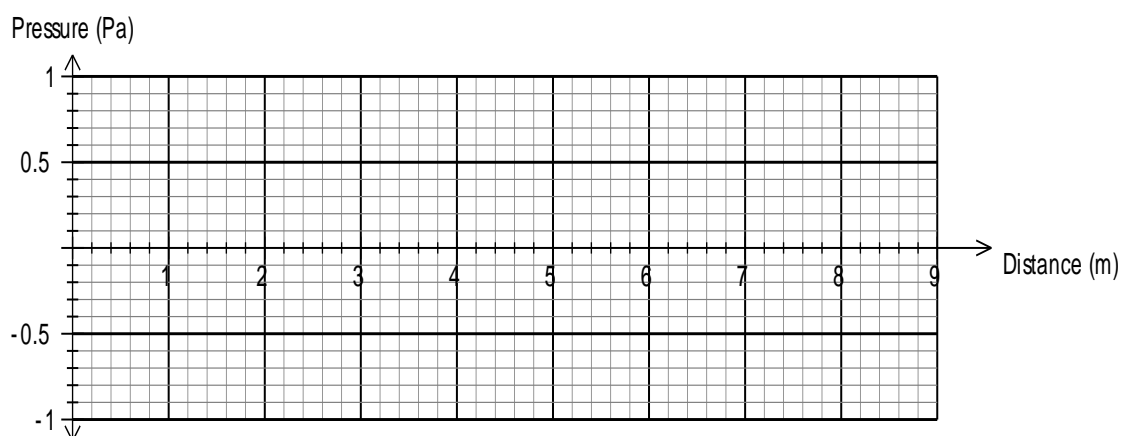
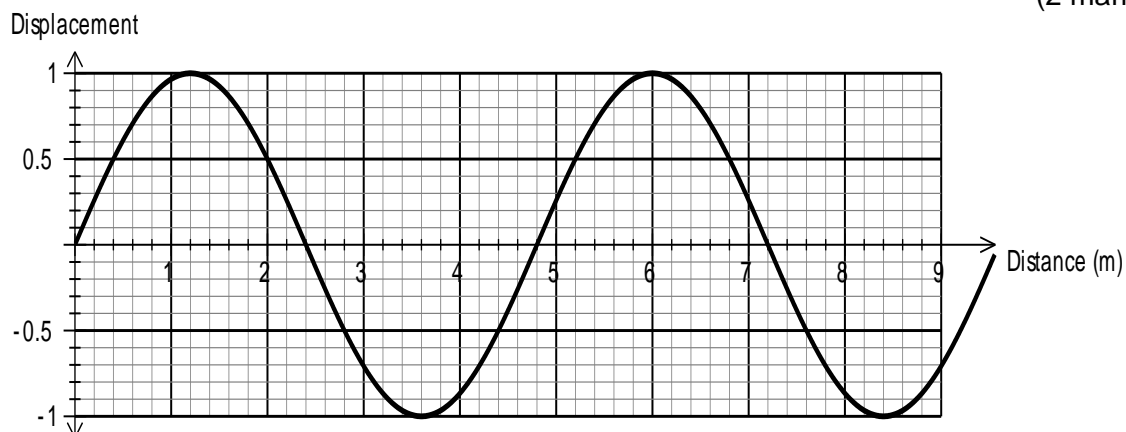
(1 mark)

- c) The distance from Heidi to the cliff is now measured using an accurate (laser) measuring tape. The measuring tape records a distance of 792.000 m. If the answer from the measuring tape can be trusted, what is the % error in the distance calculated from the echo and stopwatch?

(1 mark)

**Question 10****(4 marks)**

- a) Convert the below displacement - distance graph into a pressure - distance graph. Assume that the maximum and minimum pressure is 1 pascal (Pa).

**(2 marks)**

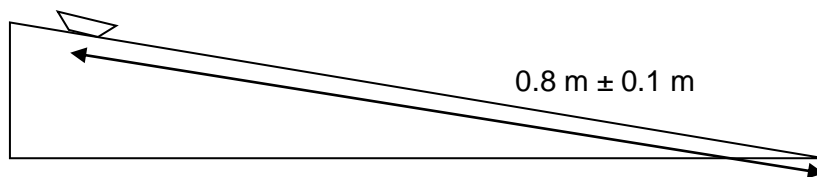
- b) If this is a sound wave in air, what is the period of the wave?

**(2 marks)****Question 11****(3 marks)**

A student is very hot after running a marathon. She places two identical fans directly in front of her. The first fan is switched on and runs at 3000 rpm (revolutions per minute). When the second fan is switched on the sounds from the two fans interfere with each other to produce 6 fluctuations in loudness each second. What is the frequency of the second fan in cycles per second (Hz)?

**Question 12****(4 marks)**

A student is measuring the time taken for a bath plug to slide to the bottom of an icy slope.



The slope has a length of  $0.8 \text{ m} \pm 0.1 \text{ m}$ . The student measures the time it takes for the plug to travel to the bottom of the slope 5 times. The 5 results are recorded below.

Distance (m)	$0.8 \text{ m} \pm 0.1 \text{ m}$				
Time (s)	5.16 s	1.21 s	1.56 s	1.87 s	1.64 s

- a) Calculate the average time.

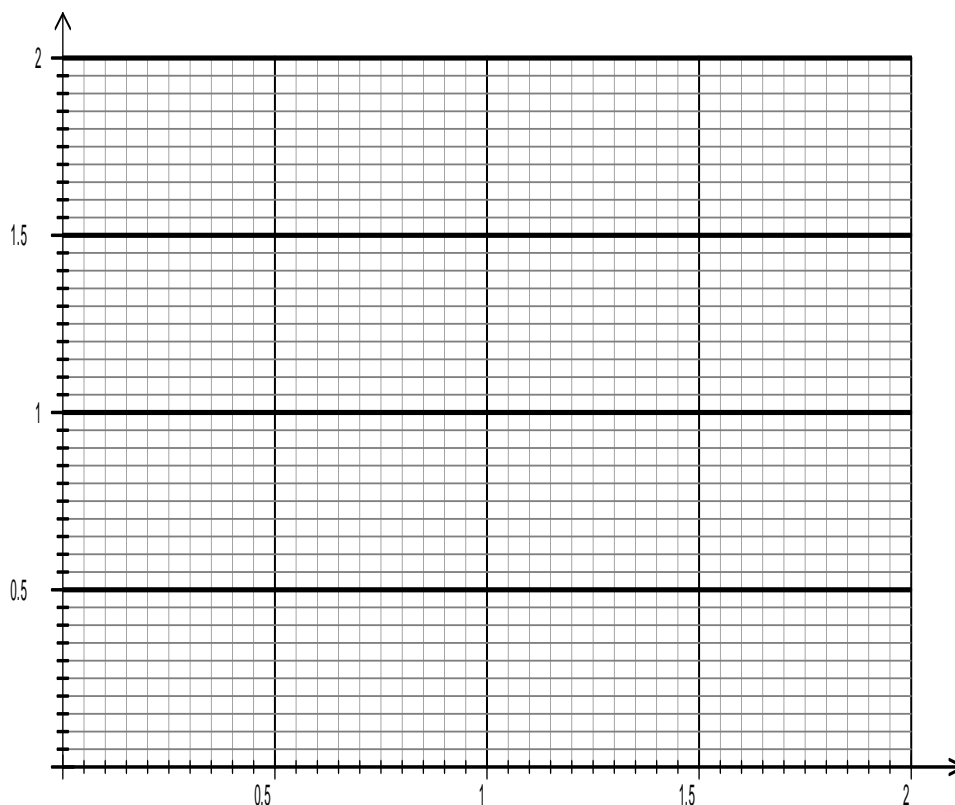
(1 mark)

- b) What is the absolute statistical error in the time?

(1 mark)

- c) Combine the above information appropriately to create a single data point to be plotted on the graph paper below. Attach to the data point error bars for distance and for time. Don't forget to label the axes.

(2 marks)



**End of Section One**

**Section Two : Problem-solving****50% (75 Marks)**

This section has **seven (7)** questions. You must answer **all** questions. Write your answers in the space provided.

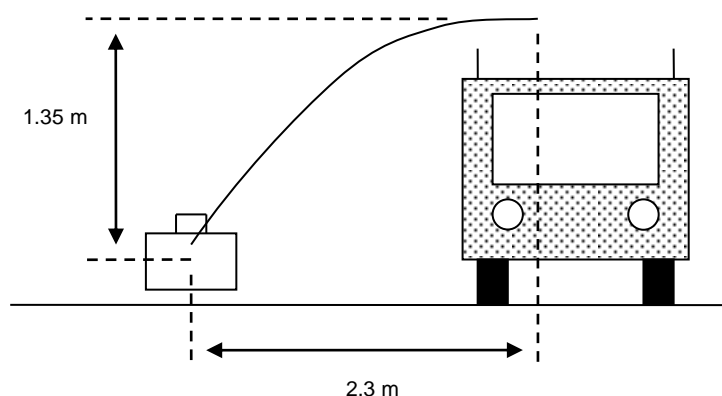
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Suggested working time for this section is 75 minutes.

**Question 13****(11 marks)**

A St Mary's student is travelling in Africa on exchange. She is taking a bus from Zanzibar to Timbuktu. The bus stores baggage on the roof. A person loading the baggage throws her full bag to a second person standing on the roof of the bus. The distances are as shown on the diagram.



- a) With what initial vertical velocity must the bag be thrown to just reach the person on the roof?

(2 marks)

- b) How long did it take the bag to reach the roof?

(2 marks)

c) What is the horizontal velocity of the bag?

(2 marks)

d) What is the initial angle of take off of the bag?

(2 marks)

e) When the bag is empty it is very “light”. When her possessions are in it, the bag is very heavy. Explain how and why the trajectory of the empty and full bag would differ when air resistance is taken into account.

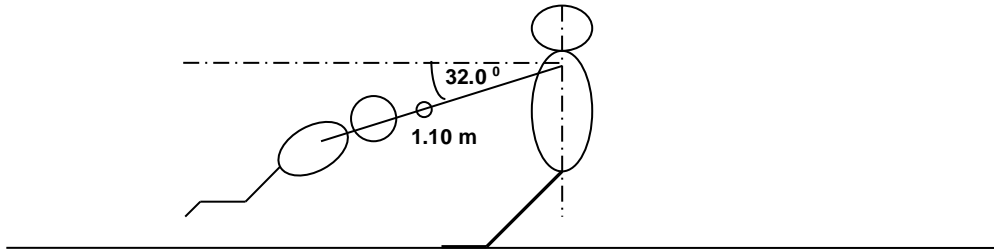
(3 marks)

**Question 14****(10 marks)**

A silly parent is playing a game with a child called “dizzy wizzies”. The parent holds one of the child’s hands and swings them around in a circle. The child has a mass of 25.0 kg and the arms of the parent / child form an angle of  $32.0^\circ$  to the horizontal. The distance from the shoulders of the adult to the centre of mass of the child is 1.10 m along the line of the arms. Assume the child revolves around the vertical central line passing through the middle of the adult.

- a) Draw the forces acting on the child.

(2 marks)



- b) What is the tension in the arms of the child?

(2 marks)

- c) What is the centripetal force acting on the child?

(1 mark)

d) What is the velocity of the child's centre of mass?

(2 marks)

e) The child's shoulder joint can withstand a maximum tension of 600 N before it dislocates. At what speed will this occur?

(3 marks)

**Question 15****(14 marks)**

A 12.5 kg space probe is attempting to enter into a stable circular orbit around Neptune at a speed of  $550 \text{ m s}^{-1}$ .

**Facts about Neptune**

Neptune's Mass	$1.02 \times 10^{24} \text{ kg}$
Radius of Neptune	$2.48 \times 10^7 \text{ m}$
Period of Rotation of Neptune	0.6713 earth days

- a) At what distance from the surface of Neptune should the space probe be placed to achieve this orbit?

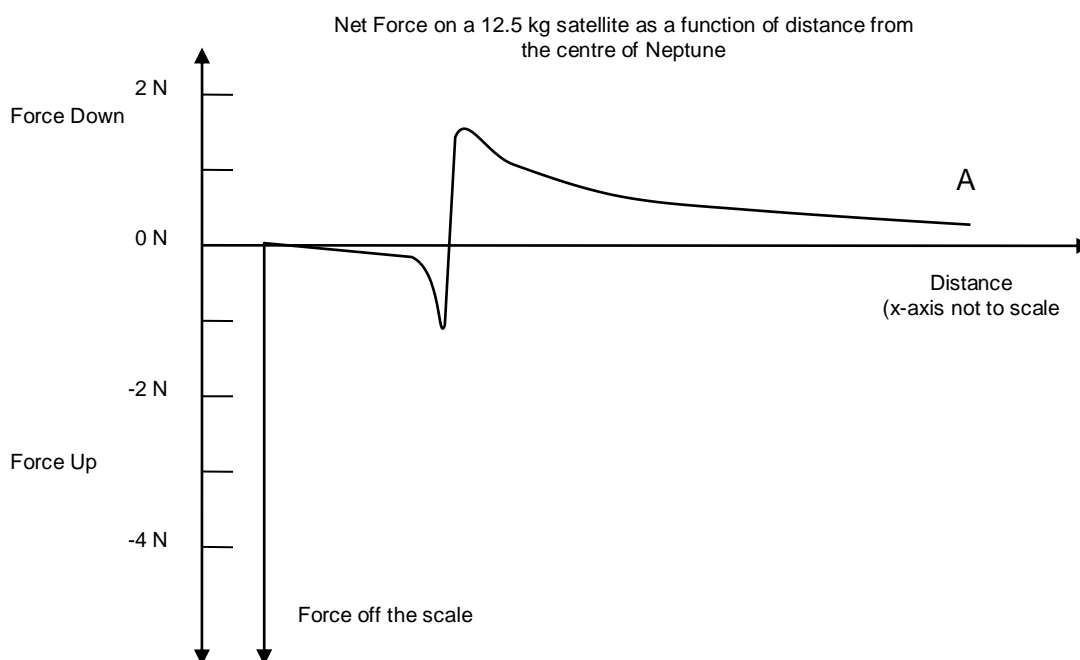
(3 marks)

- b) Is it possible to place a "geostationary" satellite in an orbit around Neptune? Explain why or why not with the support of calculations.

(3 marks)



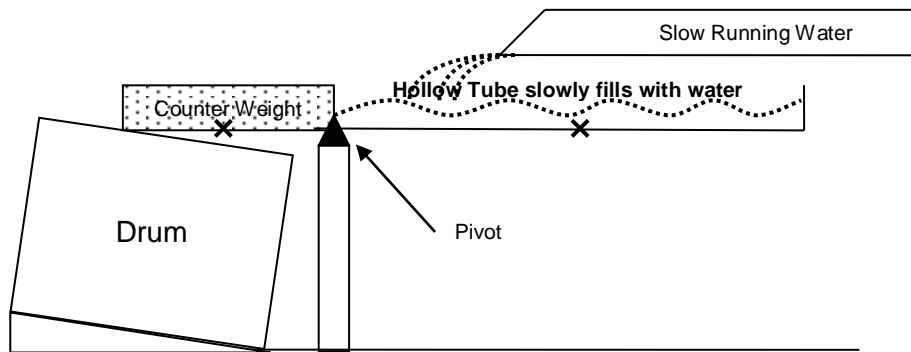
Unfortunately the space probe is misaligned and travels directly towards the centre of the planet. Astronomers define the “surface” of Neptune as being where its thick atmosphere begins. The atmosphere of Neptune becomes even thicker as you proceed towards the core. The resultant force on the space probe as it journeys from remote space (A) to the core of Neptune is shown in the graph below.



- c) What is the resultant force on the spacecraft as the point A (the start of the graph)? (1 mark)
- d) Calculate from your answer to part c) the distance of the spacecraft above the centre of Neptune. (3 marks)
- e) Why does the net force on the space probe increase as it approaches Neptune even though its rockets are switched off? (2 marks)
- f) Based on your interpretation of the graph, mark with an **X** on the curve the location at which the space probe first encounters the “surface” (atmosphere) of Neptune. (1 mark)
- g) What does the area under the graph represent? (1 mark)

**Question 16****(12 marks)**

A Japanese bird scarer is a noise making device that is used to scare birds away from rice fields. The device uses the weight of water filling a hollow lever to tip the lever. When the lever tips, the water in the hollow tube empties causing the lever to return to horizontal hitting the drum and so scaring the birds away.



The counter weight has a mass of 134 g and has its centre of mass positioned 6.00 cm from the pivot. The hollow tube has a mass of 24.0 g when empty and has its centre of mass positioned 18.0 cm from the pivot. The hollow tube has a total length of 36.0 cm.

- a) When the tube is empty, what type of equilibrium is the tube in? Be specific. Explain how you came to this conclusion.

(2 marks)

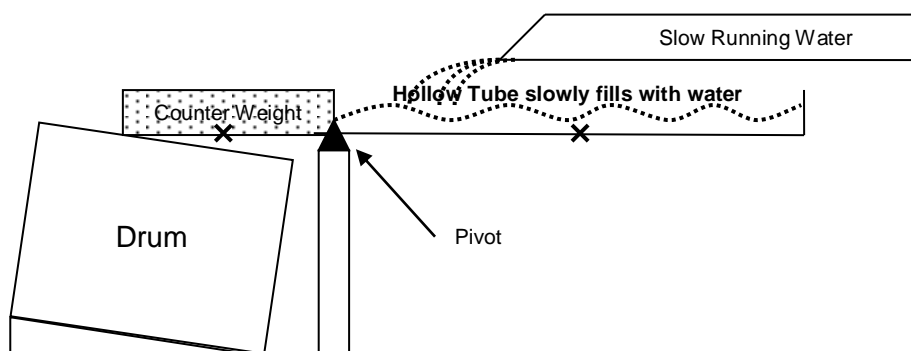
- b) What is the force of the drum acting on the counter weight when the hollow tube is empty?

(2 marks)

- c) What is the normal force provided by the pivot when the hollow tube is empty?

(2 marks)

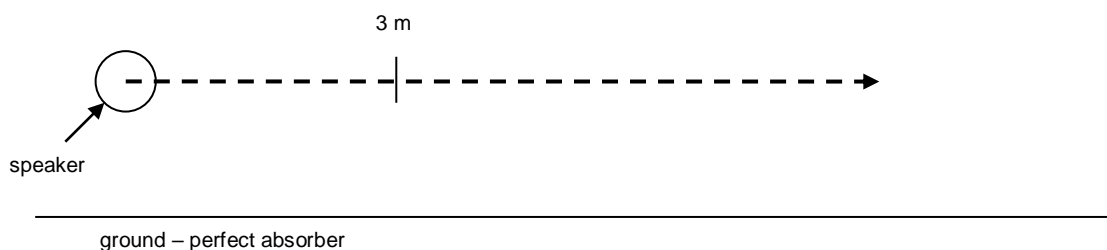
- d) What volume of water (in mL) centred 18.0 cm from the pivot is required to just cause the hollow tube to tip? (Note - 1 mL of water has a mass of 1g.) (3 marks)



- e) Just before the tube, which is slowly filling with water tips; state what type of equilibrium the system is in? Be specific. (1 mark)
- f) Will the location on the drum hit by the counter weight experience a pressure node or anti-node when it is struck? Explain. (2 marks)

**Question 17****(13 marks)**

A microphone is set up at a distance from a stereo speaker. The stereo speaker is sending out sound spherically around it. The ground absorbs all sound waves that strike it. The stereo speaker is emitting 1.00 J of sound energy each second at a frequency of 500 Hz.



- a) What is the intensity of the sound at a distance of 3 m?

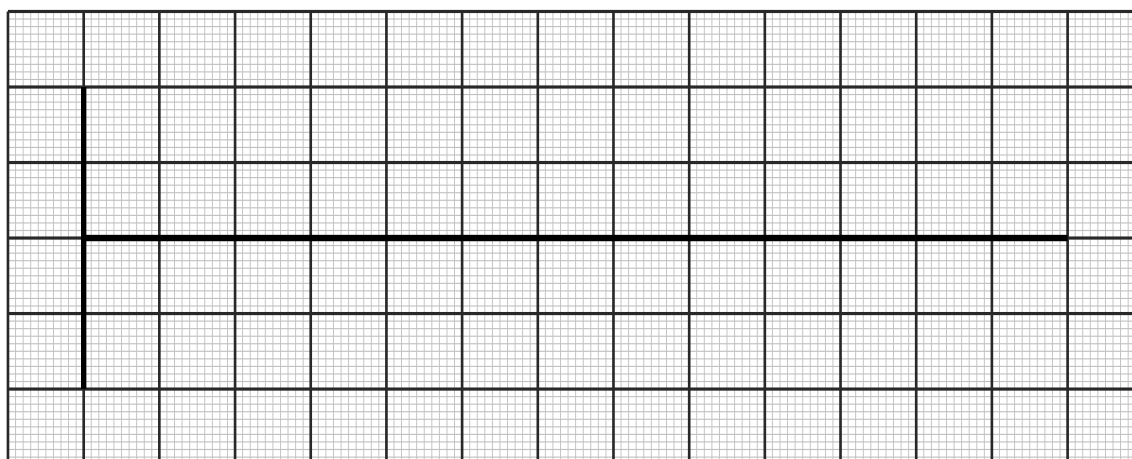
(3 marks)

- b) At what distance from the speaker will the intensity of the graph drop to  $1/16^{\text{th}}$  of the value calculated in part a)?

(2 marks)

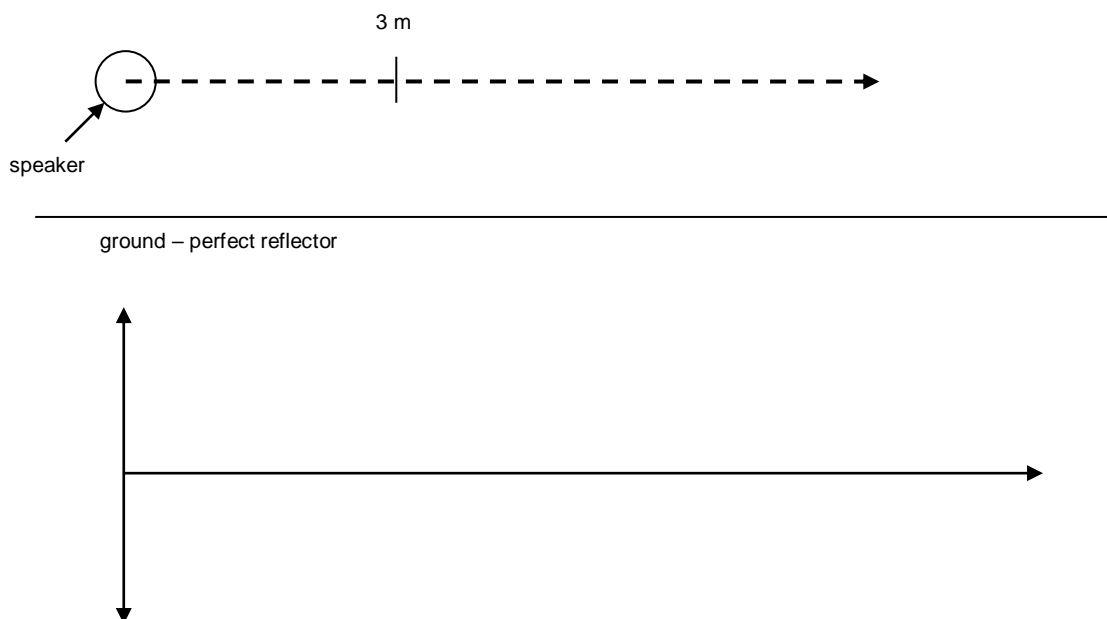
- c) Draw 3 cycles of a displacement - time graph for this 500 Hz sound.

(3 marks)



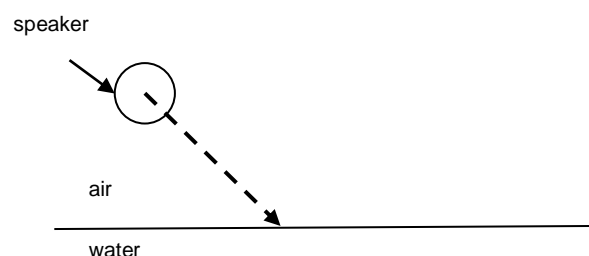
- d) The ground is now altered so that it is a perfect reflector and the centre of the speaker is positioned 2.00 m from the ground. Sketch the intensity as recorded by the microphone now as a function of distance as the microphone moves away from this speaker along the dotted line.

(3 marks)



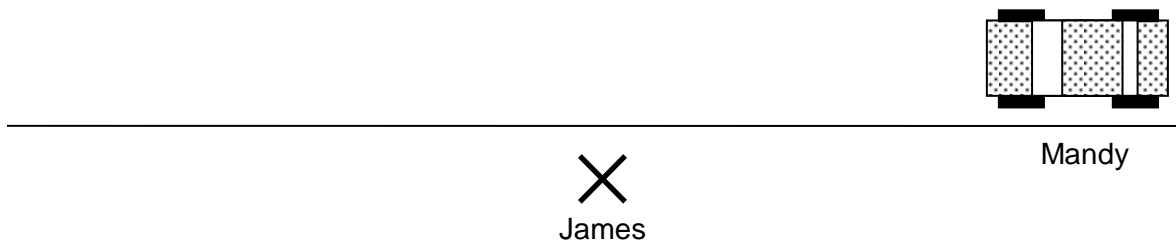
- e) The ground is now changed a final time to a still water surface. A particular part of the wave front strikes the water surface at an angle of  $45.0^\circ$ . Some of the energy of the wave is reflected and the rest is refracted. Show the pathways taken by the reflected and refracted energy at the air - water boundary.

(2 marks)



**Question 18****(7 marks)**

Mandy has just got her driver's licence. She sees her friend, James, standing stationary on the side of the road waiting for a bus. Mandy holds the horn of the car down as she drives past to get his attention, starting 30.0 m before she passes and finishing 30.0 m after she has passed.

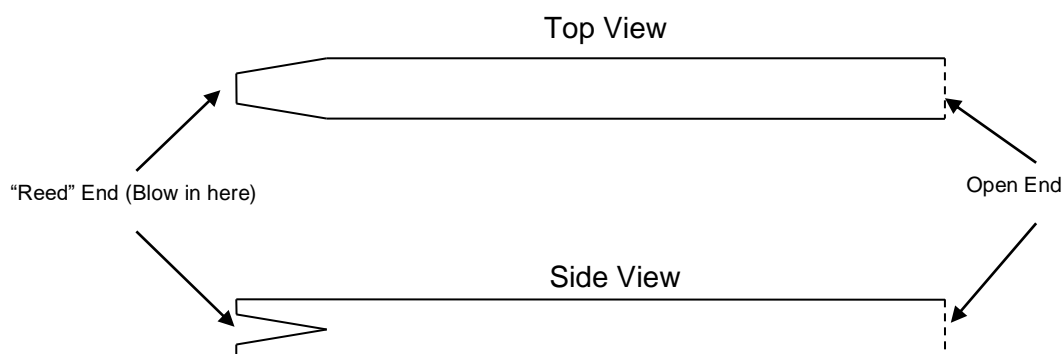


- a) What is the name of the effect that James hears as the car approaches and then passes? (1 mark)
- 
- b) If the horn has a frequency of 300 Hz and the car is travelling at  $48 \text{ km h}^{-1}$ , what is the difference in frequency between the approaching and receding horn? (3 marks)

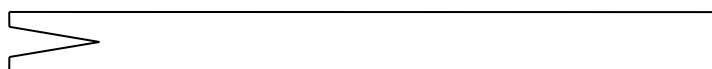
- c) Mark on the picture above using the letter **Z** the position of the car at which the frequency of the car horn will be un-altered as heard by James. (1 mark)
- d) At what speed should Mandy travel in her car while sounding the horn to produce a 50 Hz alteration below 300 Hz? (2 marks)

**Question 19****(8 marks)**

A year 9 has made a “buzzy” drinking straw by flattening the straw at one end and cutting it into the shape of an oboe reed shape. When the student blows through the straw the reed opens and closes creating fluctuations in air pressure inside the straw, resulting in a buzz.



- a) Will the straw act as an open or closed pipe? Explain your answer. (1 mark)
- b) If the drinking straw is 25.0 cm long what is the lowest frequency it can produce? (3 marks)
- c) What is the wavelength of this lowest frequency? (2 marks)
- d) By tightening her lips on the straw the student can make the reed vibrate at 3 times the straw's fundamental frequency. Draw the standing wave that is produced in the straw at this frequency. (2 marks)



### Section Three: Comprehension 20% (30 Marks)

This section contains **two (2)** questions. You must answer both questions. Write your answers in the space provided.

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Suggested working time for this section is 30 minutes.

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#### Question 21

(15 marks)

### The Angel of the North

#### Paragraph 1

The Angel of the North is a contemporary sculpture designed by Antony Gormley, which is located in Gateshead, England. As the name suggests, it is a steel sculpture of a graceful angel, standing 20 m tall, with wings that span 54 m across.

#### Paragraph 2

It stands on a hill, on the southern edge of Low Fell. It is seen by an estimated 90,000 travellers a day – travelling on the nearby A1 and on the East Coast Main Line rail route.

#### Construction

#### Paragraph 3

Work began on the project in 1994, the total cost coming to £1m. Most of the project funding was provided by the National Lottery. The work was completed in 1998, having taken the construction company Hartlepool Steel Fabrications five months to build.



#### Paragraph 4

The enormous statue is made from approximately 200 tonnes of a special, weather-resistant mix of steel and copper. The metal of the angel is designed to turn a mellow reddish-brown colour over time as the surface oxidises. The statue has an external skeleton of ribs constructed from 50 mm thick metal. The skin of the statue is formed from 6 mm thick metal. The inside of the statue is hollow.



#### Paragraph 5

The sculpture itself was created offsite, at Hartlepool Steel Fabrications Ltd in three parts – with the body weighing 100 tonnes, and two wings weighing 50 tonnes each – then brought to its site by road. It took seven hours for the body to be transported from its construction site in Hartlepool, up the A19 to the site.

#### Paragraph 6

The 20 m deep 600 tonne concrete foundations were laid by Thomas Armstrong (Construction) Ltd. The concrete foundations anchor the statue to naturally occurring rock 20 m below.

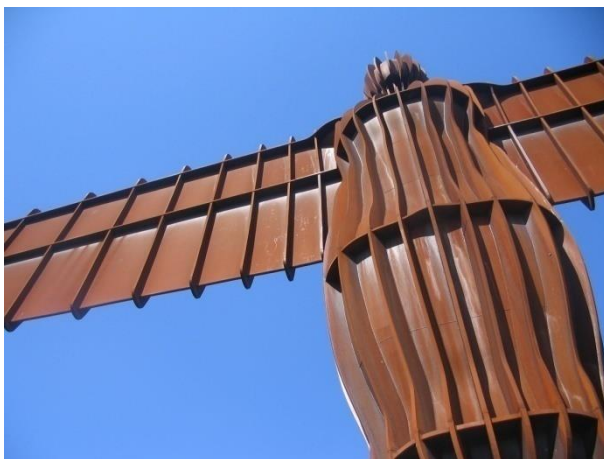


#### Paragraph 7

Due to its exposed location, the sculpture has been built to withstand winds of over 160 km/h.

#### Paragraph 8

The wings themselves are not planar, but are angled 3.5 degrees forward, which Gormley has said aims to create "a sense of embrace".



End of Article

1. Why are the ribs on the outer surface of the statue thicker than the “skin” of the statue?  
(2 marks)

2. If the angel is not anchored to its concrete base and there is no wind blowing, would the structure topple? Explain.  
(2 marks)

3. What are the general advantages and disadvantages of creating a steel structure?  
(4 marks)

Advantages	Disadvantages

The statue has been built to withstand the toppling forces created by air resistance in windy conditions. The formula for air resistance is ...

$$F(\text{air}) = C_d \rho A v^2 / 2$$

Where

Symbol	Definition	Units	Number for statue
$C_d$	coefficient of drag representing the roughness of the surface		0.4
$\rho$	The density of air	$\text{kg m}^{-3}$	1.40
$A$	Cross sectional area exposed to the wind.	$\text{m}^2$	330 (as viewed from the front)
$v$	Wind velocity	$\text{m s}^{-1}$	

4. What are the units for the drag coefficient in the formula above? (dimensional analysis).  
(2 marks)
5. Convert  $160 \text{ km h}^{-1}$  to  $\text{m s}^{-1}$ .  
(1 mark)

6. What is the air resistance of the statue when the wind blows at 160 km/h from the front?  
(2 marks)
7. If the air resistance force acts on the statue 15.0 m above its base, what is the torque exerted about the base of the statue by the wind?  
(2 marks)

## The Physics of Making a Soprano Recorder Musical Instrument.

### Paragraph 1

A soprano recorder is perhaps the first musical instrument that people ever get to play. It looks pretty simple. A pipe with a whistle opening at the top that you blow in and an open end at the bottom. The tube has holes drilled in it along its length. Cover the finger holes with the fingers in order to produce a low sound and uncover the holes to produce a high sound. By lifting the fingers off the finger holes one at a time starting at the bottom, the distance from the whistle opening to the nearest open finger hole is reduced. This shortens the length of resonating pipe. What could be simpler?

Figure 1



### Paragraph 2

If however you were asked to **build** a soprano recorder for yourself. That is a more challenging task! So, what physics would need to be considered in its construction?

### Paragraph 3

Perhaps the first question which will affect the construction is ...

“What is the lowest frequency (note) that I need the recorder to be able to play?”

Standard length recorders are built so that their lowest notes or tunings are ...

Table 1 – Lowest notes of standard recorder sizes from shortest to longest in length.

Recorder Name	Musical Tuning (Letter Name when all finger holes are closed)	Frequency (Hz) (All finger holes closed)
Sopranino	F	349.2
*** Soprano ***	C	261.6
Alto	F	174.6
Tenor	C	130.8
Bass	F	87.2

### Paragraph 4

The average temperature of the air in the recorder pipe is 25.0 °C. Based on this information the required length of pipe from whistle opening to the bottom end can be calculated.

### Paragraph 5

The second question is ...

“How do I tune it to other instruments under different temperature conditions?”

The speed of sound in air changes depending on the air temperature. This speed change effects the frequency (pitch) produced by the recorder. On a cold day when the air temperature is 8.00 °C the soprano recorder you have built (with all holes covered) will produce a lower frequency sound than the same recorder at 25.0 °C.

The speed of sound as a function of temperature (in kelvin) formula is ...

$$v = 20.04 T^{\frac{1}{2}}$$

Where...

Symbol	Definition	Units
v	Speed of sound in air	m s <sup>-1</sup>
T	Temperature	K (Kelvin)

The converting degrees celcius to kelvin formula is ...

$$T(K) = T(^{\circ}C) + 273$$

### Paragraph 6

If you wish to play with other instruments (in tune), you will need to be able to adjust the frequency played by your instrument regardless of the air temperature. This is achieved by adjusting the length of the pipe so that its lowest note can be set to 261.6 Hz regardless of air temperature. This length adjustment is achieved by incorporating a small telescopic joint between the head piece (containing the whistle) and the body of the recorder containing the finger holes.

### Paragraph 7

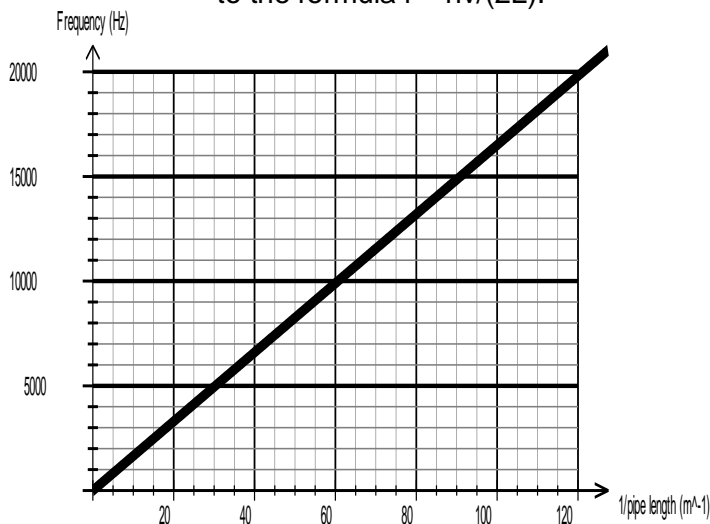
The third and final question is ...

“Where and how far apart to place the finger holes?”

If the holes are placed randomly along the length of the pipe, they will all produce a frequency (note) as each finger is progressively lifted off the finger holes but the frequencies created will not collectively form a musical scale unless the spacing between the finger holes is correct.

### Graph 1

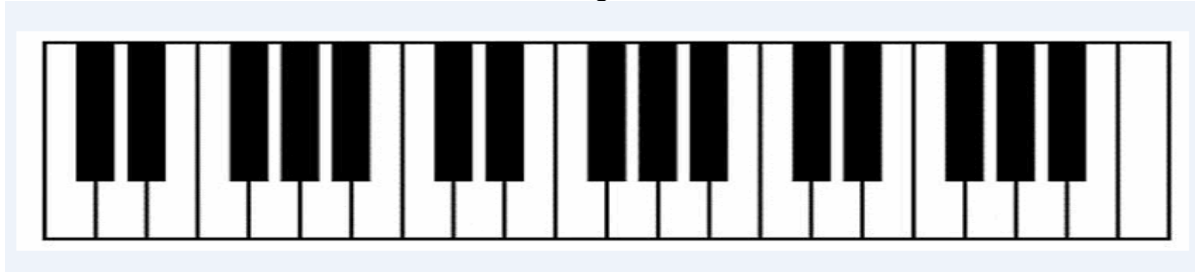
Any length of pipe (whistle to drilled finger hole) is capable of producing a frequency according to the formula  $f = nv/(2L)$ .



#### Paragraph 8

In music the smallest distance between one note and the very next note in a musical scale is called a semi tone. This can be pictured on a piano keyboard as the frequency difference between one piano key (button) and the very next piano key (button) regardless of piano key colour (black or white). This frequency difference does not remain constant but gradually increases as you progress from the lowest notes to the highest notes on a keyboard or musical instrument.

Figure 2



#### Paragraph 9

We need a formula that can (given a reference starting frequency) calculate the frequency of the next note of the musical scale (a semi tone or more above it). The reference note required is the lowest note played by the full length of pipe measured from the whistle to the bottom end.

The musical scale formula is ...

$$f_{\text{higher frequency (note) being sought}} = f_{\text{reference frequency (note)}} 2^{(z / 12)}$$

Where ...

Symbol	Definition	Unit
$f_{\text{higher note being sought}}$	Frequency of the note (sound) to be produced when the finger hole is drilled in the pipe.	Hz
$f_{\text{reference note}}$	Frequency of the note (sound) produced when there are no holes drilled in the pipe	Hz
2	Two	Constant
$\wedge$	to the power of ...	Mathematical operation
$z$	The number of semitones higher than the original reference frequency.	A whole number (unitless)

Paragraph 10

Using the musical scale formula, the frequencies required for the finger holes will be as shown in the table below...

Table 2 – Notes in a musical scale for a soprano recorder (C major)

Number of holes open (starting from the bottom of the pipe.)	Number of semitones from reference note ( <b>z</b> )	Frequency (Hz)	Musical Note (letter name)
0 (reference frequency)	0	261.6	C
1	2	293.6	D
2	4	329.6	E
3	5	349.2	F
4	7		G
5	9	440.0	A
6	11	493.8	B
7	12	523.2	C

Paragraph 11

Using the pipe formula from any high school physics course and the musical scale formula above, the pipe length (hole position measured from the whistle end) can be calculated.

Paragraph 12

With the concepts of lowest frequency, tuning at different temperatures and finger hole placement, you are well on your way to drawing the plans from which you can make your very own recorder.

End of Article

1. Is a recorder an open or closed pipe? Explain your reasoning.  
(2 marks)
2. Calculate, using your pipe formula, with assistance from **Table 1** the length of a **soprano recorder** from whistle to the open pipe end at the bottom when the speed of sound in air is  $346 \text{ m s}^{-1}$ ?  
(3 marks)
3. When you lift your fingers one at a time off the finger holes from bottom to top, which variable changes in the pipe formula to cause the change in frequency?  
(1 mark)

4. What is the speed of sound in air, when the air is at a temperature of  $8.00^{\circ}\text{C}$ ?  
(**Paragraph 5**) (2 marks)
5. Calculate from **Graph 1** the speed of sound in air on the day the graph was created.  
Show all working to obtain full marks. (4 marks)
6. Using the musical scale formula (**Paragraph 9**) calculate the missing value in **Table 2**.  
(3 marks)

End of Exam

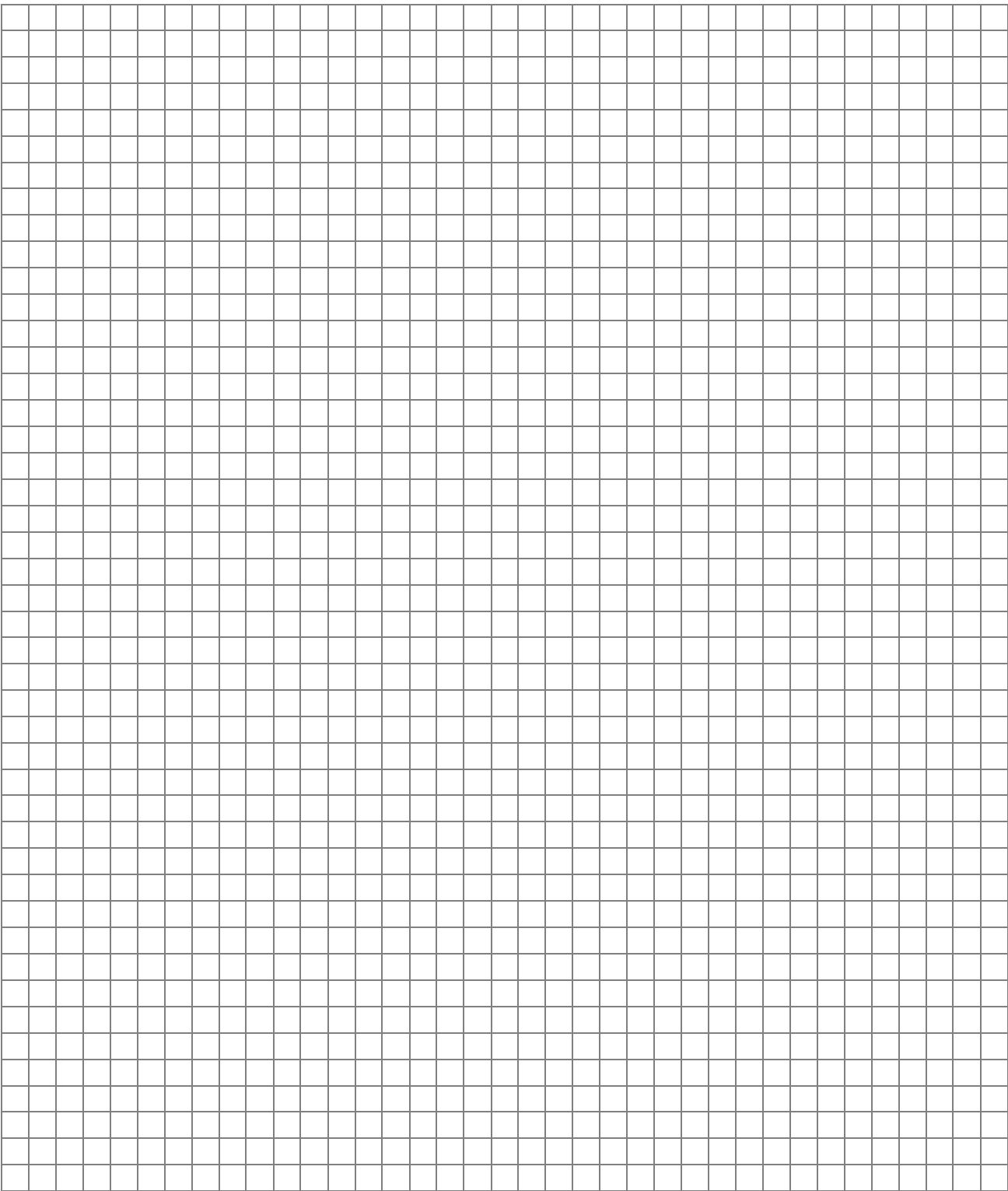






### Additional working space





## ACKNOWLEDGEMENTS

### Angel of the North

[http://en.wikipedia.org/wiki/Angel\\_of\\_the\\_North](http://en.wikipedia.org/wiki/Angel_of_the_North)

(extracted 14/4/2010)

<http://www.icons.org.uk/theicons/collection/angel/biography/angel-of-the-north>

(extracted 14/4/2010)

### Recorders

[www.aulosusa.com](http://www.aulosusa.com) (aulos recorders website)

(extracted 21/4/2010)

[www.music-for-music-teachers.com](http://www.music-for-music-teachers.com) (picture of keyboard)

(extracted 22/4/2010)



## Semester One Examination, 2010

### Question/Answer Booklet

## 3AB PHYSICS

Answers

Student Number: In figures

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In words

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### Time allowed for this paper

Reading time before commencing work: Ten minutes  
Working time for paper: Two hours thirty minutes

### Materials required/recommended for this paper

#### *To be provided by the supervisor*

This Question/Answer Booklet  
Formulae and Constants Sheet

#### *To be provided by the candidate*

Standard items: pens, pencils, eraser, correction fluid, ruler, highlighters

Special items: non-programmable calculators satisfying the conditions set by the Curriculum Council for this course

### Important note to candidates

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. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

	A	B	C	Total
Score				
Out of	45	75	30	150
%				

## Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Short response	12	12	45	45	30
Section Two: Problem-solving	7	7	75	75	50
Section Three: Comprehension	2	2	30	30	20
					100

## Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2010*. Sitting this examination implies that you agree to abide by these rules.
2. Write answers in this Question/Answer Booklet.
3. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.
5. Working or reasoning should be clearly shown when calculating or estimating answers.
5. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
  - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
  - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.



**Section One: Short response****30% (45 marks)**

This section has **12** questions. Answer **all** questions. Write your answers in the space provided.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time for this section is 45 minutes.

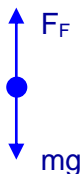
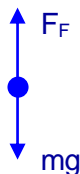
**Question 1****(3 marks)**

You are standing on a balcony of a building. Explain a procedure by which you can calculate the height of the balcony using only a ball and a stop watch.

- Drop the ball from the balcony.
- Start the stopwatch as you drop it
- Stop the stopwatch as it hits the ground
- use  $s = \frac{1}{2} at^2$

**Question 2****(3 marks)**

A person with a parachute open arrives at the ground much later than a person whose parachute has failed to open. If both parachutists have the same mass and both parachutists fall at a constant (but very different) velocity from the same height. Explain the large difference in their terminal velocities.

Parachute open	Parachute closed
<p>Free body diagram (<math>mg = f_f</math>)</p> 	<p>Free body diagram (<math>mg = f_f</math>)</p> 

In both situations the air resistance equals the weight – **so is constant**

The air resistance depends on the cross sectional area and velocity squared.

$$v^2 A k = F_f = k A v^2$$

$$\downarrow \uparrow k = k = k \downarrow \uparrow$$

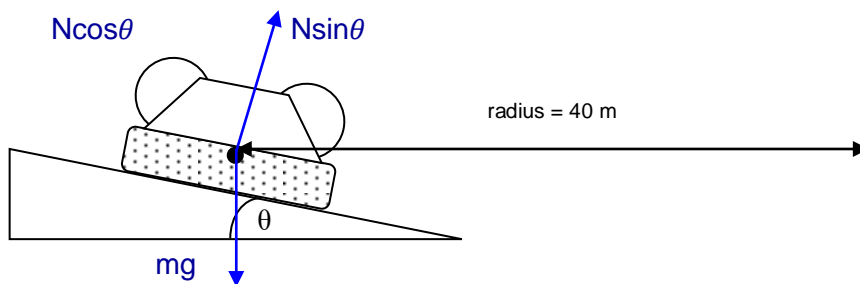
Hence, large areas mean small velocity<sup>2</sup>, small area means large v<sup>2</sup>

### Question 3

$$\frac{50}{3.6} = 13.8 \text{ m/s}$$

(4 marks)

A hovercraft is travelling around a banked curve (burr). The hovercraft is travelling at 50.0 km/h and the curve has a radius of 40.0 m. The hovercraft and driver have a combined mass of 200 kg. The hovercraft glides on a cushion of air and experiences no friction.



What is the angle for the burr?

Horizontal	Vertical
$(-mg) + N\cos\theta = 0$ $N\cos\theta = mg$ $N = \frac{mg}{\cos\theta}$	$N\sin\theta = \frac{mv^2}{r}$ $\frac{mg}{\cos\theta} \times \frac{\sin\theta}{1} = \frac{mv^2}{r}$ $\tan\theta = \frac{v^2}{rg}$ $\theta = \text{Arctan} \frac{r^2}{rg}$ $\theta = \frac{13.8^2}{40 \times 9.8}$ $\theta = 26.2^\circ$

### Question 4

$$16.6 \text{ m/s}$$

(3 marks)

A person is driving to the airport with their 40 kg suitcase in the back of a ute. When the ute goes around a wide corner at 60 km/h the bag in the back does not "slide around" in the back of the ute. When the ute goes around a tight corner at the same speed the bag does "slide around" in the back of the ute. Explain why the bag does or does not slide using example calculations.

Tight corner	Wide corner
$F_F = \frac{mv^2}{r}$ Tight $r = 3\text{m}$ $F_F = \frac{40 \times 16.6^2}{3}$ $F_F = 3674 \text{ N}$	$F_F = \frac{mv^2}{r}$ Wide $r = 10\text{m}$ $F_F = \frac{40 \times 16.6^2}{10}$ $F_F = 1111 \text{ N}$

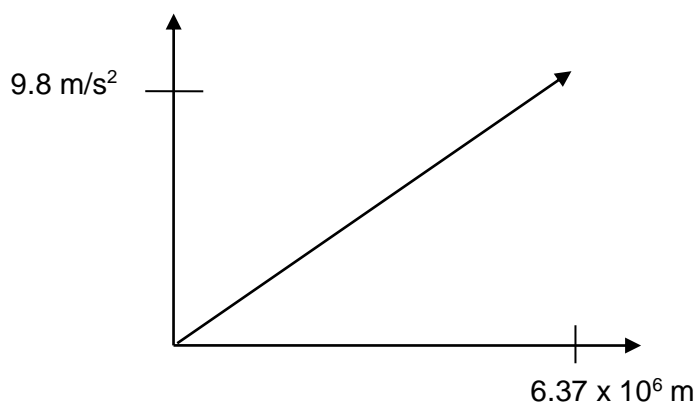
$F_c$  is provided by  $F_f$ .

When the  $F_c$  required is greater than the maximum value of static friction, the suitcase slips.

A tight radius increases the  $F_c$  required which increases the  $F_f$  required.

**Question 5****(5 marks)**

- a) Gravity decreases linearly to zero when you travel inside the earth from the surface to the centre. Sketch a graph of this line showing the values for gravity at the centre and at the surface as a function of distance.

**(3 marks)**

- b) What is the mathematical equation for this line?

**(2 marks)**

$$g = \frac{9.8}{6.37 \times 10^6} r$$

$$g = 1.54 \times 10^{-6} r$$

**Question 6****(4 marks)**

- a) A new planet is discovered. It has a mass that is 384 times that of earth and a radius 8 times that of earth. What is the strength of its gravitational field?

**(3 marks)**

$$g = \frac{Gm}{r^2}$$

$$g = \frac{6.67 \times 10^{-11} \times 384 \times 5.98 \times 10^{24}}{(8 \times 6.37 \times 10^6)^2}$$

$$g = 59.0 \text{ m/s}^2$$

- b) What is the ratio of the gravitational field strength on the surface of this planet as compared to earth?

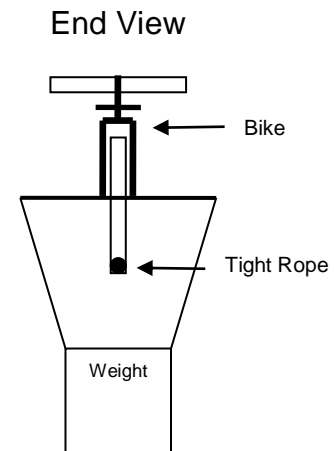
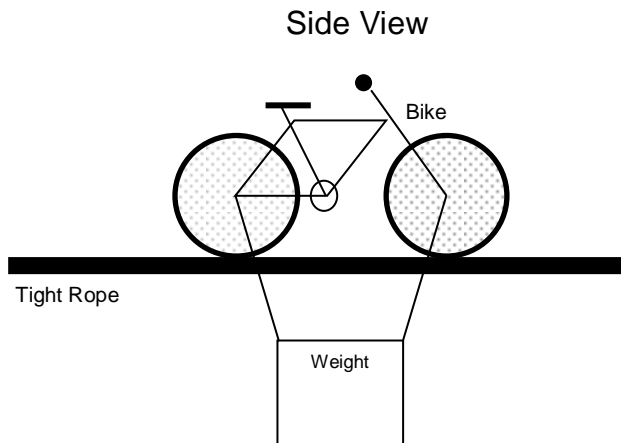
**(1 mark)**

Earth : Planet

1 : 6.02

**Question 7****(4 marks)**

A bike with no tyres (just the metal rims) is stationary on a tightrope. The bike has axles that extend out sideways off which a large, heavy counter weight has been suspended below the tight rope.



- a) Is the situation shown above in mechanical or static equilibrium?

**mechanical****static**

(please circle one only)

**(1 mark)**

- b) Explain why.

The bike is stationary (static)

**(1 mark)**

- c) Is the above situation in stable, unstable or neutral equilibrium?

(please circle one only)

**stable****unstable****neutral?**

(please circle one only)

**(1 mark)**

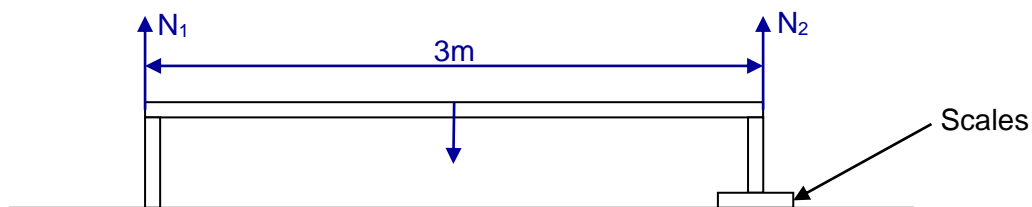
- d) Explain why.

**(1 mark)**

The centre of mass of the system is below the support point. Any tipping force applied to the bike causes the COM to rise. When the tipping force is removed the COM falls to original position.

**Question 8****(4 marks)**

A boy wants to measure the weight of a park bench using a set of bathroom scales calibrated in newtons. He cannot fit the whole bench on the scales. He can only fit one complete end on the scales. The scales read 98 N. If the bench is uniform and level and nobody is sitting on it, what is the total weight of the bench?



$$\Sigma M_C = \Sigma M_A$$

Let the length of the bench be 1.00 m

Take moments about the left hand leg.

$$0.5 \times mg = 1 \times 98$$

$$mg = 196 \text{ N Down}$$

**Question 9****(4 marks)**

Heidi is standing in front of a very large cliff. Heidi claps her hands while facing the cliff. Gertrude who is standing next to Heidi, uses a stopwatch to time how long it takes for the echo to return to them, having bounced off the cliff. It takes 4.74 seconds.

- a) How far are Heidi and Gertrude from the cliff?

**(2 marks)**

$$v = \frac{s}{t}$$

$$s = v \times t$$

$$s = 346 \times 4.74$$

$$s = 1640\text{m} \quad (\text{there and back})$$

$$\frac{1}{2} s = 8.20 \times 10^2 \text{ m}$$

- b) What is the major source of error in this activity?

**(1 mark)**

Reflex error in the timing.

Possibly the assumption about the speed of sound in air also.

- c) The distance from Heidi to the cliff is now measured using an accurate (laser) measuring tape. The measuring tape records a distance of 792.000 m. If the answer from the measuring tape can be trusted, what is the % error in the distance calculated from the echo and stopwatch?

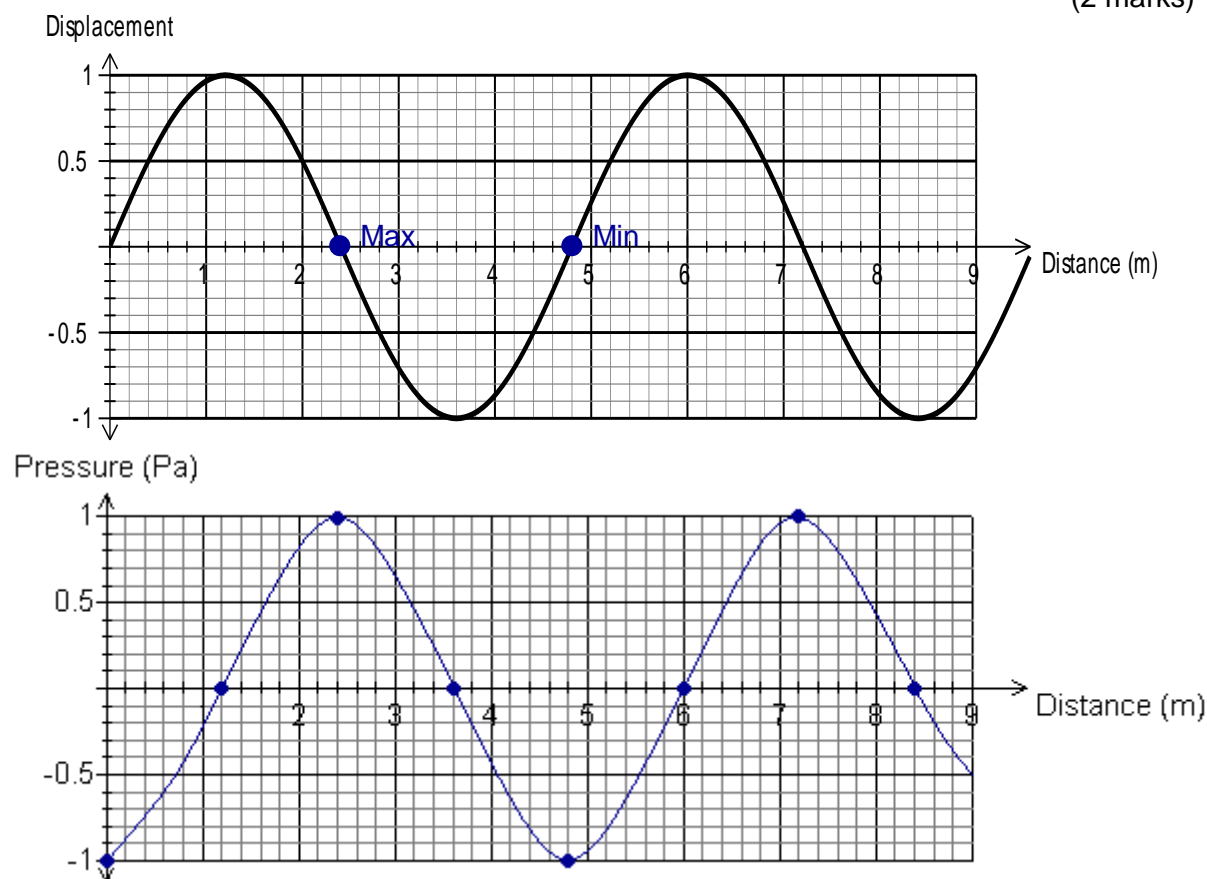
**(1 mark)**

$$\% \text{ error} = \left( \frac{820 - 792}{792} \right) \times 100$$

$$= 3.54\%$$

**Question 10****(4 marks)**

- a) Convert the below displacement - distance graph into a pressure - distance graph. Assume that the maximum and minimum pressure is 1 pascal (Pa).

**(2 marks)**

- b) If this is a sound wave in air, what is the period of the wave?

**(2 marks)**

$$\lambda = 4.8 \text{ m}$$

$$v = 346 \text{ m/s}$$

$$f = ?$$

$$v = f \times \lambda$$

$$346 = f \times 4.8$$

$$f = \frac{346}{4.8}$$

$$f = 72.08$$

$$T = 1/f$$

$$T = 0.0139 \text{ s}$$

**Question 11****(3 marks)**

A student is very hot after running a marathon. She places two identical fans directly in front of her. The first fan is switched on and runs at 3000 rpm (revolutions per minute). When the second fan is switched on the sounds from the two fans interfere with each other to produce 6 fluctuations in loudness each second. What is the frequency of the second fan in cycles per second (Hz)?

$$f_1 = 3000 / 60 = 50 \text{ Hz}$$

$$f_{\text{beat}} = |f_1 - f_2|$$

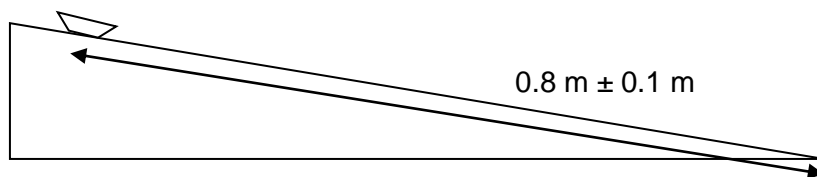
$$6 = |50 - f_2|$$

$$f_2 = 56 \text{ Hz or } 44 \text{ Hz}$$

### Question 12

(4 marks)

A student is measuring the time taken for a bath plug to slide to the bottom of an icy slope.



The slope has a length of  $0.8 \text{ m} \pm 0.1 \text{ m}$ . The student measures the time it takes for the plug to travel to the bottom of the slope 5 times. The 5 results are recorded below.

Distance (m)	$0.8 \text{ m} \pm 0.1 \text{ m}$				
Time (s)	5.16 s	1.21 s	1.56 s	1.87 s	1.64 s

a) Calculate the average time.

(1 mark)

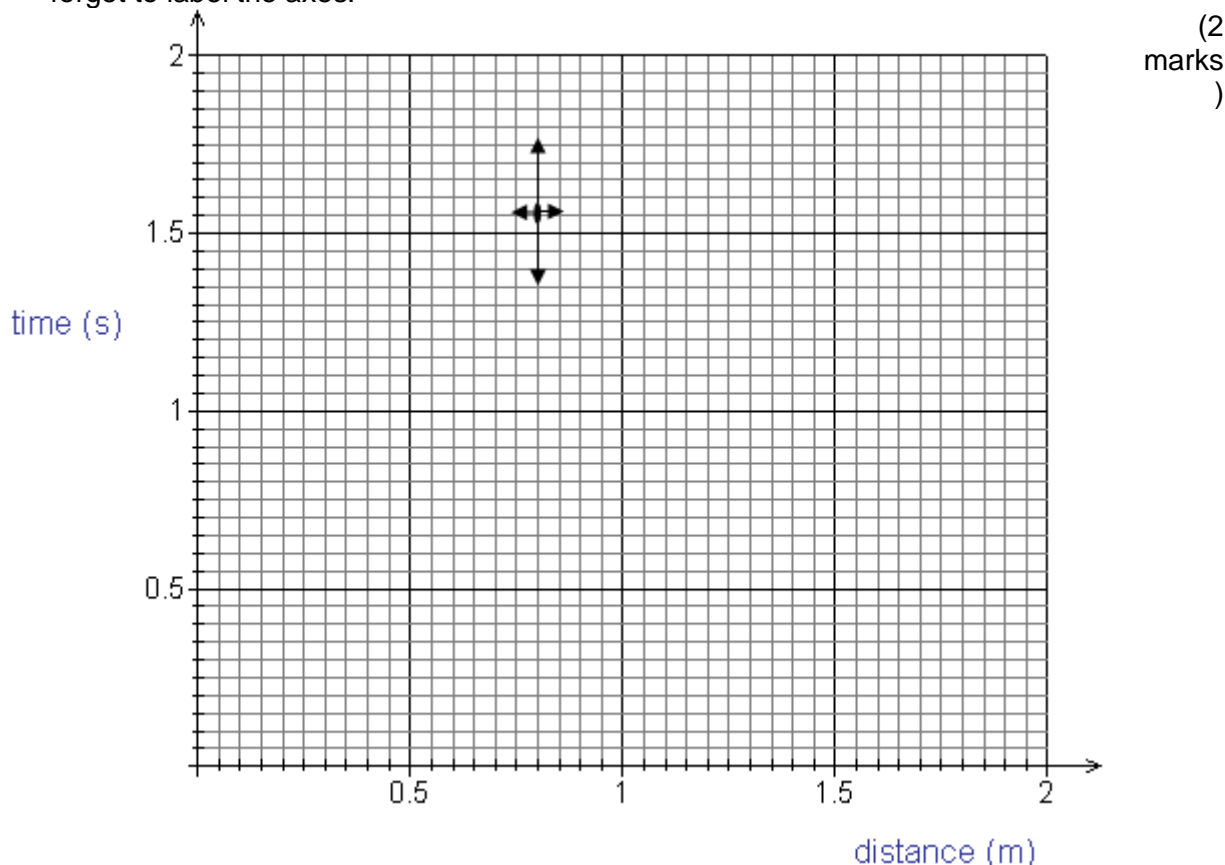
$$\text{Average time} = (1.21 + 1.56 + 1.87 + 1.64) / 4 = \mathbf{1.57 \text{ s}}$$

b) What is the absolute statistical error in the time?

(1 mark)

$$1.57 - 1.21 = \mathbf{0.36 \text{ s}}$$

c) Combine the above information appropriately to create a single data point to be plotted on the graph paper below. Attach to the data point error bars for distance and for time. Don't forget to label the axes.



**End of Section One**



**Section Two : Problem-solving****50% (75 Marks)**

This section has **seven (7)** questions. You must answer **all** questions. Write your answers in the space provided.

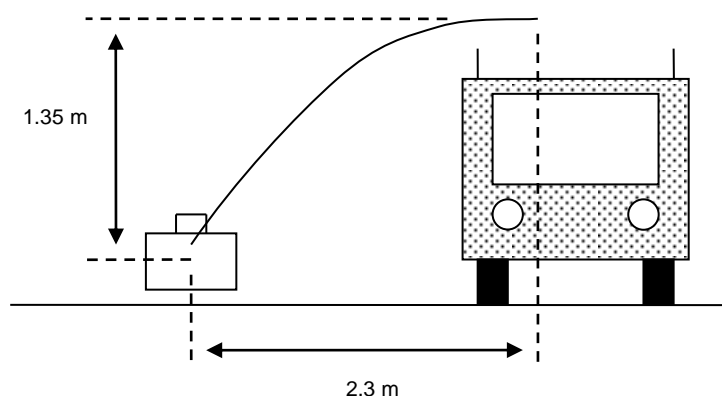
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Suggested working time for this section is 75 minutes.

**Question 13****(11 marks)**

A St Mary's student is travelling in Africa on exchange. She is taking a bus from Zanzibar to Timbuktu. The bus stores baggage on the roof. A person loading the baggage throws her full bag to a second person standing on the roof of the bus. The distances are as shown on the diagram.



- a) With what initial vertical velocity must the bag be thrown to just reach the person on the roof? (2 marks)

$$v^2 = u^2 + 2as$$

$$0 = u^2 + 2 \times -9.8 \times 1.35$$

$$-u^2 = -26.46$$

$$u = 5.14 \text{ m/s up}$$

- b) How long did it take the bag to reach the roof? (2 marks)

$$v = u + at$$

$$0 = (+5.14) + (-9.8) \times t$$

$$\frac{-5.14}{-9.8} = t$$

$$t = 0.525 \text{ s}$$

- c) What is the horizontal velocity of the bag?

(2 marks)

$$u = \frac{s}{t}$$

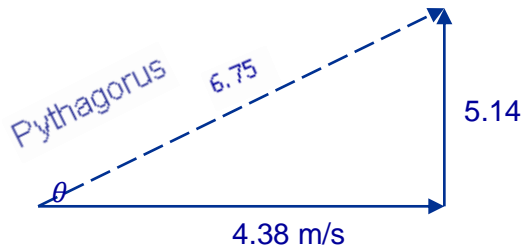
$$u = \frac{2.3}{0.525}$$

$$u_H = 4.38 \text{ m/s}$$

- d) What is the initial angle of take off of the bag?

(2 marks)

$$u =$$

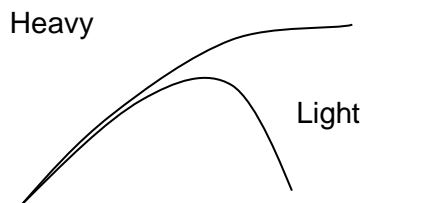


$$\tan \theta = \frac{5.14}{4.38}$$

49.6° above horizontal

- e) When the bag is empty it is very “light”. When her possessions are in it, the bag is very heavy. Explain how and why the trajectory of the empty and full bag would differ when air resistance is taken into account.

(3 marks)



$$F_{\text{air resistance}} = \frac{k}{m} a \quad \begin{matrix} \uparrow \\ \downarrow \end{matrix} \quad \text{stays near to parabolic shape}$$

$$F_{\text{air resistance}} = \frac{k}{m} a \quad \begin{matrix} \downarrow \\ \uparrow \end{matrix} \quad \text{strays from parabolic shape because deceleration is significant.}$$

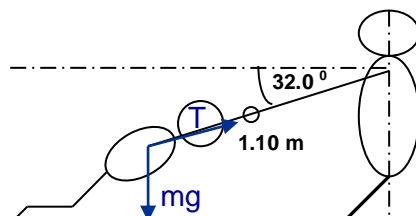
### Question 14

(10 marks)

A silly parent is playing a game with a child called “dizzy wizzies”. The parent holds one of the child’s hands and swings them around in a circle. The child has a mass of 25.0 kg and the arms of the parent / child form an angle of  $32.0^\circ$  to the horizontal. The distance from the shoulders of the adult to the centre of mass of the child is 1.10 m along the line of the arms. Assume the child revolves around the vertical central line passing through the middle of the adult.

- a) Draw the forces acting on the child.

(2 marks)



- b) What is the tension in the arms of the child?

(2 marks)

V	H
$T \sin 32^\circ = mg$ $T \sin 32^\circ = 25 \times 9.8$ $T \sin 32^\circ = 245 \text{ N}$ <b><math>T = 462 \text{ N}</math></b>	

- c) What is the centripetal force acting on the child?

(1 mark)

$$T_H = \frac{mv^2}{r}$$

$$T \cos 32^\circ = F_c$$

$$462 \cos 32^\circ$$

$$\mathbf{392 \text{ N Horizontal}}$$

- d) What is the velocity of the child’s centre of mass?

(2 marks)

$$392 = \frac{mv^2}{r}$$

$$392 = \frac{25 \times v^2}{1.10 \cos 32^\circ}$$

$$\mathbf{v = 3.82 \text{ m/s}}$$

- e) The child's shoulder joint can withstand a maximum tension of 600 N before it dislocates. At what speed will this occur?

(3 marks)

$F_c$  given by Pythagoras

$$600^2 = F_c^2 + (mg)^2$$

$$F_c = 547.69 \text{ N}$$

$$547.69 = \frac{mv^2}{r}$$

$$\sqrt{\frac{600}{m}} \times r = v$$

Angle given by  $\sin \theta = (mg / 600)$

$$\theta = 24.1^\circ$$

Radius given by  $r = 1.1 \cos 24.1^\circ$

$$v = \sqrt{\frac{600}{25}} \times 1.1 \cos 24.1$$

$$\mathbf{v = 4.69 \text{ ms}^{-1}}$$

### Question 15 (14 marks)

A 12.5 kg space probe is attempting to enter into a stable circular orbit around Neptune at a speed of  $550 \text{ m s}^{-1}$ .

#### Facts about Neptune

Neptune's Mass	$1.02 \times 10^{24} \text{ kg}$
Radius of Neptune	$2.48 \times 10^7 \text{ m}$
Period of Rotation of Neptune	0.6713 earth days

- a) At what distance from the surface of Neptune should the space probe be placed to achieve this orbit?

(3 marks)

$$\frac{Gmm}{r^2} = \frac{mv^2}{r}$$

$$\frac{Gm}{v^2} = r$$

$$\frac{6.67 \times 10^{-11} \times 1.02 \times 10^{24}}{550^2} = r$$

$$r = 2.249 \times 10^8$$

$$h = r - r_{\text{nep}}$$

$$h = 2.00 \times 10^8 \text{ m}$$

- b) Is it possible to place a “geostationary” satellite in an orbit around Neptune? Explain why or why not with the support of calculations.

(3 marks)

$$\frac{r^3}{T^2} = \frac{Gm}{4\pi^2}$$

$$r = \sqrt[3]{\frac{GmT^2}{4\pi^2}}$$

$$r = \sqrt[3]{\frac{6.67 \times 10^{-11} \times 1.02 \times 10^{24} \times (0.6713 \times 24 \times 3600)^2}{4\pi^2}}$$

$$r = \sqrt[3]{\frac{6.67 \times 10^{-11} \times 1.02 \times 10^{24} \times (58000)^2}{4\pi^2}}$$

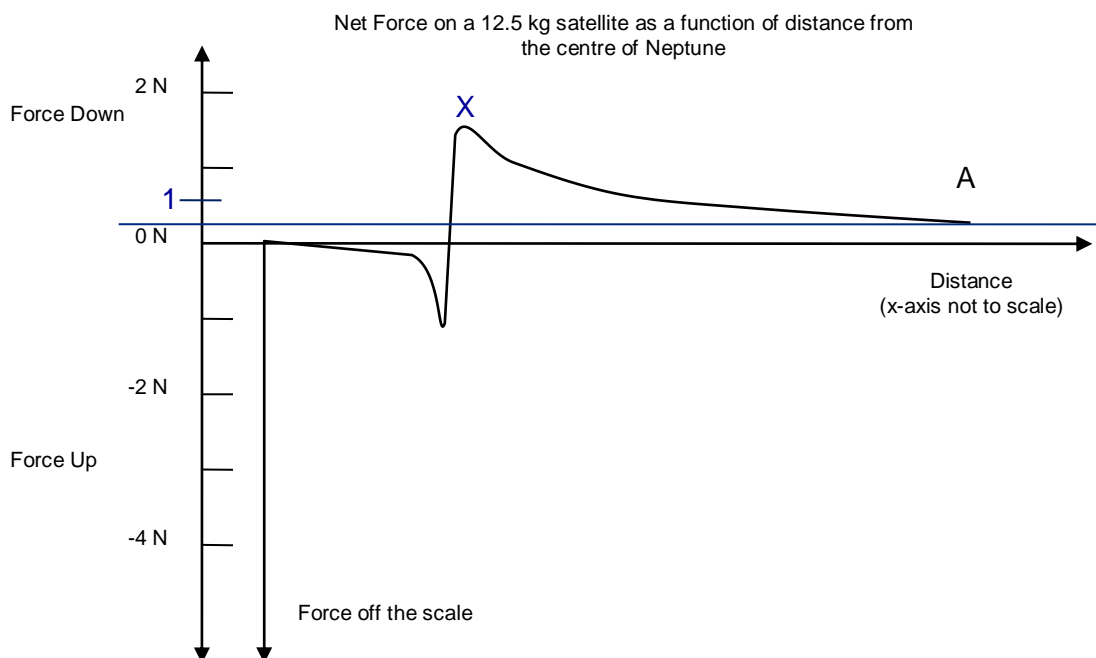
$$r^3 = 5.797317 \times 10^{21}$$

$$r = 1.796 \times 10^7 \text{ m}$$

$$r = 1.80 \times 10^7 \text{ m}$$

This is less than  $r_{\text{Neptune}}$  so no.

Unfortunately the space probe is misaligned and travels directly towards the centre of the planet. Astronomers define the “surface” of Neptune as being where its thick atmosphere begins. The atmosphere of Neptune becomes even thicker as you proceed towards the core. The resultant force on the space probe as it journeys from remote space (A) to the core of Neptune is shown in the graph below.



- c) What is the resultant force on the spacecraft as the point A (the start of the graph)? (1 mark)

$$\approx 0.3 \text{ N} \pm 0.1 \text{ N}$$

- d) Calculate from your answer to part c) the distance of the spacecraft above the centre of Neptune. (3 marks)

$$F = \frac{Gmm}{r^2}$$

$$0.3 = \frac{6.67 \times 10^{-11} \times 12.5 \times 1.02 \times 10^{24}}{r^2}$$

$$r = 5.32 \times 10^7 \text{ m} \quad (\text{depends on you answer to part c})$$

- e) Why does the net force on the space probe increase as it approaches Neptune even though its rockets are switched off? (2 marks)

As  $r \downarrow$   $F \uparrow$  inversely proportional square

$$\uparrow$$

$$F = \frac{Gmm}{\downarrow r^2}$$

- f) Based on your interpretation of the graph, mark with an **X** on the curve the location at which the space probe first encounters the “surface” (atmosphere) of Neptune. (1 mark)

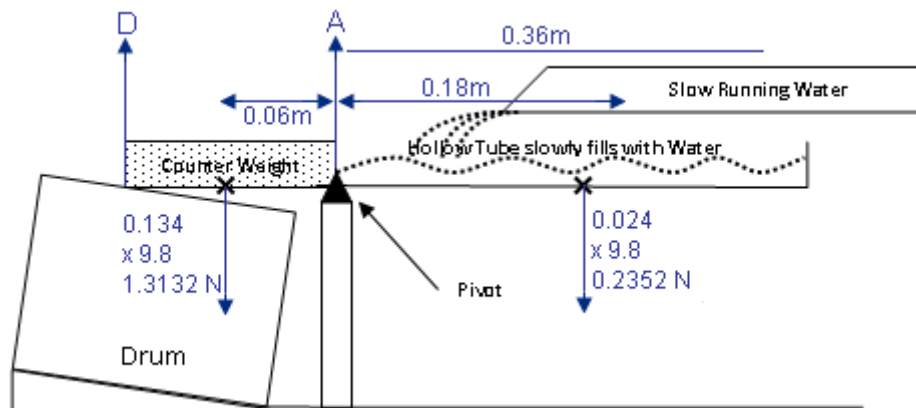
- g) What does the area under the graph represent? (1 mark)

Energy or work

### Question 16

(12 marks)

A Japanese bird scarer is a noise making device that is used to scare birds away from rice fields. The device uses the weight of water filling a hollow lever to tip the lever. When the lever tips, the water in the hollow tube empties causing the lever to return to horizontal hitting the drum and so scaring the birds away.



The counter weight has a mass of 134 g and has its centre of mass positioned 6.00 cm from the pivot. The counter weight has a full length of 12 cm. The hollow tube has a mass of 24.0 g when empty and has its centre of mass positioned 18.0 cm from the pivot. The hollow tube has a total length of 36.0 cm.

- a) When the tube is empty, what type of equilibrium is the tube in? Be specific. Explain how you came to this conclusion. (2 marks)

Static equilibrium

Weight of com of system passes through the "base" between drum and pivot.

When nudged the system returns to original position.

- b) What is the force of the drum acting on the counter weight when the hollow tube is empty? (2 marks)

Take m about A

$$\sum M_A = \sum M_C$$

$$(0.06 \times 1.3132) = (0.2352 \times 0.18) + (0.12 \times D)$$

$$(0.078792) = (0.042336) + (0.12 D)$$

$$D = 0.304 \text{ N up}$$

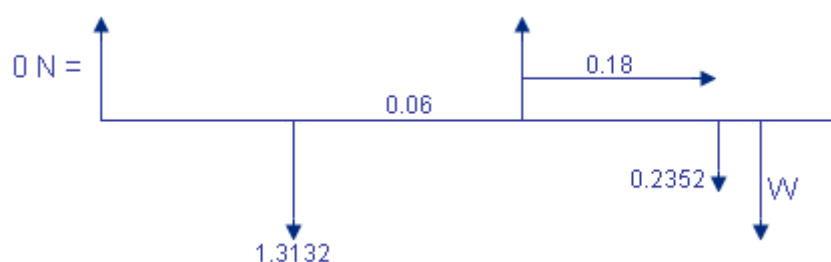
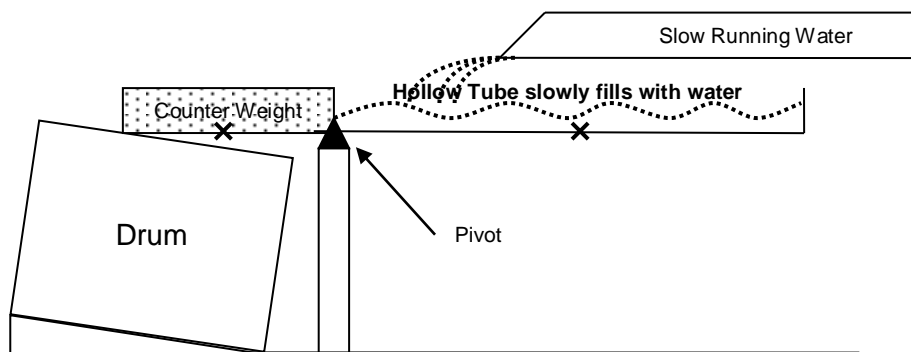
- c) What is the normal force provided by the pivot when the hollow tube is empty? (2 marks)

$$\sum F_{\uparrow} = \sum F_{\downarrow}$$

$$0.304 + A = 1.3132 + 0.2352$$

$$A = 1.24 \text{ N up}$$

- d) What volume of water (in mL) centred 18.0 cm from the pivot is required to just cause the hollow tube to tip? (Note - 1 mL of water has a mass of 1g.) (3 marks)



$$\begin{aligned}\Sigma M_C &= \Sigma M_A \\ (0.18 \times W) + (0.18 \times 0.2352) &= (0.06 \times 1.3132) \\ (0.18 \times W) + (0.042336) &= (0.078792) \\ (0.18 \times W) &= (0.036456) \\ W &= 0.203 \text{ N} \\ \text{mass} &= 0.203 / 9.8 \\ \text{mass} &= 0.0207 \text{ kg} \\ \text{mass} &= 20.7 \text{ g} \\ \text{mass} &= 20.7 \text{ mL}\end{aligned}$$

- e) Just before the tube, which is slowly filling with water tips; state what type of equilibrium the system is in? Be specific. (1 mark)

Unstable equilibrium

- f) Will the location on the drum hit by the counter weight experience a pressure node or anti-node when it is struck? Explain. (2 marks)

Pressure antinode  
Collision creates high pressure

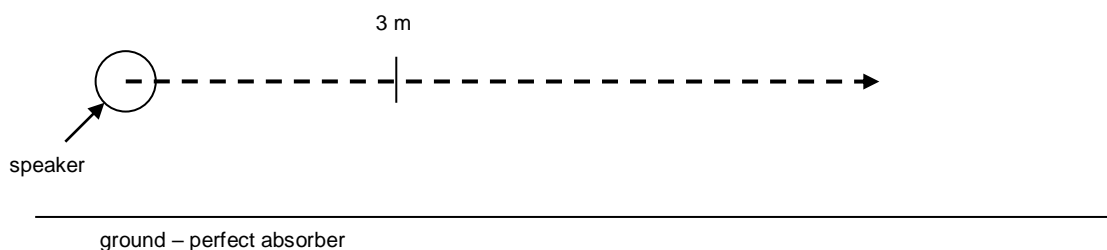
Paid any answer depending on the reasoning.



### Question 17

(13 marks)

A microphone is set up at a distance from a stereo speaker. The stereo speaker is sending out sound spherically around it. The ground absorbs all sound waves that strike it. The stereo speaker is emitting 1.00 J of sound energy each second at a frequency of 500 Hz.



- a) What is the intensity of the sound at a distance of 3 m?

(3 marks)

$$I = \frac{P}{A}$$

$$I = \frac{1}{4\pi \times 3^2}$$

$$I = 8.84 \times 10^{-3} \text{ Wm}^{-2}$$

- b) At what distance from the speaker will the intensity of the graph drop to  $1/16^{\text{th}}$  of the value calculated in part a)?

(2 marks)

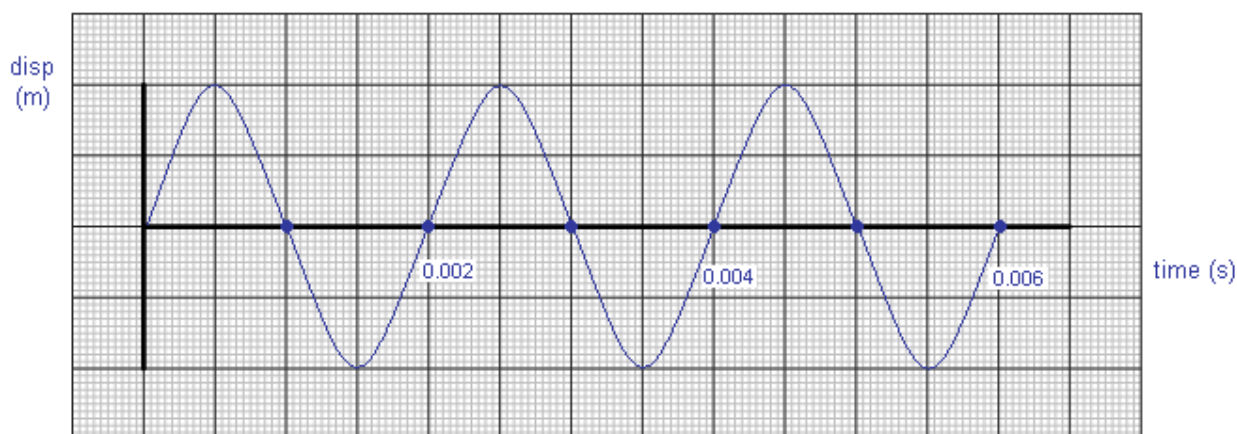
$$\frac{8.84 \times 10^{-3}}{16} = \frac{1}{4\pi r^2}$$

$$r = \sqrt{\frac{1}{4 \times \pi \times 8.84 \times 10^{-3}}}$$

$$r = 12.0 \text{ m}$$

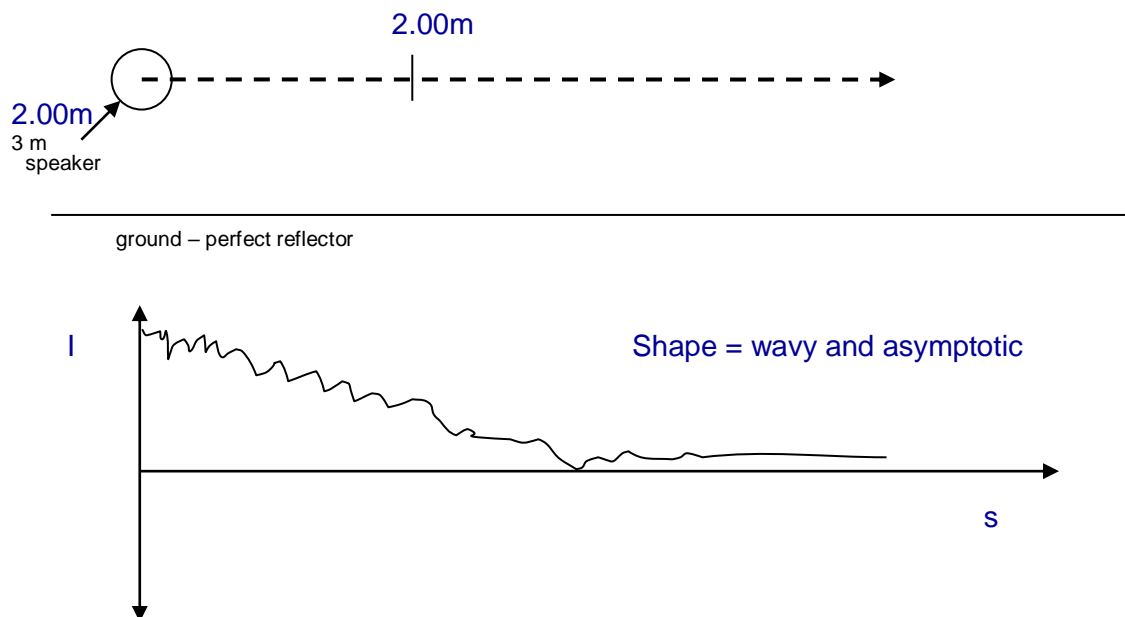
- c) Draw 3 cycles of a displacement - time graph for this 500 Hz sound.

(3 marks)



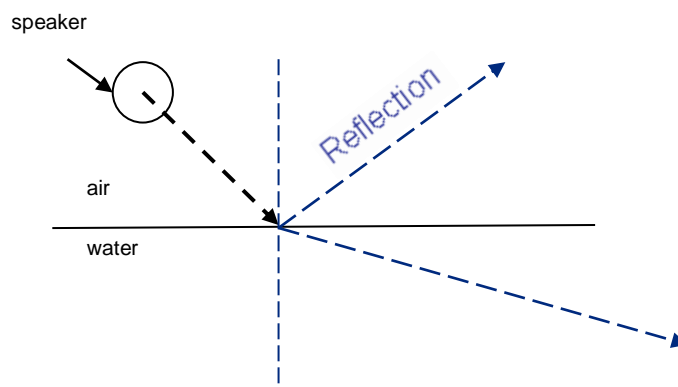
- d) The ground is now altered so that it is a perfect reflector and the centre of the speaker is positioned 2.00 m from the ground. Sketch the intensity as recorded by the microphone now as a function of distance as the microphone moves away from this speaker along the dotted line.

(3 marks)



- e) The ground is now changed a final time to a still water surface. A particular part of the wave front strikes the water surface at an angle of  $45.0^\circ$ . Some of the energy of the wave is reflected and the rest is refracted. Show the pathways taken by the reflected and refracted energy at the air - water boundary.

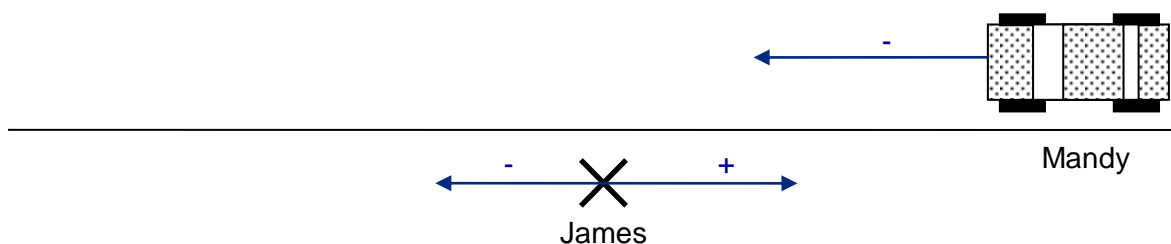
(2 marks)



### Question 18

(7 marks)

Mandy has just got her driver's licence. She sees her friend, James, standing stationary on the side of the road waiting for a bus. Mandy holds the horn of the car down as she drives past to get his attention, starting 30.0 m before she passes and finishing 30.0 m after she has passed.



- a) What is the name of the effect that James hears as the car approaches and then passes?

(1 mark)

- b) If the horn has a frequency of 300 Hz and the car is travelling at 48 km h<sup>-1</sup>, what is the difference in frequency between the approaching and receding horn?

(3 marks)

approaching	leaving
$\frac{f_L}{346+0} = \frac{300 \text{ Hz}}{346-13.333}$ $f_L = \frac{300 \times 346}{(346-13.333)}$ $f_L = 312.02 \text{ Hz}$	$\frac{f_L}{346+0} = \frac{300 \text{ Hz}}{346+13.333}$ $f_L = \frac{300 \times 346}{(346+13.333)}$ $f_L = 288.86 \text{ Hz}$

Frequency Difference = 312.02 Hz - 288.86 Hz

**Frequency Difference = 23.16 Hz**

- c) Using the letter **X** mark on the picture above the position of the car at which the frequency of the car horn will be un-altered as heard by James.

(1 mark)

- d) At what speed should Mandy travel in her car while sounding the horn to produce a 50 Hz alteration below 300 Hz?

(2 marks)

$$\frac{f_L 250}{346} = \frac{300}{[346 + ( \quad )]}$$

$$0.72254$$

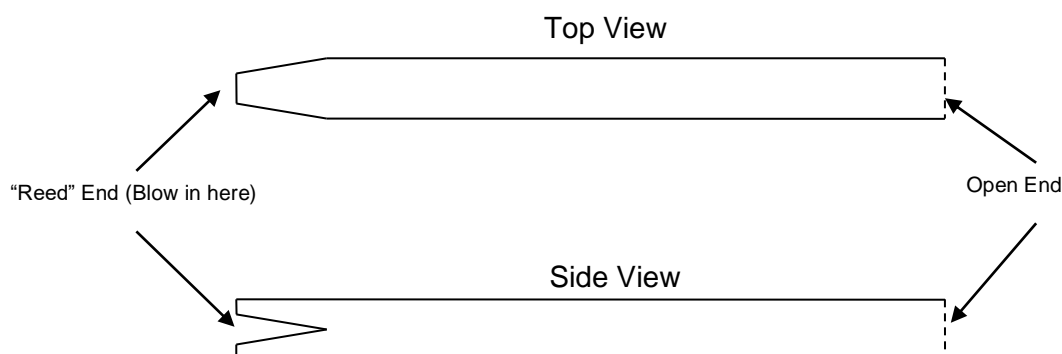
$$\frac{346+x}{300} \times \left( \frac{346 \times 300}{250} \right) - 346$$

**69.2 m/s away from James**

### Question 19

(8 marks)

A year 9 has made a “buzzy” drinking straw by flattening the straw at one end and cutting it into the shape of an oboe reed shape. When the student blows through the straw the reed opens and closes creating fluctuations in air pressure inside the straw, resulting in a buzz.



- a) Will the straw act as an open or closed pipe? Explain your answer.

(1 mark)

Open.

Reed = open = non rigid

Other end open = non rigid

- b) If the drinking straw is 25.0 cm long what is the lowest frequency it can produce?

(3 marks)

$$f = \frac{nr}{2l}$$

$$f = \frac{1 \times 346}{2 \times 0.25}$$

$$f = 692 \text{ Hz}$$

- c) What is the wavelength of this lowest frequency?

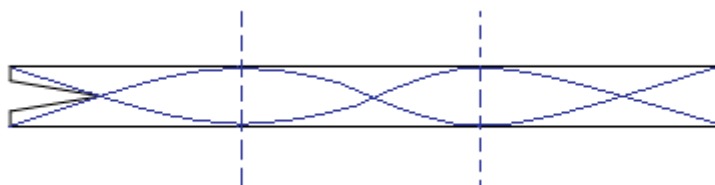
(2 marks)

$$346 = \lambda \times 692$$

$$\lambda = 0.500 \text{ m}$$

- d) By tightening her lips on the straw the student can make the reed vibrate at 3 times the straw's fundamental frequency. Draw the standing wave that is produced in the straw at this frequency.

(2 marks)



### Section Three: Comprehension 20% (30 Marks)

This section contains **two (2)** questions. You must answer both questions. Write your answers in the space provided.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time for this section is 30 minutes.

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#### Question 21

(15 marks)

### The Angel of the North

#### Paragraph 1

The Angel of the North is a contemporary sculpture designed by Antony Gormley, which is located in Gateshead, England. As the name suggests, it is a steel sculpture of a graceful angel, standing 20 m tall, with wings that span 54 m across.

#### Paragraph 2

It stands on a hill, on the southern edge of Low Fell. It is seen by an estimated 90,000 travellers a day – travelling on the nearby A1 and on the East Coast Main Line rail route.

#### Construction

#### Paragraph 3

Work began on the project in 1994, the total cost coming to £1m. Most of the project funding was provided by the National Lottery. The work was completed in 1998, having taken the construction company Hartlepool Steel Fabrications five months to build.



#### Paragraph 4

The enormous statue is made from approximately 200 tonnes of a special, weather-resistant mix of steel and copper. The metal of the angel is designed to turn a mellow reddish-brown colour over time as the surface oxidises. The statue has an external skeleton of ribs constructed from 50 mm thick metal. The skin of the statue is formed from 6 mm thick metal. The inside of the statue is hollow.

#### Paragraph 5

The sculpture itself was created offsite, at Hartlepool Steel Fabrications Ltd in three parts – with the body weighing 100 tonnes, and two wings weighing 50 tonnes each – then brought to its site by road. It took seven hours for the body to be transported from its construction site in Hartlepool, up the A19 to the site.

#### Paragraph 6

The 20 m deep 600 tonne concrete foundations were laid by Thomas Armstrong (Construction) Ltd. The concrete foundations anchor the statue to naturally occurring rock 20 m below.

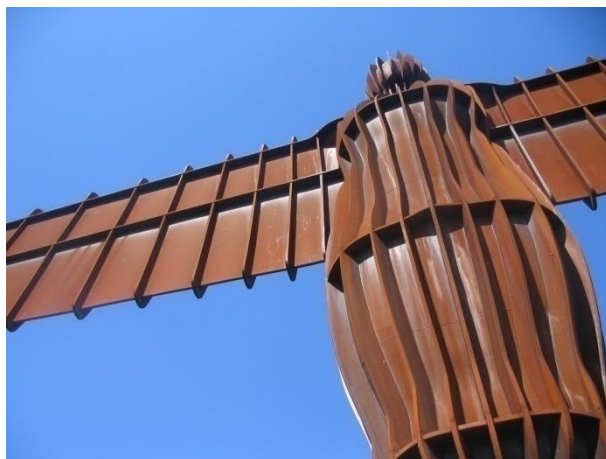


#### Paragraph 7

Due to its exposed location, the sculpture has been built to withstand winds of over 160 km/h.

#### Paragraph 8

The wings themselves are not planar, but are angled 3.5 degrees forward, which Gormley has said aims to create "a sense of embrace".



End of Article

1. Why are the ribs on the outer surface of the statue thicker than the “skin” of the statue? (2 marks)

The ribs experience the most stretch and squash as the statue bends in the wind. The ribs have to be thicker to withstand the extra tension and compression. The “skin” is not as close to the surface. It is closer to the neutral line.

2. If the angel is not anchored to its concrete base and there is no wind blowing, would the structure topple? Explain. (2 marks)

No The statue is symmetrical. Its centre of mass is positioned above its base. While the base is small it is not a point. It is in stable equilibrium

3. What are the general advantages and disadvantages of creating a steel structure? (4 marks)

Advantages	Disadvantages
Strong under both tension and compression.  Mouldable (malleable).	Expensive to Build  Rusts – High maintenance costs.

The statue has been built to withstand the toppling forces created by air resistance in windy conditions. The formula for air resistance is ...

$$F(\text{air}) = C_d \rho A v^2 / 2$$

Where

Symbol	Definition	Units	Number for statue
$C_d$	coefficient of drag representing the roughness of the surface		0.4
$\rho$	The density of air	$\text{kg m}^{-3}$	1.40
$A$	Cross sectional area exposed to the wind.	$\text{m}^2$	330 (as viewed from the front)
$v$	Wind velocity	$\text{m s}^{-1}$	

4. What are the units for the drag coefficient in the formula above? (dimensional analysis).  
(2 marks)

$$F(\text{air}) = C_d \rho A v^2 / 2$$

Rearrange the formula for to solve for the coefficient.

$$C_d = \frac{F(\text{air}) \times 2}{\rho A v^2}$$

Replace the symbols with units.

(The 2 is unitless, the squared on the velocity squares the units)

$$C_d = \frac{\text{(N)}}{(\text{kg m}^{-3}) (\text{m}^2) (\text{m s}^{-1})^2}$$

Replace N with  $\text{kg m s}^{-2}$  (by  $F = ma$ ) and cancel any common terms

$$C_d = \frac{(\text{kg m s}^{-2})}{(\text{kg m}^{-3}) (\text{m}^2) (\text{m s}^{-1})^2}$$

$$C_d = \frac{(\text{kg m s}^{-2})}{(\text{kg m}^{-3}) (\text{m}^2) (\text{m}^2 \text{s}^{-2})}$$

$$C_d = \frac{\text{m}^3}{\text{kg}} \frac{\text{s}^2}{\text{m}^2} \frac{\text{kg m}}{\text{s}^2}$$

$$C_d = \frac{\text{kg m}^3}{\text{kg m}^2} \frac{\text{m}}{\text{m}^2} \frac{\text{s}^2}{\text{s}^2}$$

Unitless

(This should only take 4 lines but I have deliberately gone slow to not lose you. It is algebra).

5. Convert  $160 \text{ km h}^{-1}$  to  $\text{m s}^{-1}$ .

(1 mark)

$$160 / 3.6 = v(\text{m/s})$$

$$v = 44.4 \text{ m s}^{-1}$$

6. What is the air resistance of the statue when the wind blows at  $160 \text{ km/h}$  from the front?  
(2 marks)

$$F(\text{air}) = C_d \rho A v^2 / 2$$

$$F(\text{air}) = 0.4 \times 1.4 \times 330 \times 44.4^2 / 2$$

$$F(\text{air}) = 1.82 \times 10^5 \text{ N}$$

7. If the air resistance force acts on the statue  $15.0 \text{ m}$  above its base, what is the torque exerted about the base of the statue by the wind?

(2 marks)

$$M = r F$$

$$M = 15 \times 1.82 \times 10^5$$

$$M = 2.73 \times 10^6 \text{ N m}$$



## The Physics of Making a Soprano Recorder Musical Instrument.

### Paragraph 1

A soprano recorder is perhaps the first musical instrument that people ever get to play. It looks pretty simple. A pipe with a whistle opening at the top that you blow in and an open end at the bottom. The tube has holes drilled in it along its length. Cover the finger holes with the fingers in order to produce a low sound and uncover the holes to produce a high sound. By lifting the fingers off the finger holes one at a time starting at the bottom, the distance from the whistle opening to the nearest open finger hole is reduced. This shortens the length of resonating pipe. What could be simpler?

Figure 1



### Paragraph 2

If however you were asked to **build** a soprano recorder for yourself. That is a more challenging task! So, what physics would need to be considered in its construction?

### Paragraph 3

Perhaps the first question which will affect the construction is ...

“What is the lowest frequency (note) that I need the recorder to be able to play?”

Standard length recorders are built so that their lowest notes or tunings are ...

Table 1 – Lowest notes of standard recorder sizes from shortest to longest in length.

Recorder Name	Musical Tuning (Letter Name when all finger holes are closed)	Frequency (Hz) (All finger holes closed)
Sopranino	F	349.2
*** Soprano ***	C	261.6
Alto	F	174.6
Tenor	C	130.8
Bass	F	87.2

### Paragraph 4

The average temperature of the air in the recorder pipe is 25.0 °C. Based on this information the required length of pipe from whistle opening to the bottom end can be calculated.

### Paragraph 5

The second question is ...

“How do I tune it to other instruments under different temperature conditions?”

The speed of sound in air changes depending on the air temperature. This speed change effects the frequency (pitch) produced by the recorder. On a cold day when the air temperature is 8.00 °C the soprano recorder you have built (with all holes covered) will produce a lower frequency sound than the same recorder at 25.0 °C.

The speed of sound as a function of temperature (in kelvin) formula is ...

$$v = 20.04 T^{\frac{1}{2}}$$

Where...

Symbol	Definition	Units
v	Speed of sound in air	m s <sup>-1</sup>
T	Temperature	K (Kelvin)

The converting degrees celcius to kelvin formula is ...

$$T(K) = T(^{\circ}C) + 273$$

### Paragraph 6

If you wish to play with other instruments (in tune), you will need to be able to adjust the frequency played by your instrument regardless of the air temperature. This is achieved by adjusting the length of the pipe so that its lowest note can be set to 261.6 Hz regardless of air temperature. This length adjustment is achieved by incorporating a small telescopic joint between the head piece (containing the whistle) and the body of the recorder containing the finger holes.

### Paragraph 7

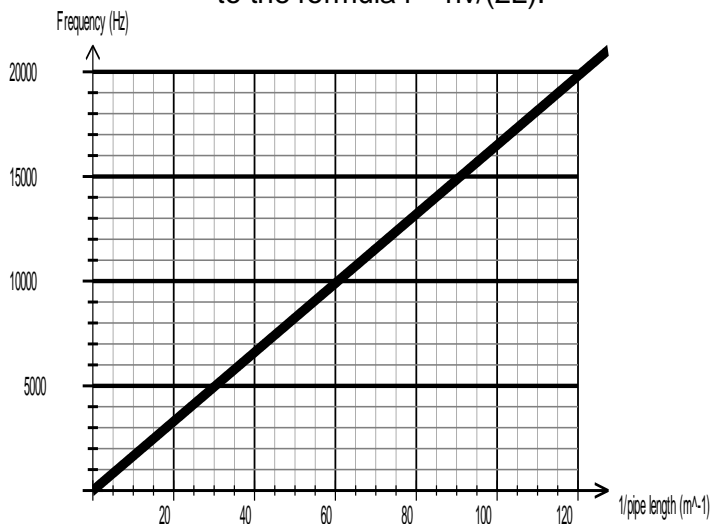
The third and final question is ...

“Where and how far apart to place the finger holes?”

If the holes are placed randomly along the length of the pipe, they will all produce a frequency (note) as each finger is progressively lifted off the finger holes but the frequencies created will not collectively form a musical scale unless the spacing between the finger holes is correct.

### Graph 1

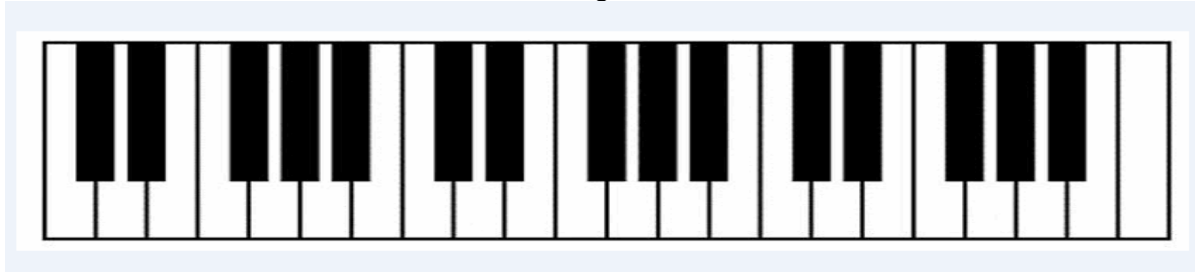
Any length of pipe (whistle to drilled finger hole) is capable of producing a frequency according to the formula  $f = nv/(2L)$ .



### Paragraph 8

In music the smallest distance between one note and the very next note in a musical scale is called a semi tone. This can be pictured on a piano keyboard as the frequency difference between one piano key (button) and the very next piano key (button) regardless of piano key colour (black or white). This frequency difference does not remain constant but gradually increases as you progress from the lowest notes to the highest notes on a keyboard or musical instrument.

Figure 2



### Paragraph 9

We need a formula that can (given a reference starting frequency) calculate the frequency of the next note of the musical scale (a semi tone or more above it). The reference note required is the lowest note played by the full length of pipe measured from the whistle to the bottom end.

The musical scale formula is ...

$$f_{\text{higher frequency (note) being sought}} = f_{\text{reference frequency (note)}} 2^{(z / 12)}$$

Where ...

Symbol	Definition	Unit
$f_{\text{higher note being sought}}$	Frequency of the note (sound) to be produced when the finger hole is drilled in the pipe.	Hz
$f_{\text{reference note}}$	Frequency of the note (sound) produced when there are no holes drilled in the pipe	Hz
2	Two	Constant
$\wedge$	to the power of ...	Mathematical operation
$z$	The number of semitones higher than the original reference frequency.	A whole number (unitless)

Paragraph 10

Using the musical scale formula, the frequencies required for the finger holes will be as shown in the table below...

Table 2 – Notes in a musical scale for a soprano recorder (C major)

Number of holes open (starting from the bottom of the pipe.)	Number of semitones from reference note (z)	Frequency (Hz)	Musical Note (letter name)
0 (reference frequency)	0	261.6	C
1	2	293.6	D
2	4	329.6	E
3	5	349.2	F
4	7		G
5	9	440.0	A
6	11	493.8	B
7	12	523.2	C

Paragraph 11

Using the pipe formula from any high school physics course and the musical scale formula above, the pipe length (hole position measured from the whistle end) can be calculated.

Paragraph 12

With the concepts of lowest frequency, tuning at different temperatures and finger hole placement, you are well on your way to drawing the plans from which you can make your very own recorder.

End of Article

1. Is a recorder an open or closed pipe? Explain your reasoning.

(2 marks)

Open Pipe

Non rigid barrier at both ends (whistle and end hole)

2. Calculate, using your pipe formula, with assistance from **Table 1** the length of a **soprano recorder** from whistle to the open pipe end at the bottom when the speed of sound in air is  $346 \text{ m s}^{-1}$ ?

(3 marks)

$$f = nv / 2L$$

$$261.6 = 1 \times 346 / 2 \times L$$

$$L = 0.661 \text{ m}$$

3. When you lift your fingers one at a time off the finger holes from bottom to top, which variable changes in the pipe formula to cause the change in frequency?

(1 mark)

L (the length of the pipe)

4. What is the speed of sound in air, when the air is at a temperature of 8.00 °C?  
(Paragraph 5)

(2 marks)

$$v = 20.04 T^{1/2}$$

$$v = 20.04 \times (273 + 8)^{1/2}$$

$$v = 336 \text{ m / s}$$

5. Calculate from **Graph 1** the speed of sound in air on the day the graph was created.  
Show all working to obtain full marks.

(4 marks)

$$\text{slope} = \text{rise} / \text{run}$$

$$\text{slope} = \Delta f / \Delta (1/L)$$

$$\text{slope} = 19000 / 115$$

$$\text{slope} = 165.2$$

$$f = \frac{nv}{2} \times \frac{1}{L}$$

$$\frac{\Delta f}{\Delta (1/L)} = \frac{nv}{2}$$

$$165.2 = \frac{nv}{2}$$

$$\text{but } n = 1$$

$$\frac{165.2 \times 2}{1} = v$$

$$v = 330 \text{ m s}^{-1}$$

6. Using the musical scale formula (Paragraph 9) calculate the missing value in **Table 2**.

(3 marks)

$$f_{\text{higher frequency (note) being sought}} = f_{\text{reference frequency (note)}} 2^{(z / 12)}$$

$$f_{\text{higher}} = 261.6 \times 2^{(7 / 12)}$$

$$f_{\text{higher}} = 392 \text{ Hz}$$

End of Exam

## ACKNOWLEDGEMENTS

### **Angel of the North**

[http://en.wikipedia.org/wiki/Angel\\_of\\_the\\_North](http://en.wikipedia.org/wiki/Angel_of_the_North)

(extracted 14/4/2010)

<http://www.icons.org.uk/theicons/collection/angel/biography/angel-of-the-north>

(extracted 14/4/2010)

### **Recorders**

[www.aulosusa.com](http://www.aulosusa.com) (aulos recorders website)

(extracted 21/4/2010)

[www.music-for-music-](http://www.music-for-music-teachers.com) teachers.com (picture of keyboard)

(extracted 22/4/2010)