Section One: Short response **30% (54 Marks)**

This section has **14** questions. Answer **all** questions. Write your answers in the space provided.

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.

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.

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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- 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: 50 minutes.

Question 1 **(4 marks)**

The kinetic particle model is based on some fundamental assumptions. List two assumptions indicating the type of energy (potential and kinetic) involved.

1.

Type of energy: ______________________________

2.

Type of energy: ______________________________

Question 2 **(5 marks)**

a) There are two types of β particles. Name them.

i) ____________________________________ and

ii) ____________________________________ (1 mark)

b) What is the difference between these two particles?

(1 mark)

c) Complete the following table for β particles. (3 marks)

Mass relative to a proton	
Speed	
Ionising Power	

Question 3 **(5 marks)**

Electricians must replace fuses with residual current devices (RCD) when they do some work on houses in Western Australia.

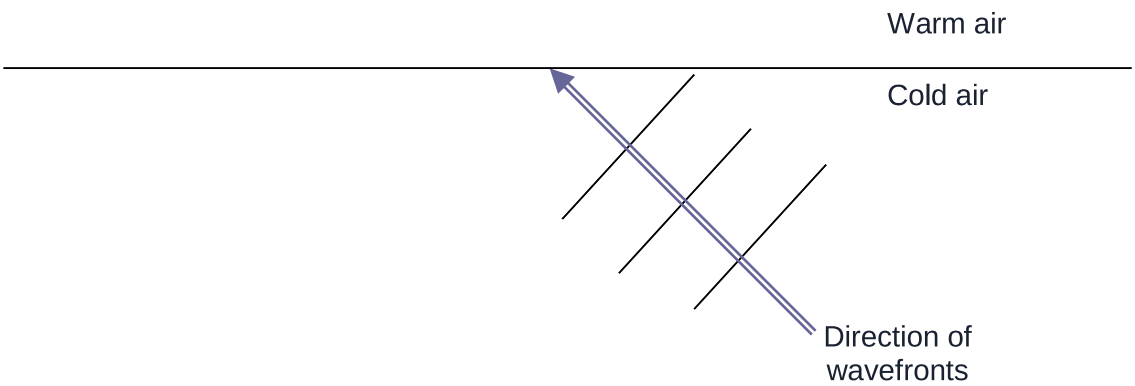
a) Explain how RCDs protect people from electrocution. (2 marks)

b) Is it possible for people using electricity to still be electrocuted in a house, even if all circuits in the house are protected by RCDs? _________ (1 mark)

Explain. (2 marks)

Question 4 **(3 marks)**

Sound travels faster in warm air than in cold air. The following diagram represents a temperature inversion, where a layer of warm air rests above cold air. A beam of sound is directed upward at an angle.
Complete the diagram to show the direction of the wavefronts and the new wavelength of the sound refracted in the warm layer. Include a labelled normal, refracted wave and wave fronts.

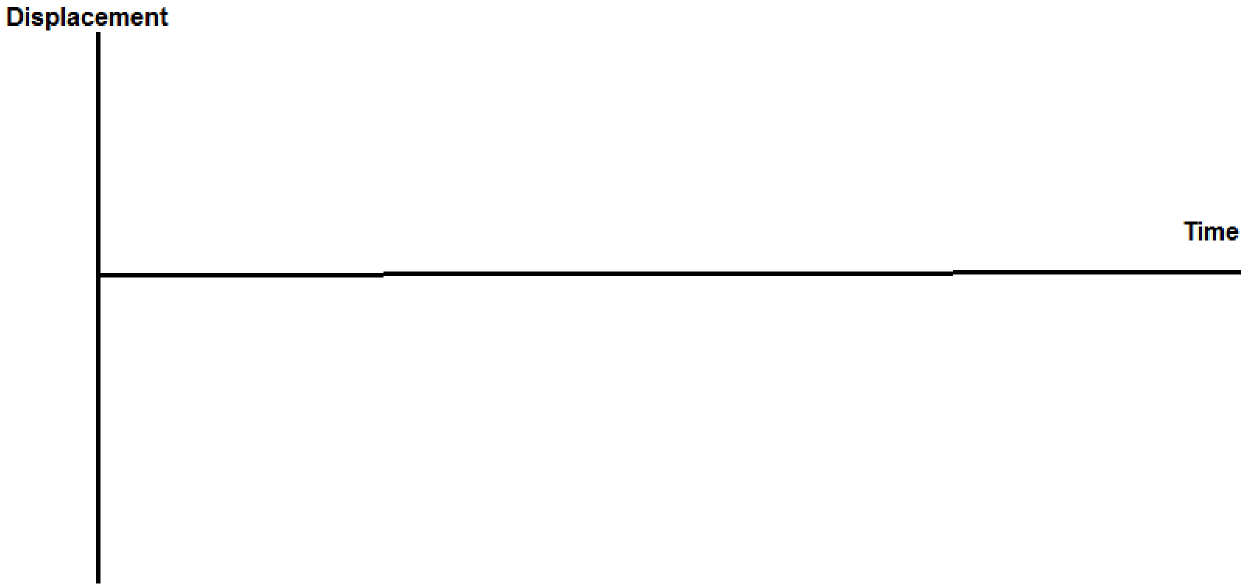


Question 5 **(3 marks)**

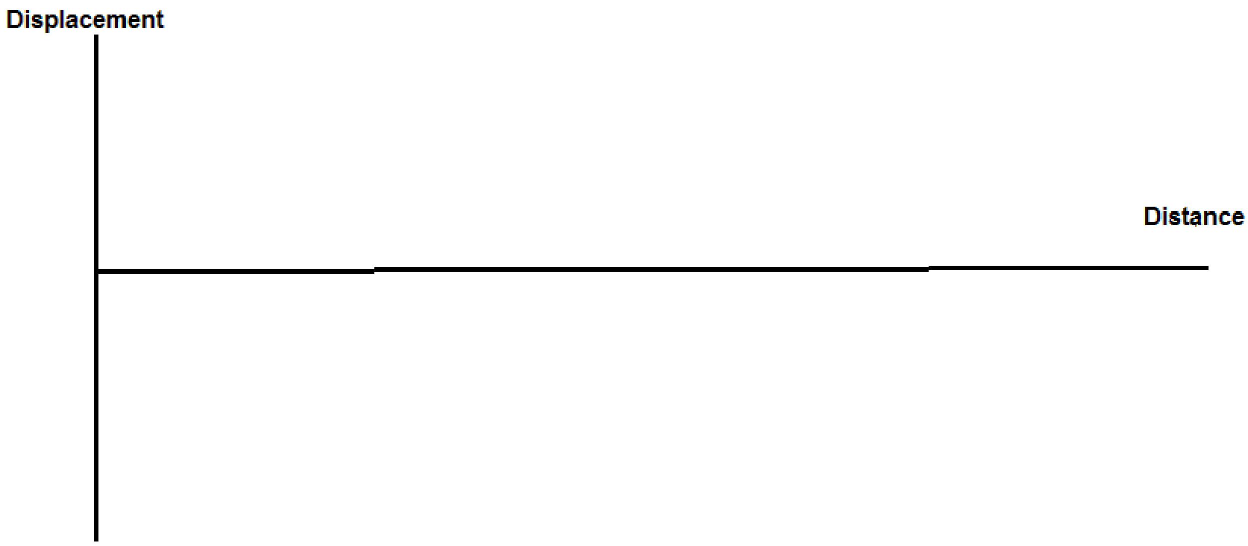
Draw two graphs (displacement/time and displacement/distance) to represent a wave.

On these graphs label the period, amplitude and wavelength.

i) Displacement/time

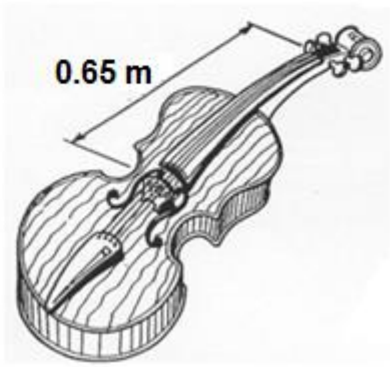


ii) Displacement/distance



Question 6 **(6 marks)**

a) A violin string is 0.650 m in length. Sketch the standing waves produced for the 1st and 2nd harmonics and determine their wavelengths. (4 marks)



1st **Sketch** (1 mark) **Wavelength = ________** (1 mark)

2nd **Sketch** (1 mark) **Wavelength = ________** (1 mark)

b) If the wave speed in the string is 4.00×10^2 m s^{-1}, calculate the frequencies of the first two harmonics. (2 marks)

Question 7 **(3 marks)**

On hot summer days at the cricket you can sometimes see players with a wet cloth around their necks. Referring to thermal concepts, explain how a wet cloth placed on the neck can help a person stay cool.

Question 8 **(4 marks)**

A student heated 337 g of nickel in a Bunsen burner flame until it reached a temperature of 534 °C. She then placed the nickel into 1.59 L of water at a temperature of 21.0 °C. The final temperature of the nickel and water mixture was 32.3 °C when thermal equilibrium was reached.

a) Calculate the energy that transferred out of the nickel into the water. (2 marks)

b) Calculate the specific heat of the nickel. (2 marks)

Question 9 **(3 marks)**

A sample of thigh bone from a recently deceased dog was tested and found to have an activity of 0.360 Bq. A similar size sample was obtained from a sabre tooth tiger thigh bone uncovered at an archaeological site and its activity was measured. Over a one day period a reading of 7.776×10^3 counts was registered on a Geiger counter for the archaeological sample. The half-life of radioactive carbon is approximately 5730 years.

(a) Determine the activity (in becquerels) for the archaeological sample. (1 mark)

(b) Determine the age of the thigh bone from the archaeological site. (2 marks)

Question 10 **(2 marks)**

A glass of water stored at room temperature will slowly evaporate even though it is not being heated to the boiling point of water. Explain how it is possible for evaporation to occur.

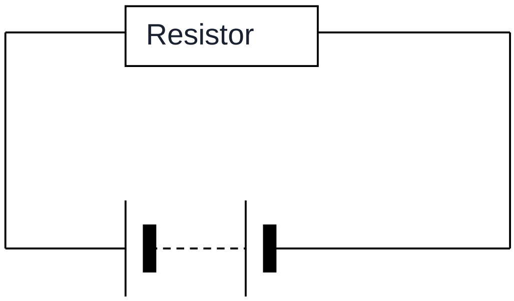
Question 11 **(4 marks)**

a) Explain why gold is a better electrical conductor than rubber. (2 marks)

b) Explain why gold is a better heat conductor than rubber. (2 marks)

Question 12 **(4 marks)**

a) When a resistor is connected to a battery, 6.02×10^{23} electrons pass through the resistor in a time of 70.0 s. Calculate the current in the resistor. (2 marks)



b) (i) Draw a labelled arrow on the diagram to indicate the direction of net electron drift in this circuit. (1 mark)

(ii) Also, draw a labelled arrow on the diagram to indicate the direction of conventional current in this circuit. (1 mark)

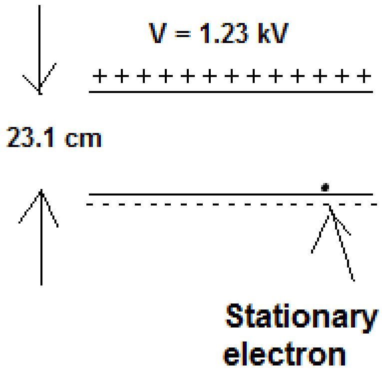
Question 13 **(5 marks)**

A bullet is discharged accidentally from a rifle and travels due east with a velocity of 3.70×10^2 m s^{-1}. It strikes a rock and ricochets off due north at 1.80×10^2 m s^{-1}. The bullet has a mass of 1.90 g. You may ignore any effects due to gravity and assume that the collision is completely elastic.

Calculate the change in momentum of the bullet, including a vector diagram.

Question 14 **(3 marks)**

A stationary electron is resting between two plates when the power source is switched on producing an emf of 1.23 kV between the plates, which are 23.1 cm apart.



Calculate the work done (joules and electron volts) in accelerating the electron across the gap. (3 marks)

End of Section One

Section Two: Problem-solving **50% (90 Marks)**

This section has **eight (8)** questions. Answer **all** questions. Write your answers in the spaces provided.

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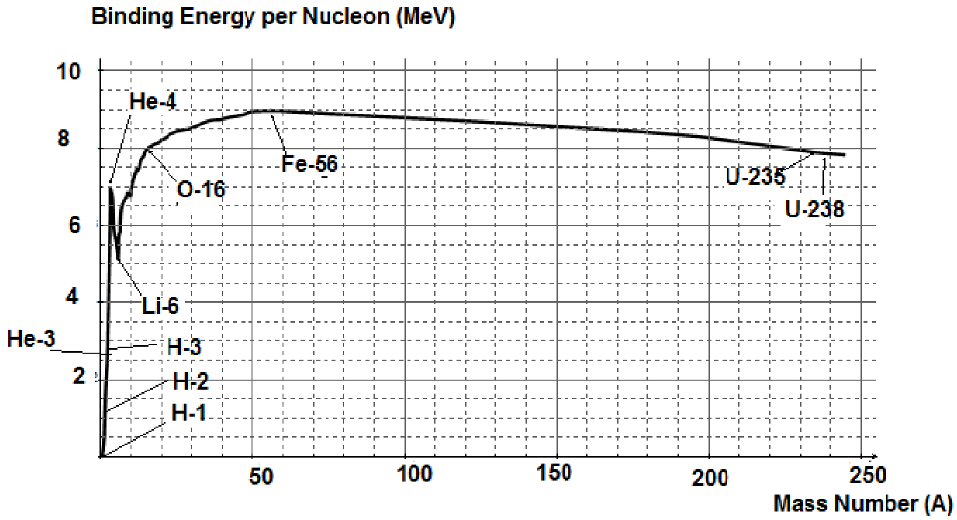
Suggested working time: 90 minutes.

Question 15 **(6 marks)**

The graph below shows the binding energy per nucleon versus mass number for some common isotopes.



(a) Estimate the average binding energy per nucleon (MeV) of the hydrogen-2 nucleus. (1 mark)

(b) Refer to the graph to explain which elements can undergo nuclear fusion. (2 marks)

(c) Estimate the difference in mass between a lithium-6 nucleus and the individual nucleons that go into making the nucleus. State your answer in atomic mass units. (3 marks)

Question 16 **(13 marks)**

Vanessa Williams celebrates a victory by climbing into the crowd and smashing a tennis ball vertically upwards. The ball is hit from a position 2.75 m above the ground with an initial velocity of 55.1 m s^{-1} upwards.

The ball has a mass of 57.3 g.

(a) Calculate the time the ball takes to reach the ground. (3 marks)

(b) Calculate the velocity of the ball after 5.10 s. (2 marks)

Question 16 (cont.)

(c) Calculate the distance that the ball travels to reach the ground. (3 marks)

(d) Calculate the mechanical energy of the ball whilst in flight. (3 marks)

(e) The tennis racquet is in contact with the ball for 0.312 s. Calculate the impulsive force on the ball. (2 marks)

Question 17 **(13 marks)**

Nuclear power stations produce electricity by using the power released from the artificial transmutation of radioactive atoms such as uranium-235. This fission reaction results in the formation of various products e.g. lanthanum-148, bromine-85, and neutrons. Much research is currently directed towards the production of working nuclear fusion reactors.

(a) What is meant by the term 'artificial transmutation'? (1 mark)

(b) What is a chain reaction, and how is it involved in the generation of power from a nuclear power station? (Include and refer to a diagram as part of your answer if you wish). (3 marks)

(c) What are three advantages of nuclear fusion over nuclear fission? (3 marks)

See next page

Question 17 (cont.)

Workers at a nuclear power station must wear safety devices which indicate the amount of exposure they have had to radioactivity. The badge of a 93.0 kg employee indicates that they have been exposed to 27.0 J of energy during one work period as a resulting of handling contaminated waste fuel.

(d) Calculate the absorbed dose for the worker. (2 marks)

(e) Calculate the dose equivalent for the worker, assuming all the absorbed radiation is due to slow neutrons. (2 marks)

(f) What are the likely effects of this dose equivalent upon the worker's health in the short and long term? What advice should the power station's medical officer give to the worker? (2 marks)

See next page

Question 18 **(14 marks)**

Some liquid alcohol of mass 1.30 g was placed in a sealed glass container and vaporised at 70.0 °C. The container with the vapour was placed in a large water bath that was kept at room temperature. The change in temperature of the alcohol was recorded every two minutes. There was a constant rate of energy output from the alcohol such that 2330 J of energy was transferred out in a 50 minute time period.

Assume that heat loss to the surroundings was negligible.

The room temperature during the experiment was 26.0 °C.

Temp (°C)	Time (min)
70	0
64	2
59	4
53	6
48	8
42	10
42	12

Temp (°C)	Time (min)
42	14
42	16
42	18
42	20
42	22
42	24
42	26

Temp (°C)	Time (min)
42	28
42	30
42	32
42	34
41	36
39	38
37	40

Temp (°C)	Time (min)
35	42
33	44
31	46
29	48
27	50
26	52
26	54

(a) Draw a graph of the data in the table. (4 marks)

A spare grid is at the end of the paper (page 37) in case you need to redo your graph.

See next page

Question 18 (cont.)

(b) Using the graph, compare (quantitatively) the specific heat capacity of the liquid alcohol with the specific heat capacity of its vapour? (3 marks)

(c) What state(s) of matter is/are present in the container between fifteen and twenty five minutes? (1 mark)

(d) There was a constant rate of energy output from the alcohol such that 2330 J of energy was transferred out in a 50.0 min time period. This assumption was used to enable calculations to be carried out.

Explain what is wrong with this assumption. You can still assume that heat loss to the surroundings was negligible. (2 marks)

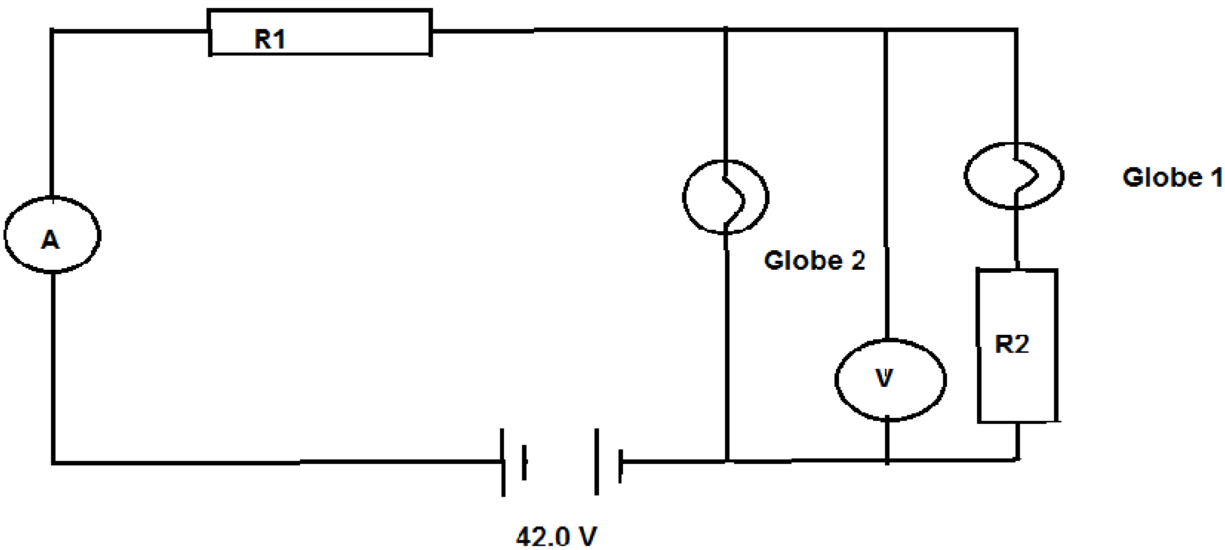
Question 18 (cont.)

(e) Determine the latent heat of vaporisation of the alcohol. (2 marks)

(f) In terms of energy, explain why the temperature of the substance did not decrease while energy transferred from it to the water between fifteen and thirty minutes. (2 marks)

See next page

Question 19 **(16 marks)**



Globe 1 is rated at 12.0 V and 3.00 W

Globe 2 is rated at 36.0 V and 12.0 W

Assume that this circuit allows both globes to work at the exact values for which they are rated.

(a) Calculate the following:

(i) Current in Globe 1 (2 marks)

(ii) Current in Globe 2 (2 marks)

(iii) Resistance of R2 (3 marks)

Question 19 (cont.)

(iv) Resistance of R1 (3 marks)

(v) The total resistance of the circuit (3 marks)

(b) What is the reading on the:

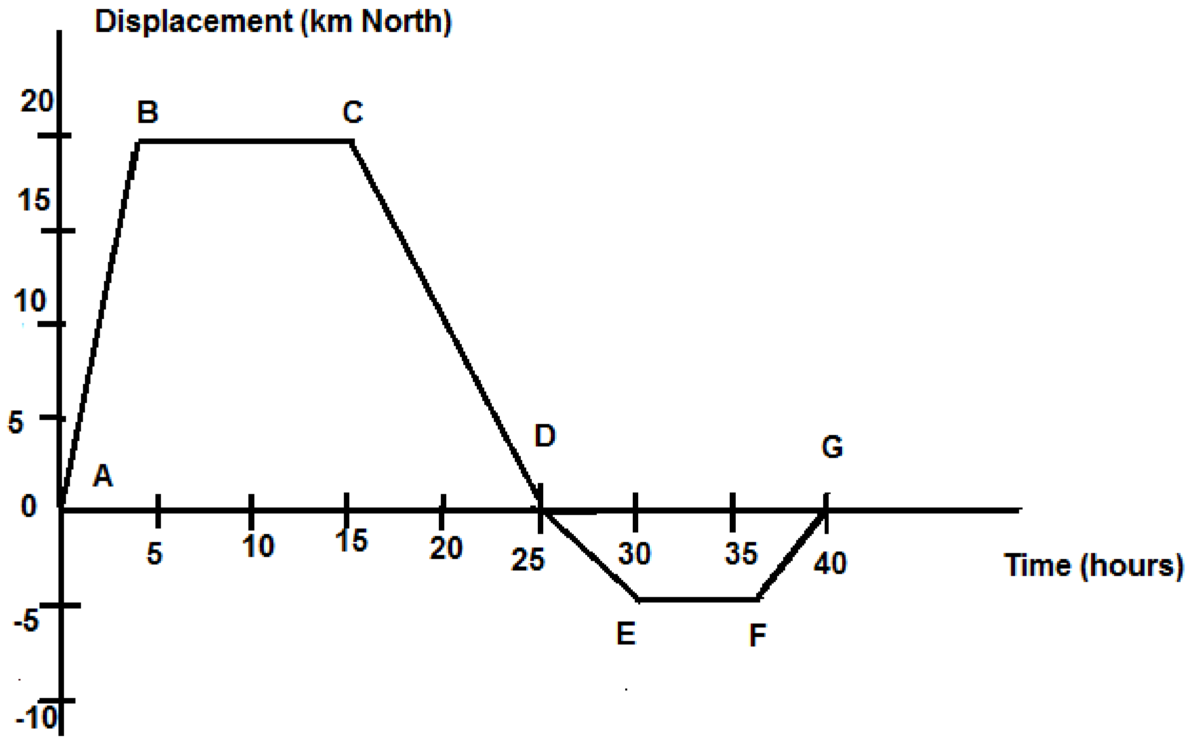
(i) Ammeter? (2 marks)

(ii) Voltmeter? (1 mark)

See next page

Question 20 **(9 marks)**

A keen bushwalker went for an extended hike as shown by the following graph.



Use the graph to determine the following information:

(a) How far did the hiker walk? (1 mark)

(b) Calculate the velocity (km h^{-1}) in the following segments:

(i) AB (1 mark)

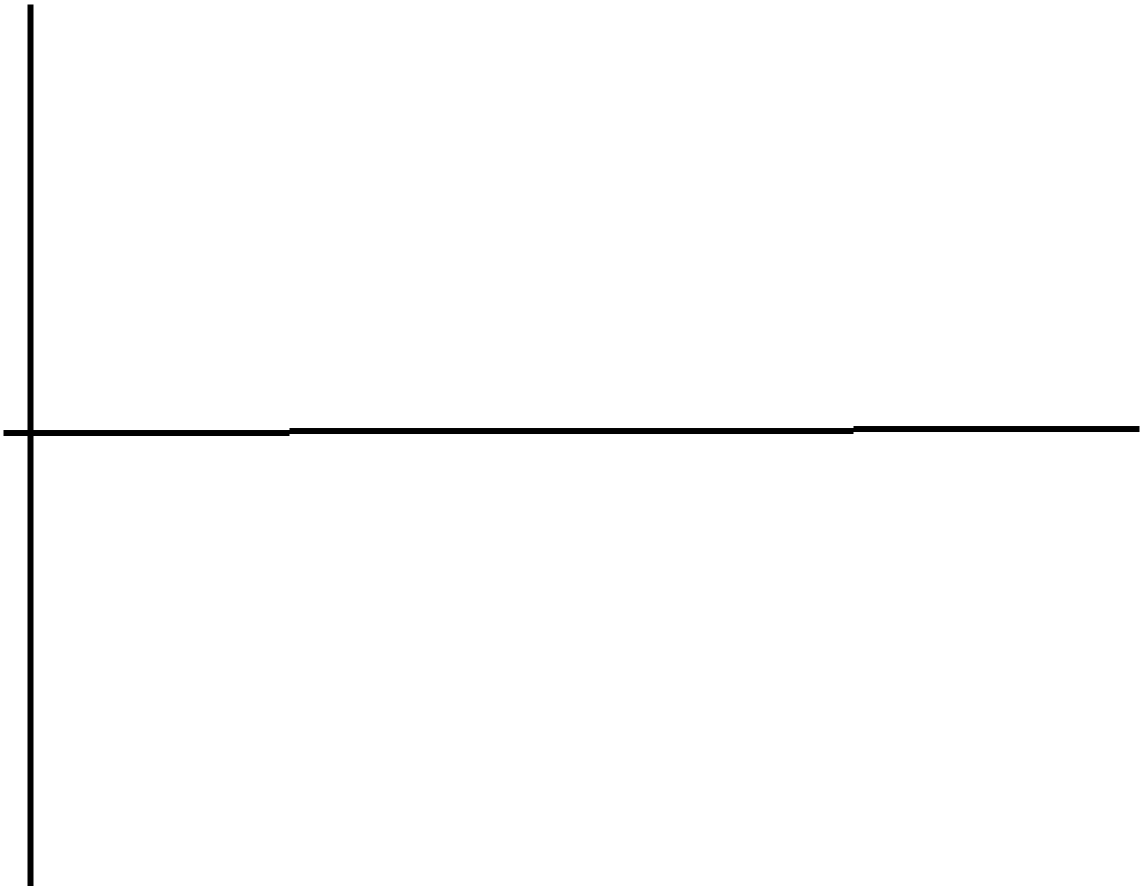
(ii) EF (1 mark)

(iii) AG (1 mark)

(iv) DE (1 mark)

Question 20 (cont.)

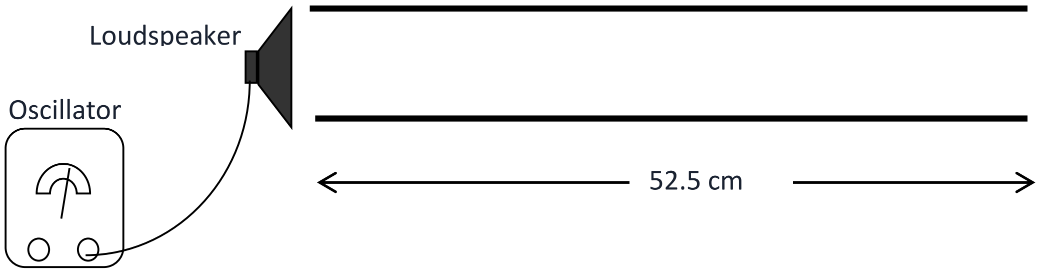
(c) Draw a graph of velocity versus time. (3 marks)



(d) For how long was the walker stationary? (1 mark)

Question 21 **(10 marks)**

In an experiment a student sets up the following apparatus. A loudspeaker is placed at one end of an open pipe. The loudspeaker is connected to an oscillator which allows vibrations with variable frequencies to be produced.



The student gradually increases the frequency of sound from zero and notices that at a frequency of 333 Hz the pipe makes a loud sound.

(a) Why is the sound loud at this frequency? (2 marks)

(b) On the above diagram draw a wave pattern (wave envelope) for the displacement of air particles at this fundamental frequency. (1 mark)

(c) At what position inside the pipe could a small burning candle be placed so that the flame remained steady (not being blown from side to side)? Explain briefly. (2 marks)

Question 21 (cont.)

The pipe is 52.5 cm long.

(i) What is the wavelength of the sound? (2 marks)

(ii) What is the speed of sound in the tube? (1 mark)

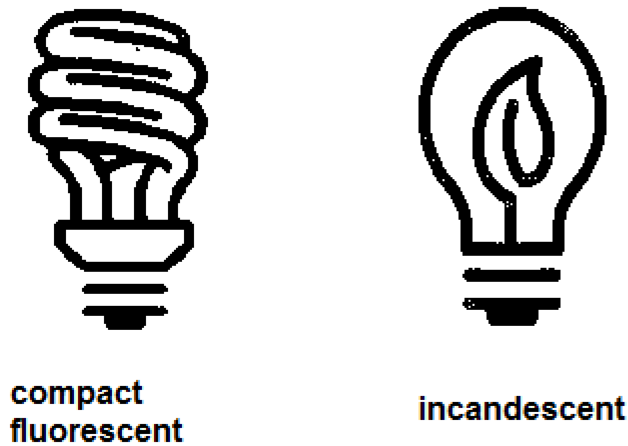
(e) The student now increases the frequency until another loud sound can be heard.

(i) Draw the wave patterns for the displacement of particles for this harmonic (1 mark)

(ii) What is the frequency of this overtone? (1 mark)

Question 22 **(9 marks)**

Compact fluorescent globes are becoming more popular and eventually you will not be able to buy incandescent globes. A compact fluorescent globe was advertised at a rating of 18.0 W but with equal brightness to that of a 100.0 W incandescent globe.



(a) What is the essential difference between these globes and why is the incandescent globe being phased out? (3 marks)

(b) If the compact fluorescent globe is assumed to be 80.0% efficient, what is the efficiency of the incandescent globe? (2 marks)

(c) Assuming the waste energy in both types of globe is released as heat, calculate the heat lost by each of the globes in one hour.

(i) compact fluorescent globe (3 marks)

(ii) incandescent globe (1 mark)

End of Section Two

Section Three: Comprehension **20% (36 Marks)**

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

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Suggested working time: 40 minutes.

Question 23 **(20 marks)**

Alpha Particles Target Cancer

By Calla Cofield

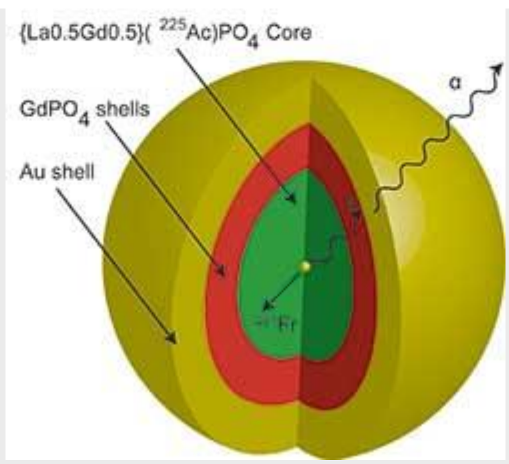


Photo courtesy of J. David Robertson/University of Missouri

In 2013, the Food and Drug Administration (FDA) approved the first cancer treatment drug containing an alpha-emitting isotope. In 2014 J. David Robertson, professor of chemistry at the University of Missouri, discussed a new technique that involves embedding alpha emitters inside a layered, gold-coated nanoparticle to make them safe for treatment for even more cancers.

Endoradiotherapy is a form of internal radiation therapy in which a radioactive substance is ingested by, or injected into, the patient. Until last year, endoradiotherapy used beta emitters. While surgery is usually the best option for sizeable, isolated tumours, chemotherapy is utilized to destroy small groups of cancer cells (or “micrometastases”) in multiple locations.

Endoradiotherapy drugs offer a targeted alternative to chemotherapy for attacking micrometastases. The drugs can be engineered to bind to receptors that are found on the cancer cells. When released nearby, beta particles do significant damage to cell DNA by ionizing other atoms and creating reactive chemical species in the cells.

Alpha particles are more direct, delivering energy directly to the cell DNA and fatally disrupting chemical reactions. And while beta particles deliver a few hundred keV of energy over a few millimetres, alpha particles deliver a bigger punch of 5 MeV, but stop after a distance of a few microns. “That very large amount of energy deposited in short range…makes them more cytotoxic to the cell than beta emitters,” said Robertson. “And it will allow you to get the same therapeutic effect with [about an order of magnitude] less radioactivity.”

Robertson and his collaborators from Oak Ridge National Laboratory and the University of Tennessee are in the preclinical phase of research to adapt the alpha emitter actinium 225 for endoradiotherapy. The isotope has a half-life of 11 days, which is ideal, since it gives the researchers plenty of time to synthesize the drug (about 2 days) and then let it pass through the body and accumulate at the target site (another 2 to 3 days).

However, decaying particles come with certain challenges: In the case of Ac-225, the alpha particle breaks free of the actinium nucleus with an energy of 5 to 6 MeV. This gives the daughter nuclei of the actinium an energy of about 100 keV, which is more than enough to tear through a molecular chain or a layer of cells, and send the daughters traveling through the body. The isotope Ac-225 eventually decays to bismuth, which has a 46-minute half-life and can be toxic if it builds up in the kidneys.

Robertson and his colleagues think they have found a solution: wrap the actinium in a layered nanoparticle to absorb the recoil energy and contain the daughter isotopes. The final product includes inner layers of lanthanide phosphate and gadolinium phosphate, and an outer layer of gold. The alpha particles still manage to escape the nanoparticle with only 0.1% energy loss, but after 24 hours 90% of the bismuth is contained in the nanoparticle or in nearby cells. Robertson says previous efforts to contain the bismuth by-product of Ac-225 decay have succeeded in containing only 10 to 20 percent.

“We’re close to the goal of 100% [retention of bismuth],” said Robertson. The gold nanoparticle is currently being tested in the first phase of preclinical trials. Now Robertson and colleagues will have to see if the retention of bismuth is good enough to justify using the drug in humans. It comes down to the same question that doctors must ask of so many cancer drugs - “Does the benefit outweigh the risk?”

See next page

(a) Why is the gold coating on the nanoparticle important for its operation and the safety of the patient? (3 marks)

(b) Ac-225 decays via a decay series until the final stable isotope is produced. Each of these reactions occurs through an alpha decay. Write balanced nuclear equations for each of the decays and name the daughter particle produced in each reaction.

(6 marks)

(c) (i) Beta particles have a quality factor of 1 whereas alpha particles have a quality factor of 20. Using the information in the article, what two factors account for this?

(2 marks)

(ii) Gamma particles also have a quality factor of 1. What additional factor helps account for alpha's greater quality factor compared with gamma?

(1 mark)

(d) An alpha particle has a mass of 6.64424×10^{-27} kg. With what velocity does the alpha particle break free of the actinium nucleus? (3 marks)

(e) (i) Alpha particles in the body travel a few microns compared with a few millimetres for beta. Compare the volume of the body affected by a beta particle compared with the volume affected by an alpha particle. (2 marks)

(ii) Beta particles ionise atoms. Explain how this occurs. (1 mark)

(iii) The beta particles do significant damage to cell DNA. How does this help destroy the cancer? (2 marks)

Question 24 **(16 marks)**

How Safe is Your Car?

Crash Protection Features

Crash protection features provide greater levels of injury protection to drivers and passengers in car crashes. They include:

Crumple zones

Modern cars protect drivers and passengers in frontal, rear and offset crashes by using crumple zones to absorb crash energy. This means that the car absorbs the impact of the crash, not the driver or passengers.

Strong occupant compartment

The cabin of the car should keep its shape in frontal crashes to protect the driver and passengers' space. The steering column, dashboard, roof pillars, pedals and floor panels should not be pushed excessively inwards, where they are more likely to injure drivers and passengers. Doors should remain closed during a crash and should be able to be opened afterwards to assist in quick rescue, while strong roof pillars can provide extra protection in rollover crashes.

Side impact protection

Increased side door strength, internal padding and better seats can improve protection in side impact crashes. Most new cars have side intrusion beams or other protection within the door structure. Some cars also have padding on the inside door panels.

Increasingly, car manufacturers are installing side airbags that provide protection from severe injury. Head-protecting side airbags, such as curtain airbags, are highly effective in side impact and rollover crashes.

Seat belts

A properly worn seat belt provides good protection but does not always prevent injuries. Three point lap/sash seat belts offer superior protection to two point seat belts and should be installed in all seating positions. Recent improvements to seat belt effectiveness include:

- webbing clamps that stop more seat belt reeling out as it tightens on the spool
- pretensioners that pull the seat belt tight before the occupant starts to move
- load limiters that manage the forces applied to the body in a crash
- seat belt warning systems to remind you if seat belts have not been fastened.

Airbags

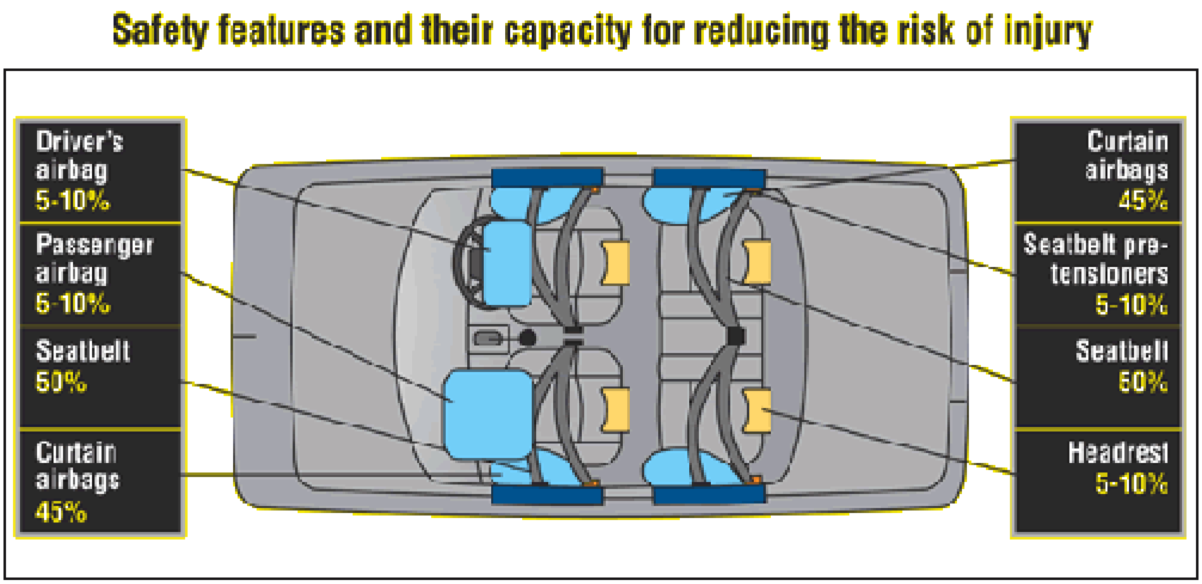
Australian airbags are designed to supplement the protection provided by seat belts - they are not a substitute. The best protection in frontal crashes is achieved using a properly worn seat belt in combination with an airbag.

See next page

Head rests

Head rests are important safety features and should be fitted to all seats - front and back. Head rest position is critical for preventing whiplash in rear impact crashes. Whiplash is caused by the head extending backward from the torso in the initial stage of rear impact, then being thrown forward. To prevent whiplash the head rest should be at least as high as the head's centre of gravity (eye level and higher) and as close to the back of the head as possible.

Diagram and Information courtesy of Folksam Research, 2005 (SWEDEN)



(a) "Modern cars protect drivers and passengers in frontal, rear and offset crashes by using crumple zones to absorb crash energy." (2 marks)

Explain the energy transformations that occur when a car's crumple zone absorbs energy in a crash.

(b) Crumple zones also reduce the force experienced when a car crashes. Explain, using Newton's Second Law (momentum), how this acts as an additional safety feature in a car.

(4 marks)

(c) Two point seat belts are belts that fit across the driver's or passenger's lap. The two points were generally on the floor. Modern car seat belts have a third point about shoulder height when sitting. Why is this advantageous?

(2 marks)

(d) You are in the passenger seat holding a 3.00 kg parcel on your lap. Your car is involved in a head on crash with a tree. The car speed goes from 72.0 km h^{-1} to zero in 0.100 s. What force is required to hold the parcel?

(3 marks)

(e) Head rests reduce whiplash injuries in car crashes. Identify and use the appropriate Newton's Law to explain why this is so. (3 marks)

(f) Airbags inflate and then deflate very quickly. Why? (2 marks)

END OF EXAMINATION

Acknowledgements

Question 23 – Calla Caulfield, Alpha Particles Target Cancer from
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Question 24 – How Safe Is Your Car?
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