# Year 11 ATAR
# Semester Two Examination 2016

## Question/Answer Booklet

# PHYSICS

*Marking Guide*

### *Time allowed for this paper*

| | |
|---|---|
| Reading time before commencing work: | Ten minutes |
| Working time for paper: | 2.5 hours |

### *Material required/recommended for this paper*

**To be provided by the supervisor**

This Question/Answer Booklet

Physics: Formulae, Constants and Data Sheet

**To be provided by the candidate**

| | |
|---|---|
| Standard Items: | Pens, pencil, eraser, correction fluid, ruler, highlighter |
| Special Items: | non-programmable calculators satisfying the conditions set by the Curriculum Council for this course, drawing templates, drawing compass and a protractor |

### *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.

## *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 | 11 | 11 | 40 | 40 | 27 |
| Section Two: Problem-solving | 6 | 6 | 80 | 78 | 52 |
| Section Three: Comprehension | 2 | 2 | 30 | 32 | 21 |
| | | | | **Total** | **100** |

## *Instructions to candidates*

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2016.* Sitting this examination implies that you agree to abide by these rules.

2. Write answers in this Question/Answer Booklet.

   When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of two significant figures and include appropriate units where applicable.

4. 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. 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 27% (40 marks)

This section has 11 questions. Answer all questions.

When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

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Suggested working time: 40 minutes.

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**Question 1** **(4 marks)**

For the following statements, indicate whether they are true (T) or false (F).

(a) Heat cannot transfer through a vacuum *F* ✓

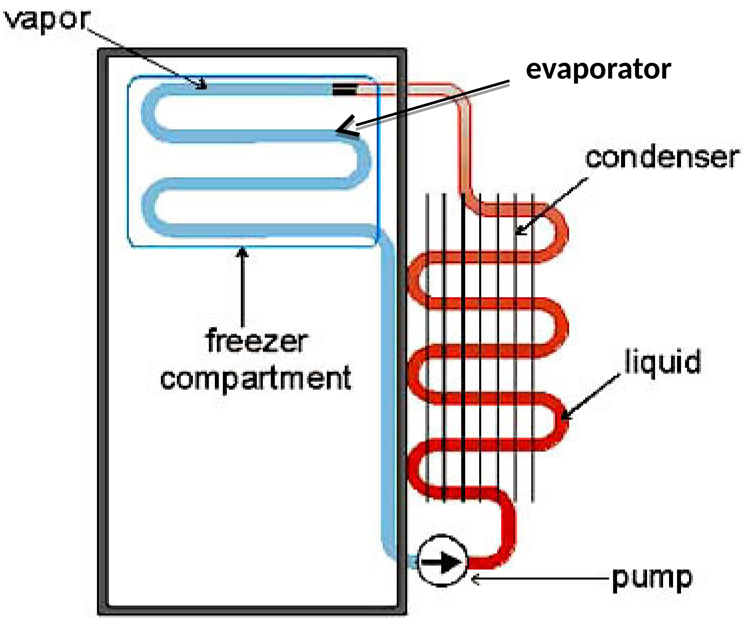
(b) Temperature is a measure of the total energy of the particles in a substance *F* ✓

(c) At 0 K, particles have no kinetic energy *T* ✓

(d) If two materials are in thermal equilibrium, they have the same internal energy *F* ✓

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

The diagram below shows the main parts of a refrigerator. Describe the phase change that takes place within the evaporator and within the condenser and explain their role in cooling the contents of the freezer compartment.



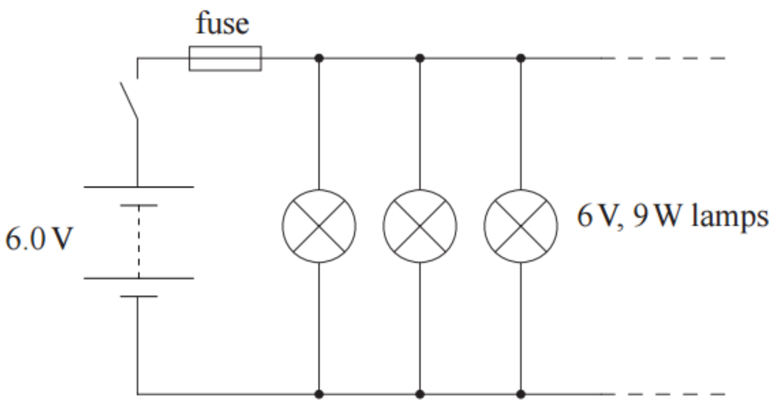

*In the evaporator, the refrigerant changes from a liquid to gas absorbing latent heat from the freezer compartment, cooling its contents.* ✓

*In the condenser, the refrigerant fluid changes from a vapour to a liquid, releasing latent heat to the air* ✓

*These two changes of state in different regions of the refrigerator, "pump" heat from the inside to outside of the fridge.* ✓

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

A lighting circuit is set up so that additional light bulbs can be added in parallel. Each bulb is rated at 6 V, 9 W.




The fuse is rated at 13 A. This means the fuse will "blow" if the total current through the circuit exceeds 13 A. Find the maximum number of bulbs that can be added without the fuse blowing.

*Current per lamp:* $I = P/V$ ✓
$= 9/6$
$= 1.5\ A$ ✓

*Number of lamps:* $= 13/1.5$
$= 8.67$ *lamps* ✓

*Therefore maximum number of lamps before fuse blowing = 8 lamps* ✓

*(could be solved by finding resistance of each lamp but more difficult)*

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

Stable nuclei with a mass number greater than 20, contain more neutrons than protons. With reference to the *strong nuclear force* and the forces of *electrostatic repulsion*, suggest an explanation for this observation.

*The strong nuclear force is only effective over very small distances.* ✓ *The (Coulombic) electrostatic repulsive force between protons is still relatively high over larger distances* ✓ *For larger atoms, extra neutrons are needed to increase the overall attractive force between nucleons without increasing the electrostatic repulsion which is only acts between like charges.* ✓

**Question 5** **(4 marks)**

Explain clearly the difference between a scalar and a vector quantity, giving one example of each.

*A scalar quantity has magnitude (size) only ✓ For example, mass, speed, length ✓*

*A vector quantity has magnitude and direction ✓ For example, force, velocity, electric field ✓*

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

A ball is thrown west at 15 m $s^{-1}$ and hits a wall. It rebounds at 12 m $s^{-1}$. Find the change in velocity of the ball and explain clearly whether or not the collision with the wall is elastic or inelastic.

*Take East as positive.*

$\Delta V = v - u$ ✓
$= 12 - (-15)$
$= 27$ m/s ✓ East ✓

*As KE is not conserved, the collision was inelastic.* ✓

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

**(3 marks)**

Eloise is sitting in the cockpit of a spaceship in “deep space”. This means that she can see nothing but darkness when looking out of the windows.

Would Eloise be able to notice whether or not her spaceship is accelerating? Explain clearly.

*Yes. Eloise would feel her spaceship accelerating ✓*

*As the ship accelerated, Eloise’s body would resist the change in motion (Newton’s 1st Law). ✓ She would feel the seat pushing into her ✓ She would also notice objects move toward the back of the space ship (from the spaceships reference frame).*

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

A model car of mass 1.8 kg is travelling at 1.45 m $s^{-1}$ westerly on a straight track. It collides with an oncoming car of the same mass, travelling at 1.20 $ms^{-1}$ in the opposite direction. After the collision, the cars lock together and continue moving. Ignoring the effects of friction, find the final velocity of the cars.

*Take East as positive*

$$P_{before} = P_{after}$$

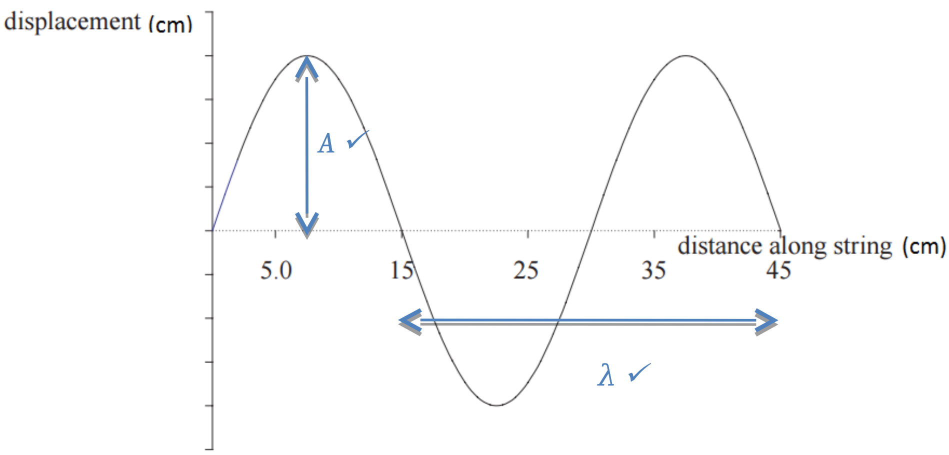
$$(1.8)(-1.45) + (1.8)(1.2) = (3.6)(v) \ ✓ ✓$$

$$v = -0.125 \ m/s \ ✓$$

*i.e. after the collision, both cars travel West at 0.125 m/s ✓*

**Question 9** **(5 marks)**

The diagram below shows a transverse wave travelling along a string that is under tension.




On the diagram above, show:

- the amplitude of the wave. Label this A.
- The wavelength of the wave. Label this λ.

Given that the period of the wave is 1.20 ms, find the velocity of the wave.

*v* = *f* x λ
= 1/T x λ ✓
= (1/0.0012) x 0.30 ✓
= 250 m/s ✓

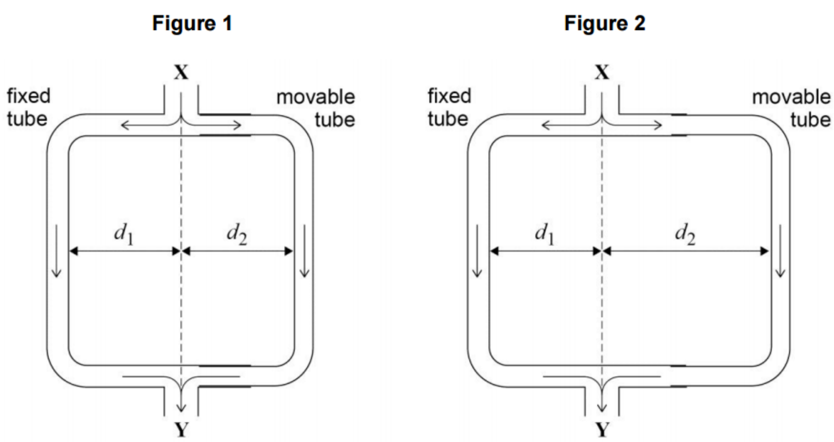
**Question 10** **(3 marks)**

Hamish is standing 25 m from a loudspeaker at a concert and measures the sound intensity to be 1.00 x $10^{-10}$ $Wm^{-2}$. He then moves to a point 100 m away from the loudspeaker. Find the intensity of the sound at this new location.

*$I \propto 1/r^2$ (from formula and constant sheet)*
*r in creased by a factor 4, so intensity decreased by a factor of 16 ✓*
*Therefore new intensity $= 10^{-10}/16$ ✓*
*$= 6.25 \times 10^{-12}\ Wm^{-2}$ ✓*

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

Figures 1 and 2 below show Quincke's tube which can be used to show the interference of sound waves. A speaker is placed at X and produces sound of one frequency. The sound then divides and travels down opposite sides of the apparatus. The resultant sound is detected at Y by a microphone. The right hand side of the tube can be moved to extend the path travelled by the sound in that side of the apparatus.




At first, when $d_1=d_2$, the sound at Y is loud. As the moveable tube is slowly shifted to the right, the sound at Y gets quieter and then louder. Explain this observation.

*When $d_1=d_2$, both sound waves travel the same distance. Therefore they arrive at Y "in phase". This means they constructively interfere to produce loud sound. ✓*
*As $d_2$ is increased, the sound travelling through the right hand side of the apparatus travels a larger distance. If this distance is half a wavelength more than the sound travelling in the LH side of the apparatus, the two sounds will arrive "out of phase" and will destructively interfere, producing a quieter sound. ✓ As $d_2$ is increased more, the sound travelling through that side increases to the point where the difference is now a full wavelength. This means that the sounds once again arrive in phase and the sound is loud. ✓*

**End of Section One**

## SECTION TWO: Problem-solving 52% (78 marks)

This section has **six (6)** questions. Answer **all** questions. Write your answers in the spaces 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.

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Suggested working time: 80 minutes.

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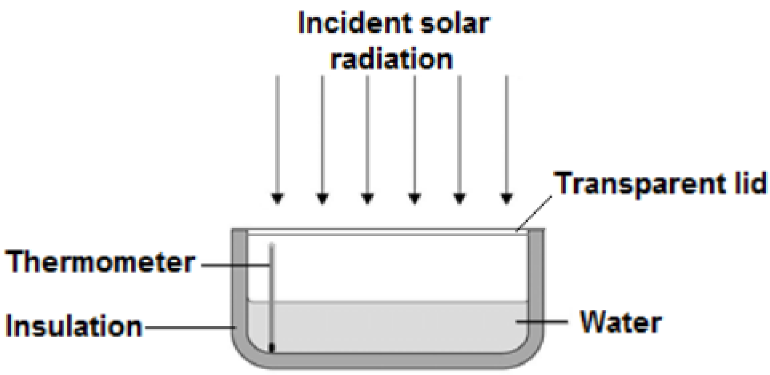
**Question 12** **(11 marks)**

Amy is conducting an experiment to find out how much energy from the Sun is incident on the Earth's surface in Perth. She put an insulated tray, containing 155 g of water in direct sunlight. The apparatus that she used is shown below. The tray had an area of 122 $cm^2$.




Amy found that the temperature of the water increased by 1.5° after 17 minutes.

(a) Find the amount of solar energy absorbed by the water in the 17 minutes. (2 marks)

$Q = mC\Delta T$
$= (0.155)(4180)(1.5)$ ✓
$= 972\ J$ ✓

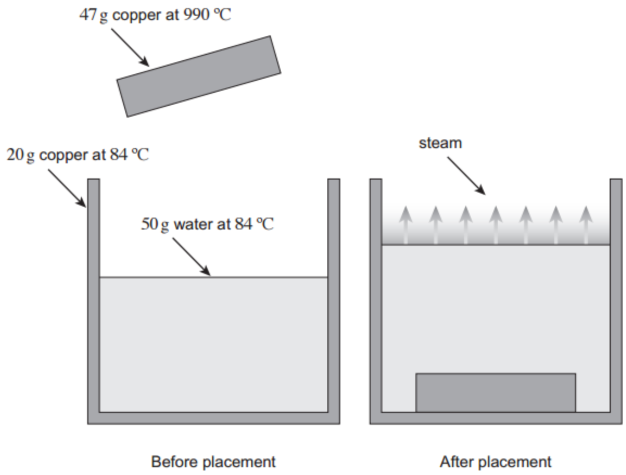
(b) Show that the solar power incident on the tray was approximately 950 mW. (2 marks)

$P = E/t$
$= 972/(17 \times 60)$ ✓
$= 0.953\ W\ (953\ mW)$ ✓

(c) Find the intensity of the sun's radiation in $Wm^{-2}$. (2 marks)

$I = P/A$
$= 0.953/(122 \times 10^{-4})$ ✓
$= 78.1\ Wm^{-2}$ ✓

Manahil is conducting another experiment in Physics. She is using a 20 g insulated copper calorimeter that contains 50 g of water at 84° C. She then places a 47 g block of copper at 990° C into the water. The water heats rapidly to 100°C and some is converted to steam. The apparatus is shown below. Note: the specific heat capacity of copper is 385 $Jkg^{-1}K^{-1}$.




(d) Find the amount of heat lost by the copper block as it cooled to 100° C. (2 marks)

$Q = mC\Delta T$
$= (0.047)(385)(990-100)$ ✓
$= 16{,}100\ J$ ✓

(e) Find the amount of heat absorbed by the water and copper container as their temperature is raised to 100° C and hence the amount of energy available from the block to produce stream. (3 marks)

$Q = (mC\Delta T)_{copper} + (mC\Delta T)_{water}$
$= (0.020)(385)(100-84) + (0.050)(4180)(100-84)$ ✓
$= 3{,}470\ J$ ✓

*Therefore 16,100 – 3,470 = 12,630 J available to produce steam.* ✓

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

(a) Uranium-238 consists of 92 protons and 146 neutrons. The mass of a U-238 nucleus is less than the sum of the masses of its protons and neutrons. Explain why. (2 marks)

*When an atom is formed, "binding energy" is released. ✓ This energy has a mass equivalence and is known as the mass defect. ✓*

(b) When a rod of Uranium-238 is placed in the core of a nuclear reactor, it absorbs a neutron and decays to Neptunium-239, which then decays to Plutonium-239. In the space below, show the two nuclear equations that represent the above reactions. (2 marks)

$$U_{92}^{238} + n_0^1 \rightarrow Np_{93}^{239} + \beta_{-1}^0 \quad ✓$$

$$Np_{93}^{239} \rightarrow Pu_{94}^{239} + \beta_{-1}^0 \quad ✓$$

*(neutrinos not required)*

(c) Find the energy released when one nucleus of Uranium-238 decays to Neptunium-239. Express your answer in MeV. (3 marks)

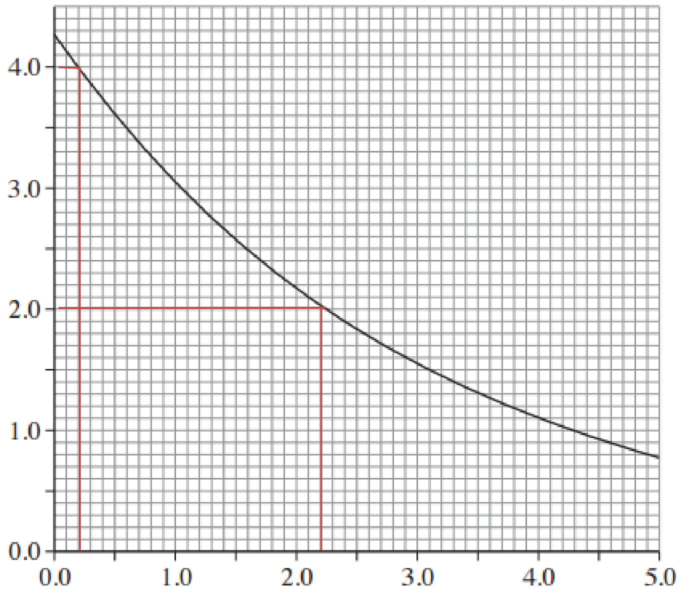
The following data will assist in this calculation:

| | |
|---|---|
| Mass of U-238: | 238.05078 u |
| Mass of Np-239: | 239.05293 u |
| Mass of Pu-239: | 239.05216 u |
| Mass of beta particle: | 0.00054858 u |
| Mass of neutron: | 1.008664 u |

*Mass defect* = (238.05078 + 1.008664) – (239.05293 + 0.00054858)
= 0.00596542 u ✓ ✓

*Therefore energy released* = 0.00596542 x 931 MeV
= 5.55 MeV ✓

A sample of the rod is removed from the reactor core and its radioactivity is monitored over time. The activity from t = 0, to t = 5 x $10^5$ s is shown below. You may assume that the Uranium-238 decays almost instantly and that the activity in the figure below comes only from the decay of Neptunium.




(d) Find the half-life for the decay of the Neptunium. (2 marks)

*Time for activity to drop from 4 x $10^{12}$ to 2 x $10^{12}$ is:*
*2.2 x $10^5$ – 0.2 x $10^5$ = 2.0 x $10^5$ s ✓ ✓*

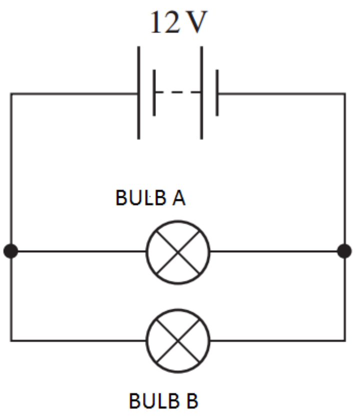
(e) Find the activity of the Neptunium after 25 days. (2 marks)

*25 days = 25 x 24 x 3600 = 21.6 x $10^5$ s*
*n (number of ½ lives) = 21.6 x $10^5$/2 x $10^5$ = 10.8 ✓*

*∴ A = 4.25 x $10^{12}$ $(½)^{10.8}$*
*= 2.38 x $10^9$ Bq ✓*

**Question 14** **(16 marks)**

Two light bulbs are connected in parallel to a 12 V battery as shown below. Bulb A is rated at 12 V, 20 W and bulb B is rated at 12 V, 5 W.




(a) Show that the resistances of bulb A and bulb B are 7.2 Ω and 28.8 Ω respectively. (2 marks)

(b) Find the total current flowing through bulb B . (2 marks)

$I = V/R$

$= 12/28.8$ ✓

$= 0.417\ A$ ✓

$P = VI$

Sub $I = V/R$

$P = V^2/R$

$R = V^2/P$

Therefore: Bulb A: $R = 12^2/20$

$= 7.2\ \Omega$ ✓

Bulb B: $R = 12^2/5$

$= 28.8\ \Omega$ ✓

(c) Find the total current flowing from the battery (2 marks)

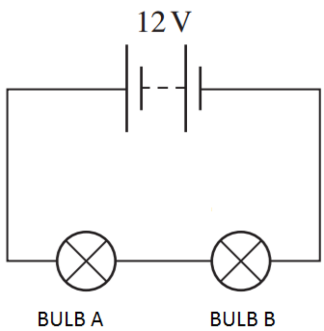
$R_T = 1/(1/28.8 + 1/7.2)$

$= 5.76\ \Omega$ ✓

$\therefore\ I_T = 12/5.76$

$= 2.08\ A$ ✓

The circuit is re-arranged so that bulb A and bulb B are connected as shown below.



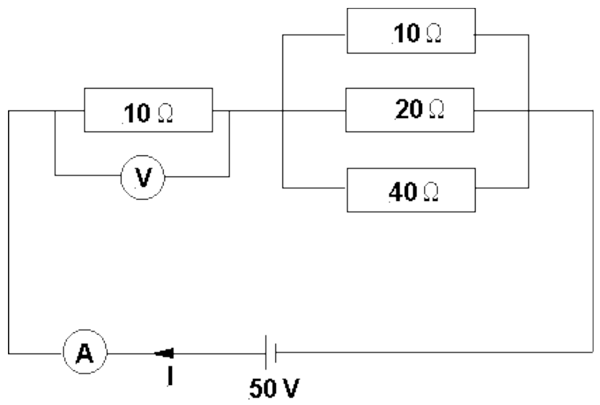
(d) Explain why both bulbs are observed to glow less brightly in this configuration. (2 marks)

*When the bulbs are in series, the total resistance is greater and the current flowing is less* ✓
*Therefore the power ($P=I^2R$) dissipated by each bulb is less* ✓

(e) Which of the bulbs will be brightest when they are connected in series? Justify your answer with suitable calculations. (4 marks)

*The power dissipated by each bulb is $I^2R$, so the bulb with the greatest resistance will dissipate the greatest power. i.e. Bulb B* ✓
$I = 12/(28.8+7.2) = 0.33$ A ✓
For bulb A: $P = (0.33)^2 \times 7.2 = 0.784$ W ✓
For bulb B: $P = (0.33)^2 \times 28.8 = 3.14$ W ✓

The rest of this question refers to the circuit below.




(f) Find the reading on the ammeter in the circuit. (3 marks)

$R_T = 10 + 1/(1/10 + 1/20 + 1/40)$ ✓ ✓
$= 15.7\ \Omega$

$I = 50/15.7$
$= 3.18$ A ✓

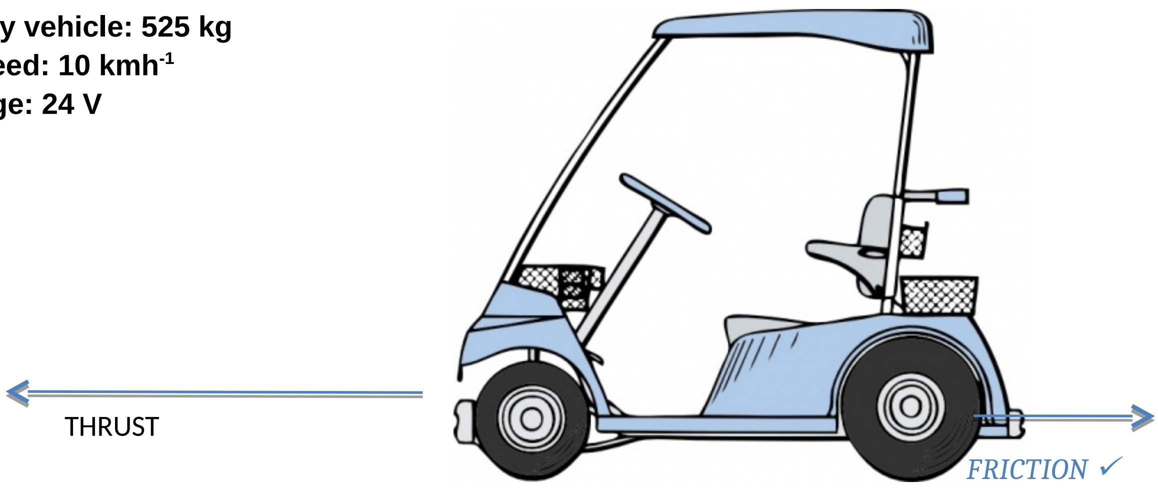
(g) Find the reading on the voltmeter in the circuit. (1 mark)

$V = IR$
$= (3.18)(10)$ ✓
$= 31.8$ V

**Question 15** **(18 marks)**

The following data refers to the electric vehicle shown below.

**Mass of empty vehicle: 525 kg**
**Maximum speed: 10 kmh$^{-1}$**
**Battery voltage: 24 V**




The car is being driven by a 92 kg man and takes 4.4 seconds to accelerate from rest to its top speed.

(a) Find the acceleration of the vehicle in m s$^{-2}$. (2 marks)

$a = (v-u)/t$
$= (10/3.6 – 0)/4.4$ ✓
$= 0.631\ ms^{-2}$ ✓

(b) Find the distance covered by the vehicle while accelerating to its top speed. (2 marks)

$s = ut + ½\ at^{2}$
$= 0 + (0.5)(0.631)(4.4)^2$ ✓
$= 6.11\ m$ ✓

(c) Find the net force acting on the vehicle whilst accelerating. (2marks)

$F = ma$
$= (525+92)(0.631)$ ✓
$= 389\ N$ ✓

(d) On the diagram above show all horizontal forces that were acting on the car whilst accelerating as clearly labelled arrows.

(2 marks)

It is found that the car's electric motor provides 500 watts of power while the car is travelling at its top speed on level ground.

(e) Explain why the motor needs to provide power although the car is not accelerating. (2 marks)

*The motor still needs to provide power so that the car can do work against friction. i.e. the car still needs to provide a force to balance the force of friction ✓ ✓*

(f) Find the power provided by the motor while the car *was* accelerating. (4 marks)
*You may assume that the force of friction was constant for the whole time that the car was accelerating and it has the same magnitude as when the car is travelling at top speed on level ground.*

| | |
|---|---|
| $F_{friction} = P/v$<br>$= 500/(10/3.6)$<br>$= 180\ N$ ✓<br><br>$W_{friction} = F \times s$<br>$= 180 \times 6.11$<br>$= 1{,}100\ J$ ✓<br><br>$KE_{gained} = \frac{1}{2} mv^2$<br>$= (0.5)(617)(10/3.6)^2$<br>$= 2{,}380\ J$ ✓<br>$\therefore P = (1100+2380)/4.4$<br>$= 791\ W$ ✓ | *OR:*<br><br>$F_{friction} = P/v$<br>$= 500/(10/3.6)$<br>$= 180\ N$ ✓<br><br>$F_{motor} = 180 + 389 = 569\ N$ ✓<br><br>$V_{ave} = (10/3.6)/2 = 1.39\ m/s$ ✓<br><br>$\therefore P = F \times v_{ave}$<br>$= 569 \times 1.39$<br>$= 791\ W$ ✓ |

(g) During a typical 18 hole game of golf, the car's motor operates for 40 minutes. Assuming that the average power output of the motor for the course is 610 W, find the total energy provided by the motor in joules. (2 marks)

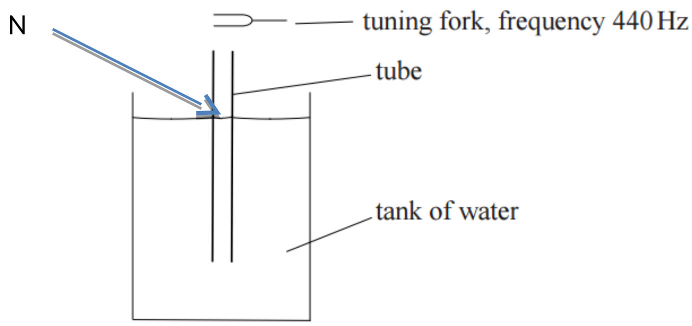
$E = P \times t$
$= 610 \times (40 \times 60)$ ✓
$= 1.46 \times 10^6\ J$ ✓

(h) The battery is then recharged with a 24 V, 1.5 A battery charger. Find the time it takes to recharge the battery after the day's use. (2 marks)

$E = P \times t$
$= VIt$
$t = E/VI$ ✓
$= 1.46 \times 10^6/(24 \times 1.5)$
$= 40{,}555\ s$ *(11 hours, 15 minutes, 56 seconds)* ✓

**Question 16** **(13 marks)**

An experiment is being carried out to estimate the speed of sound. The equipment used is shown below.




A hollow tube is placed vertically in a tank of water, until the top of the tube is just at the surface of the water. A tuning fork of frequency 440Hz is sounded above the tube. The tube is slowly raised out of the water until the loudness of the sound reaches a maximum for the first time, due to the formation of a standing wave.

(a) Explain how the standing wave is formed in the tube. (2 marks)

*The sound waves from the tuning fork travel down the tube and reflect off the water's surface (its closed end). These reflections are out of phase with the incident wave and therefore a node (point of total destructive interference) occurs at this point. The sound then travels up the tube and reflects back down the tube in phase, adding constructively to the additional waves from the tuning fork, producing an antinode. Provided that the length of the tube is n/4 wavelengths (n= 1,3,5 ....), then there will be fixed nodes and antinodes – a standing wave.* ✓ ✓

It is found that when the tube is raised an extra 37 cm, the sound at the opening reaches a maximum for the second time.

(b) Label with an "N" the point in the tube which always a displacement node during this experiment. (1 mark)

(c) Using the information provided, estimate the speed of sound. Show all working. (3 marks)

*Inter antinodal distance* $= \frac{1}{2}\lambda$

$\therefore\ 0.37\ m = \frac{1}{2}\lambda$

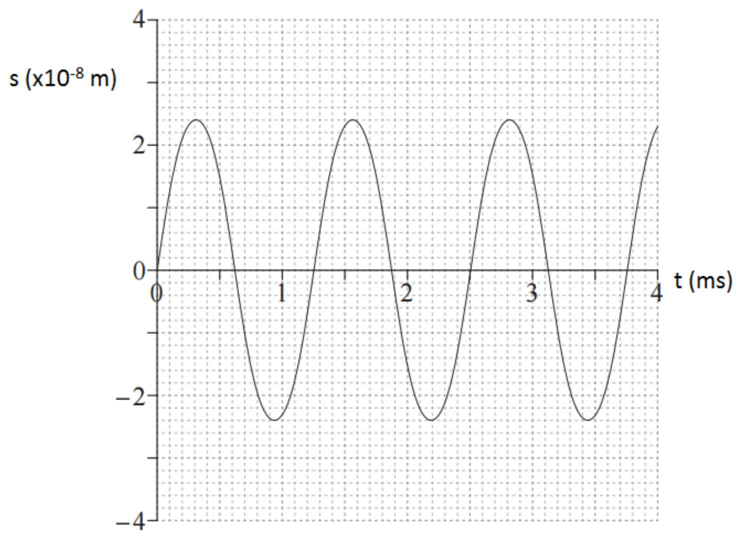
$\lambda = 0.74\ m$ ✓

$v = f \times \lambda$

$= 440 \times 0.74$ ✓

$= 326\ m/s$ ✓

A standing wave is established in a tube **open at both ends**. Point A shows the position of an air particle at one of the open ends.


The graph below shows how the position of point A varies with time.

(d) Is point A a displacement node or antinode? Explain. (2 marks)

(e) What is the frequency and wavelength of the standing wave? (3 marks)

*From graph,* $T = 1.25 \times 10^{-3}$ *s.* ✓

$f = 1/1.25 \times 10^{-3} = 800$ *Hz* ✓

$\lambda = 346/800 = 0.433$ *m* ✓ *(0.408m if speed of sound from part (c) used)*

(f) The standing wave formed in the tube corresponds to the fourth harmonic for the tube. Find the length of the tube. (2 marks)

*Point A is an antinode as its displacement varies with time* ✓ ✓

$\lambda = 2L/n$

$L = n\lambda/2$ ✓

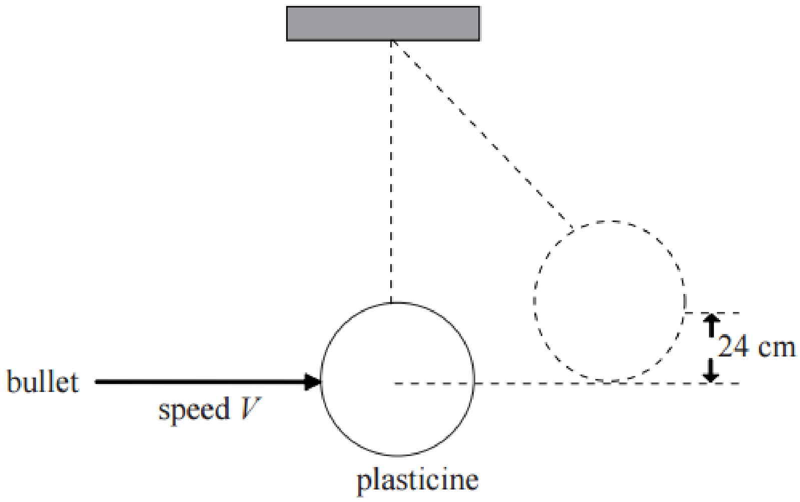
$= (4)(0.433)/2$

$= 0.866$ *m* ✓

**Question 17** **(9 marks)**

In a ballistics lab, the speed of a 5 gram bullet is determined by firing it into a 422 g piece of plasticine suspended on a string.

It is found that after impact, the piece of plasticine with the embedded bullet rose 24 cm.




(a) Find the speed of the plasticine and bullet immediately after the impact. (3 marks)

$$KE_{lost} = PE_{gained} \checkmark$$
$$\tfrac{1}{2}(\cancel{m})(v)^2 = (\cancel{m})(g)(h)$$
$$v^2 = (9.80)(0.24)(2) \checkmark$$
$$\therefore \quad v = 2.17\ m/s \checkmark$$

(b) Find the speed of the bullet immediately before the impact. (3 marks)

$$p_{bullet\ and\ plasticine} = mv$$
$$= (0.427)(2.17)$$
$$= 0.927\ kgm/s \checkmark$$
$$= p_{\ bullet}$$
$$\therefore \quad v_{bullet} = 0.927/0.005 \checkmark$$
$$= 185\ m/s \checkmark$$

(c) Was the collision between the bullet and plasticine elastic or inelastic? Show calculations to support your answer. (3 marks)

$$KE_{bullet} = (1/2)(m)(v)^2$$
$$= (0.5)(0.005)(185)^2$$
$$= 85.6\ J \checkmark$$
$$KE_{bullet\ and\ plasticine} = (0.5)(0.427)(2.17)^2$$
$$= 1.00\ J \checkmark$$

*Energy lost deforming plasticine therefore not elastic* ✓

**End of Section Two**

**SECTION THREE: Comprehension** **21% (32 marks)**

This section has **two (2) questions**. You must answer **both** questions. Write your answers in the spaces 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 that you are continuing to answer at the top of the page.

Suggested working time: 30 minutes.

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**Question 18** **(16 marks)**

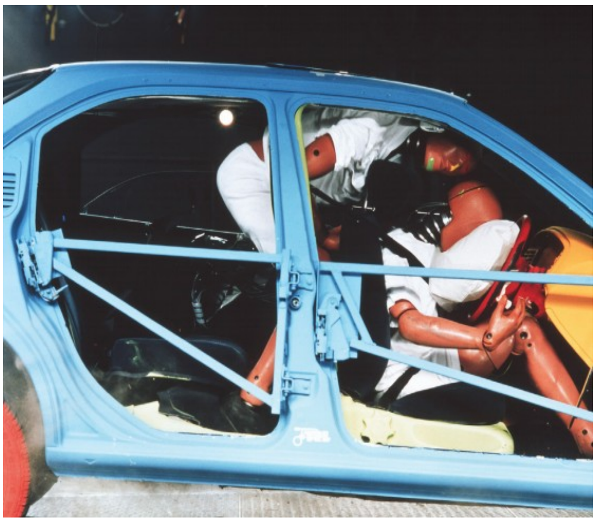
Read the following article and then answer the questions that follow.

# Car safety features

Article adapted from *Physics for the International Student*, 2010. IBN 9780170185134, pages 99-102.

### Seatbelts

The seatbelt can be explained in terms of all three of Newton's laws. The most obvious is Newton's first law. In a front-on collision, the vehicle will come to a stop in a very short period of time. If an occupant is not wearing a seatbelt, Newton's first law states that their body will keep moving forward, even though the car has stopped. This causes the occupant to collide violently with objects in front of them. These objects could be the steering wheel, dashboard or, for rear seat occupants, the seats in front of them. If you are unrestrained and travel to the windscreen at 60 km/h, when the car comes to a stop, your skull bones are likely to collapse inwards by 2.1 cm. Your skull becomes the crumple zone. At 120 km/h, the crumple zone is likely to be more than 8 cm. These collisions often cause death or massive internal and head injuries with lifelong consequences.



Unlike a restrained person, an unrestrained person continues at the impact speed until crumpling on impact with the window.

If seatbelts were to stop a person immediately, however, they would not prevent these injuries. This is where a knowledge and understanding of Newton's second law comes in. From the formula for Newton's second law, $a = F_{net}/m$, you will see that the force is directly proportional to the acceleration. So if the acceleration on the occupant's body can be reduced, the force on them can also be reduced. This is why seatbelts are not completely rigid. In fact, seatbelts are designed to stretch a little. This stretching effect is similar to a person landing on a mat instead of a hard floor when they jump from a height. It offers an element of 'cushioning' to the occupant. This cushioning means that in a front-on collision, the occupant's body will take a little more time to stop than if the seatbelt were rigid. This extra time reduces the acceleration on the occupant's body. This can be seen in the formula for average acceleration, $a_{av} = \Delta v/\Delta t$ . If $\Delta t$ is increased (the time taken for the body to stop), then $a_{av}$ will decrease. If the acceleration is less, the force on the body will also be less. The seatbelt is also designed to be worn on the parts of the body that can withstand a greater force, such as the hips, chest and shoulders.

## Air bags

Air bags were initially designed as an alternative to seatbelts in cars. They can easily be explained using Newton's second law. As with the seatbelt, if the acceleration of the occupant can be reduced, then so too can the force. Air bags increase the time it takes for a person to come to a stop in a collision. This means that the acceleration of the person is less. So, by Newton's second law of motion, the force on the person is also less. Air bags work best as a supplemental restraint system. This means that they work in combination with a seatbelt. Since the advent of the air bag, seatbelt usage in the United States has increased significantly. According to the National Highway Traffic Safety Administration, since the early 1980s, the rate of wearing seatbelts has risen from 14% to just over 80%.

## Crumple zones

Crumple zones are areas at the front and rear of a vehicle that crumple in an accident to increase the stopping time. Again, they can be

explained using Newton's second law. If the time taken to stop is increased, the acceleration is less and the force on the occupant is less. This can be seen in the formula for acceleration: $a_{av} = \Delta v / \Delta t = F_{net}/m$ It used to be thought that the 'tougher' and stronger the car, the safer it was for the occupants. This is true in terms of the safety cell, the part of a car where the occupants are located. It is untrue, however, for the car as a whole. If the front of the vehicle collapses or crumples in a front-on collision, then the solid safety cell will take longer to stop.

(a) Explain why the injuries sustained are less for people wearing seatbelts. Be sure to use appropriate Physics outlined in the article. (4 marks)

*Seatbelts bring the passenger to rest with the car ✓ and prevent the occupant's head from hitting the dashboard etc ✓ The seatbelt material is also made from material with a little "give" ✓ so that the time taken to stop is slightly greater than if the passenger slammed into the dash or windscreen ✓*

(b) The article states that an unrestrained person's head can be crushed by about 2 cm at 60 km/h but crushed by 4 times that amount when their car is travelling at twice the speed. Using appropriate Physics, suggest a reason for this. (2 marks)

*Kinetic energy varies with the square of velocity ✓, so when the speed is doubled, the KE of the occupant is quadrupled. This means that the four times the work is required to bring their head to rest – four times the crushing of their skull ✓*

(c) Racing car drivers wear a full racing harness, which is essentially a seatbelt with more straps that cross over each other. Suggest why this would reduce injury. (2 marks)

*A racing harness has more contact area with the driver's body and distributes the force over a greater area, reducing injury. ✓ ✓*

*OR*

*A racing harness holds the body more stationary preventing injury from slipping or sideways movement. ✓ ✓*

(d) Explain in terms of Newton's second law, how air bags reduce injury in a car accident.

(2 marks)

*An airbag increases the time it takes for the person's body to come to rest ✓. So the deceleration is reduced and therefore the force required to bring them to rest is reduced. ✓ (F=ma)*

(e) The article states that airbags and seatbelts are designed to work together as a supplemental restraint system. Why do you think the two systems supplement each other so well?

(2 marks)

*Seatbelts control where the person's body goes, in this way it is perfectly positioned the make best use of the airbag. Otherwise a person's head may hit the windscreen and the airbag impact their chest abdomen (or similar) ✓ ✓*

(f) The article explains the Physics behind crumple zones in terms of Newton's Laws. Explain how they reduce injury in terms of energy conservation and work done. (2 marks)

*Work needs to be done by the airbag on the person's head to remove the kinetic energy ✓ As work is force x distance, by increasing the distance taken to bring the person's head to rest, the force is reduced and less injuries sustained. ✓*

(g) Two cars of identical mass and velocity collide with a concrete wall. Car 1 has crumple zones built in and car 2 is very rigid. Describe any differences between the changes in momentum they experience. (2 marks)

*Both cars experience the same change in momentum ✓ Car 1 will have its momentum change over a longer period of time, so the forces in involved will be less ($\Delta p = F \times t$). ✓*

**Question 19** **(16 marks)**

Read the following article and then answer the questions that follow.

# The physics of an organ pipe

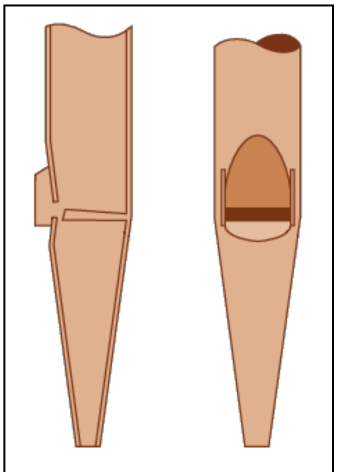


Fig 1

The air enters through the bottom of the pipe and hits the sharp edge at the front of the pipe making the air vibrate. Those vibrations that do not 'fit exactly' in the pipe drown themselves out as they interfere with themselves. Those vibrations that do fit exactly are amplified by resonance producing the primary tone and overtones of the pipe.

The length of the pipe determines which waves fit exactly inside and thus the pitch of the tone the pipe makes. Several wavelengths fit—the pictures below show the first few. The dark curve is the primary tone, the remaining dotted curves are overtones. The shape and design of the pipe and the composition of the metal alloy the pipe is made from determine the relative strength of the overtones and thus the "colour" of the sound.

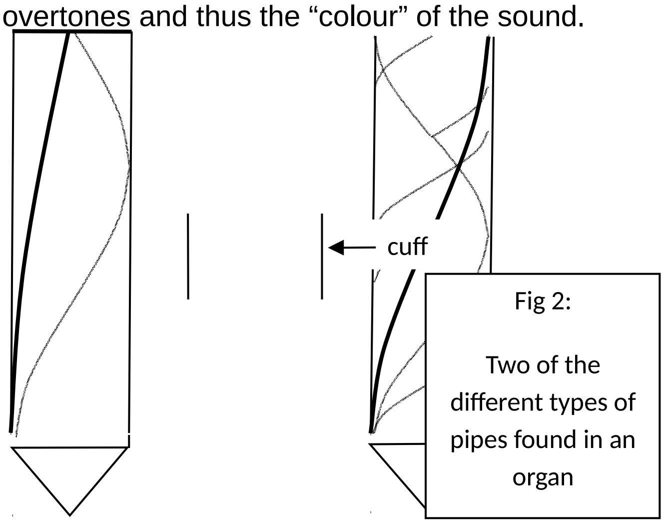



Fig 2:

Two of the different types of pipes found in an organ

Gedakt pipe Principal pipe

The organ has a number of pipes (also called stops or voices) for each key on the organ.

These include

**Principal 1.4m pipe**

This cylindrical pipe is open at the top where a cuff allows the organ tuner to slightly change the length of the pipe and thus its pitch.

**The Octave 0.35m pipe**

The Octave is a Principal pipe at quarter length and thus sounds two octaves higher.

**The Gedakt 2.8m pipe**

The Gedakt pipe is cylindrical like the Principal but covered by a cap at the top. The length of the of the Gedakt 2.8m pipe is the same as the Principal 1.4m pipe but a covered pipe sounds an octave lower—hence the two point eight meter designation.

An electric blower and weighted bellows provide constant air pressure. When the organist presses a key, a set of levers and cranks open a valve letting air into a narrow chamber under the pipes that belong to that key, one pipe for each voice of the organ. The organist chooses which of the pipes shall sound by pulling or pushing a knob that slides a thin piece of wood with holes in it under the pipes. If the holes line up with the pipes, air enters the pipe and it sounds, otherwise the pipe remains silent.

## Questions:

(a) Examine the Gedakt and Principal pipes shown in fig 2. Do the **lower ends** behave as a closed or open end of the pipes? (2 marks)

*Open* ✓✓
*(No part marks for "Gedakt open, Principal closed" or vice versa)*

(b) Explain resonance **in the context** of this article. (2 marks)

*Vibrations that fit exactly within the pipe are amplified and produce standing waves* ✓✓

*If statement is about resonance in general and not specific about resonance in pipes 1 mark only.*

(c) Explain how the cuff could be used to change the pitch of a Principal 1.4m pipe. (2 marks)

*The cuff can be adjusted to change the length of the pipe. A change in length causes a change in wavelength and frequency.* ✓✓

(d) Explain why on a hot day the cuff on an organ pipe is raised in order to maintain a fixed frequency. (2 marks)

*A hot day will have a faster wave velocity.* ✓

$f = \frac{v}{\lambda}$ *. If the velocity is increased, the wavelength must also be increased by raising the cuff to maintain the same frequency.* ✓

(e) What frequency would a Principal 1.4m pipe produce on a day when the speed of sound in air is 340 $ms^{-1}$? (2 marks)

$\lambda = 2L = 2*1.4 = 2.8\,m$ ✓

$f = \frac{v}{\lambda} = \frac{340}{2.8} = 121\,Hz$ ✓

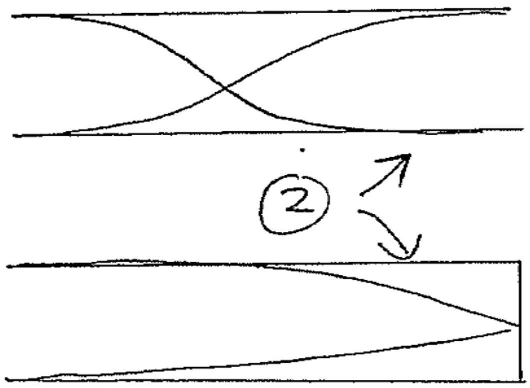
(f) How many times higher is the frequency of the Octave pipe compared with the Principal pipe. (3 marks)

$\lambda = 2L = 2*0.35 = 0.7\,m$ ✓

$f = \frac{v}{\lambda} = \frac{340}{0.7} = 486\,Hz$ ✓

$\frac{f_{octave}}{f_{principle}} = \frac{486}{121} = 4 \times ¿$ ✓

(g) Explain with the aid of a diagram why the Gedakt pipe is the same length as the Principal pipe but produces a note with twice the wavelength. (3 marks)



*Open pipe wavelength* $\lambda = 2L$ ✓

*Closed pipe wavelength* $\lambda = 4L$ ✓

*The closed Gedakt pipe produces a standing wave pattern with a wavelength 4 x the length of the pipe while the open principle pipe produces a wavelength of only 2x the length of the pipe.* ✓