

Section I (continued)

Part B – 60 marks

Attempt Questions 16–27

Allow about 1 hour and 45 minutes for this part

Answer the questions in the spaces provided.

Show all relevant working in questions involving calculations.

Question 16 (3 marks)

NASA recently landed a space probe on an asteroid found between the orbits of Earth and Mars. The 500 kg space probe had a weight of 2.5 N when it landed on the asteroid.

- (a) What would be the weight of this space probe on the surface of Earth? 1

$$500 \times 9.8 = 4900 \text{ N}$$

- (b) Before landing on the asteroid, the space probe was placed in an orbit with radius 50 km. The orbital period was
- 5.9×10^4
- s. 2

What was the mass of the asteroid?

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

$$\frac{(50000)^3}{(5.9 \times 10^4)^2} = \frac{6.67 \times 10^{-11} \times M}{4\pi^2}$$

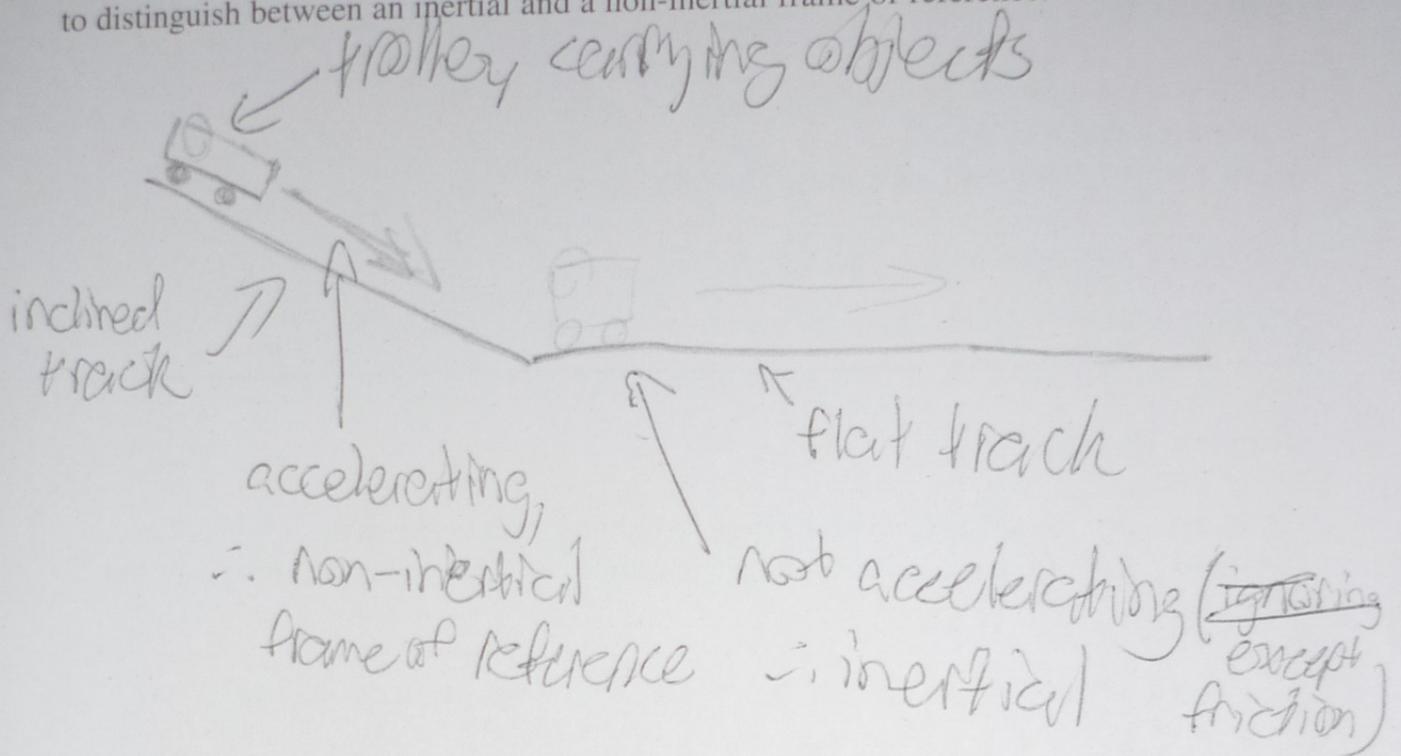
$$M = \frac{4\pi^2 \times 1.25 \times 10^{14}}{6.67 \times 10^{-11} \times (5.9 \times 10^4)^2}$$

$$= 2.254 \times 10^{16} \text{ kg}$$

Question 17 (5 marks)

2

- (a) Using labelled diagrams, show how a first-hand investigation could be performed to distinguish between an inertial and a non-inertial frame of reference.



- (b) Explain how inertial and non-inertial frames of reference relate to the principle of relativity.

3

In Newtonian relativity, all ~~mechanical~~ interactions within ~~an~~ inertial frames of reference are equivalent for the purposes of mechanics, and no mechanical experiment can distinguish between a frame of reference at rest or at constant velocity. Poincaré and Einstein extended this to cover all laws of physics, showing that all inertial frames of reference are equivalent, but that non-inertial frames of reference are not equivalent, as demonstrated by the Twins Paradox.

Question 18 (4 marks)

The nearest galaxy to ours is the Large Magellanic Cloud, with its centre located 1.70×10^5 light years from Earth. Assume you are in a spacecraft travelling at a speed of $0.99999c$ toward the Large Magellanic Cloud.

- (a) In your frame of reference, what is the distance between Earth and the Large Magellanic Cloud? 2

$$l_r = l_0 \sqrt{1 - v^2/c^2}$$

$$l_r = 1.7 \times 10^5 \times \sqrt{1 - 0.99999^2}$$

$$\approx 760.26 \text{ light years}$$

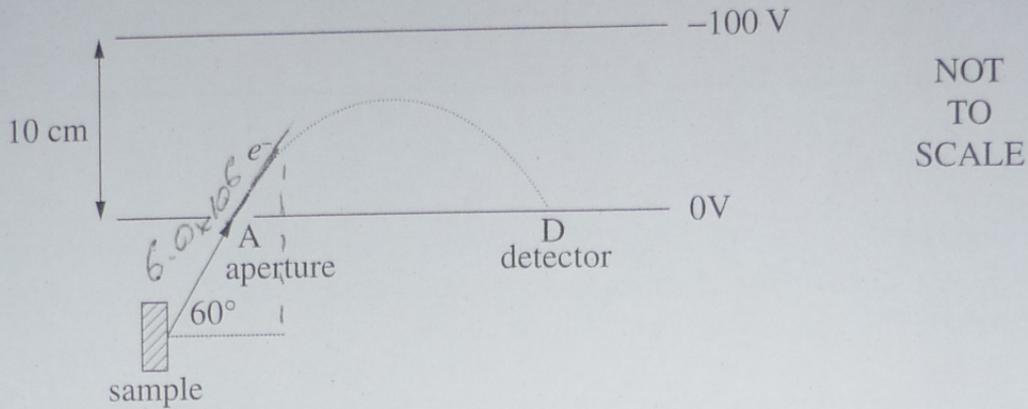
- (b) In your frame of reference, how long will it take you to travel from Earth to the Large Magellanic Cloud? 2

$$\frac{760.26}{0.99999} = 760.27 \text{ years}$$

$$0.99999$$

Question 19 (6 marks)

An electron is emitted from a mineral sample, and travels through aperture A into a spectrometer at an angle of 60° with a speed of $6.0 \times 10^6 \text{ m s}^{-1}$.



- (a) Calculate the magnitude and direction of the force experienced by the electron inside the spectrometer. 3

$$F = qE \quad E = \frac{V}{d} = \frac{-100}{0.1} = -1000$$

$$F = -1.602 \times 10^{-19} \times 1000 = 1.602 \times 10^{-16} \text{ N, downwards towards the more positive plate}$$

- (b) The electron experiences constant acceleration and eventually strikes the detector, D. 3

What is the time taken for the electron to travel from A to D?

$$v_x = 6.0 \times 10^6 \cos 60^\circ = 3.0 \times 10^6 \text{ m/s}$$

$$u_y = 6.0 \times 10^6 \sin 60^\circ = 3.0 \times 10^6 \times \sqrt{3} \text{ m/s}$$

$$F = 1.602 \times 10^{-16} \text{ N (ve for our purpose)}$$

$$\therefore a = -1.759 \times 10^{14} \text{ m/s}^2$$

$$\Delta y = u_y t + \frac{1}{2} a_y t^2$$

$$0 = 3.0\sqrt{3} \times 10^6 t + \frac{1}{2} (-1.759 \times 10^{14}) t^2$$

$$t(3.0\sqrt{3} \times 10^6 + \frac{1}{2} (-1.759 \times 10^{14}) t) = 0$$

$$\frac{1}{2} (1.759 \times 10^{14}) t = 3\sqrt{3} \times 10^6$$

$$t = \frac{3\sqrt{3} \times 10^6}{\frac{1}{2} (1.759 \times 10^{14})} = 5.91 \times 10^{-8} \text{ s}$$

Question 20 (4 marks)

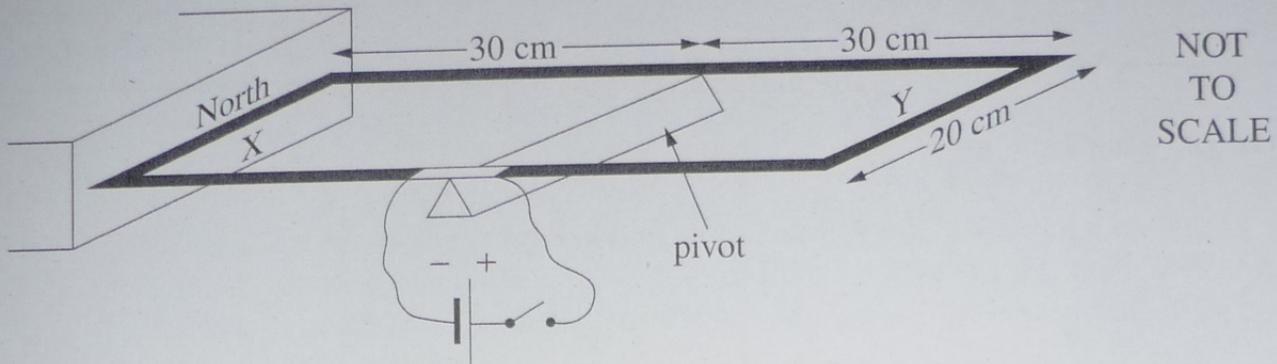
Draw a table to summarise the energy transformations and transfers for three household appliances. Each appliance must have a different type of useful energy output. Include the name of the appliance, its use and the transformation/transfer of energy involved.

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Name	Use	Transformation
Kettle	Heating water	Electricity \rightarrow Heat using a high-resistance element
Television	Watching audio-visual programs	Electricity \rightarrow Light (cathode ray tube or liquid crystal display) Electricity \rightarrow Sound (speakers) EM radiation \rightarrow electricity (antenna)
Telephone	Audio communication	Sound \rightarrow electricity (Microphone) Electricity \rightarrow Sound (speaker, ringer)

Question 21 (6 marks)

A rectangular wire loop is connected to a DC power supply. Side X of the loop is placed next to a magnet. The loop is free to rotate about a pivot.



When the power is switched on, a current of 20 A is supplied to the loop. To prevent rotation, a mass of 40 g can be attached to either side X or side Y of the loop.

- (a) On which side of the loop should the mass be attached to prevent rotation? 1

Side X

- (b) Calculate the torque provided by the 40 g mass. 2

$$\begin{aligned} \tau &= Fd \\ &= mgd \\ &= 0.04 \times 9.8 \times 0.3 \\ &= 0.1176 \text{ N m} \end{aligned}$$

- (c) Calculate the magnetic field strength around side X. 3

$$\begin{aligned} \tau &= BIA \cos \theta & \tau &= 0.1176 & \theta &= 0 \\ BIA &= 0.1176 \\ 20 \times (0.2 \times 0.6) \times B &= 0.1176 \\ 2.4B &= 0.1176 \\ B &= 0.049 \text{ T} \end{aligned}$$

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Section I – Part B (continued)

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Question 22 (4 marks)

How did the invention of the transistor transform the way communication occurs in Australia? In your answer, refer to the technology that the transistor replaced.

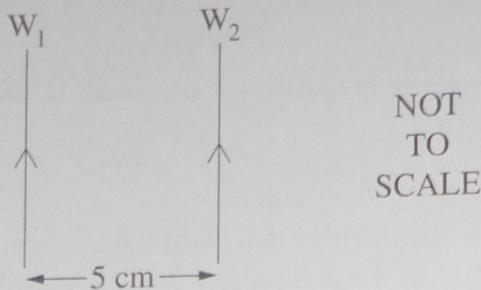
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Transistor technology replaced thermionic devices (ie. valves), allowing for more miniaturised electronics. An early application of this is the portable transistor radio, small enough to be carried around. The transistor also revolutionised second-generation computer technology, with improved processing and storage capabilities eventually leading to the development of computer networks, initially for military and scientific purposes, which were the predecessors of the internet.

Transistors were also a necessary development for the integrated circuit which revolutionised computing and electronics again.

Question 23 (6 marks)

Two identical wires, W_1 and W_2 , each 2.5 m in length, are positioned as shown. They carry identical currents in the direction indicated.



- (a) Identify the direction of the force which W_2 experiences as a result of the current in W_1 . 1

Left - towards W_1

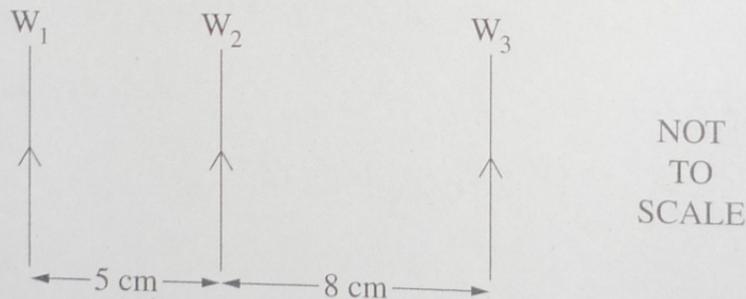
- (b) Calculate the current in each wire, given that the two wires experience a force of 6.9×10^{-4} N. 2

$$F = k \frac{I_1 I_2}{d} \quad I = I_1 = I_2$$

$$\frac{6.9 \times 10^{-4}}{2.5} = 2.0 \times 10^{-7} \times \frac{I^2}{0.05}$$

$$I = \sqrt{\frac{0.05 \times 6.9 \times 10^{-4}}{2.5 \times 2.0 \times 10^{-7}}} = 8.31 \text{ A}$$

- (c) A third wire, W_3 , carrying a smaller current, is now placed as shown. 3

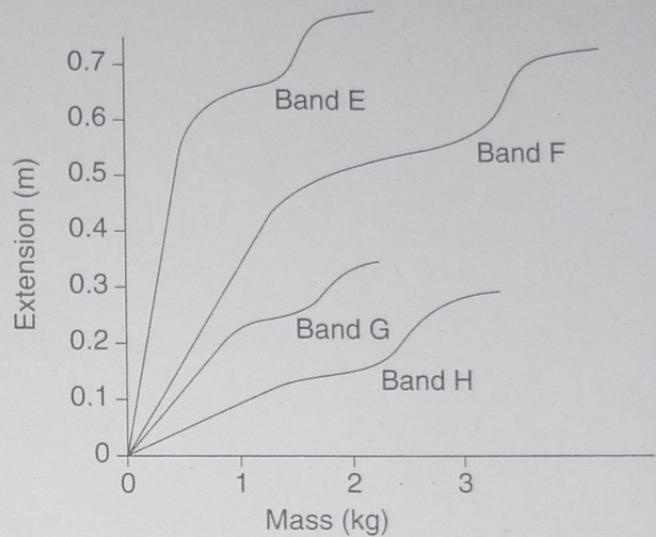
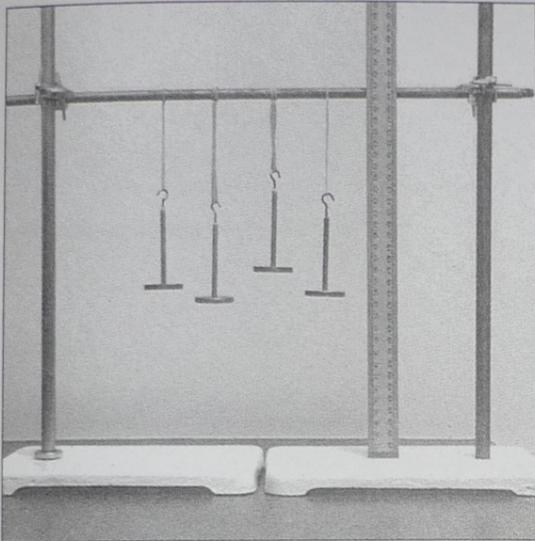


Explain qualitatively the forces on W_2 as a result of the currents in W_1 and W_3 .

The ^{net} forces on W_2 will be slightly weaker due to the force created by W_3 opposing the force of W_1 . The net force will still be towards W_1 , as the wires are closer together and carry a higher current.

Question 24 (4 marks)

An experiment was conducted to investigate the flexibility* and strength** of different types of rubber bands, all with the same initial length. A mass was attached to each band and the extension was measured. Masses were gradually increased, and the extensions measured until each band broke. The photograph was taken during the experiment. The results are summarised in the graph.



- * Flexibility: *The more flexible the rubber band, the greater its extension for a given mass.*
** Strength: *The stronger the rubber band, the more mass it is able to hold before breaking*

- (a) Which rubber band is the most flexible? Justify your answer with reference to the graph. 2

Band E. As can be seen in the graph, it has the greatest extension ~~up to~~ around 2kg

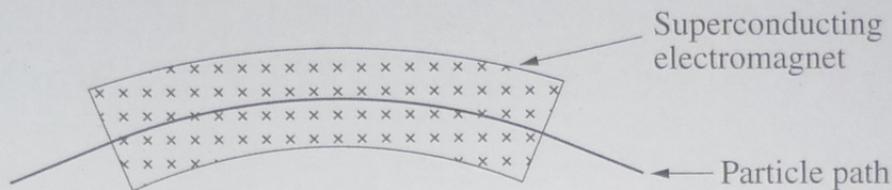
- (b) Identify the strongest rubber band and state the mass range in which the extension appears to be directly proportional to the attached mass. 2

Band F. Between 0 and 1.3kg

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Question 25 (5 marks)

In the Large Hadron Collider (LHC), the particle beams are steered using magnetic fields, as shown.



- (a) Two particles with the same mass and speed are travelling through the LHC in opposite directions. 2

What can be deduced about the charge on the particles?

They are of opposite charge

- (b) During a test run, a proton travels with a speed of $1.0 \times 10^7 \text{ m s}^{-1}$ around the LHC. The radius of curvature of its path is 4.2 m. 3

Calculate the magnetic field strength.

Centripetal force:

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

$$= \frac{1.673 \times 10^{-27} \times (1.0 \times 10^7)^2}{4.2}$$

$$= 3.98 \times 10^{-14} \text{ N}$$

Effect of field:

$$3.98 \times 10^{-14} = qvB \sin \theta$$

$$3.98 \times 10^{-14} = 1.602 \times 10^{-19} \times 10^7 \times B$$

$$B = \frac{3.98 \times 10^{-14}}{1.602 \times 10^{-19} \times 10^7} = 0.025 \text{ T}$$

$$\begin{aligned} \theta &= 90^\circ \\ v &= 10^7 \text{ m/s} \\ q &= 1.602 \times 10^{-19} \text{ C} \end{aligned}$$

Question 26 (6 marks)

In the distribution of electricity, the overall energy losses between the power plant and users can easily be between 8% and 15%, which suggests that there is still some room to improve efficiency.

Analyse this statement. In your analysis, you must refer to existing sources of energy loss, and a possible new technology to minimise such loss.

There is significant opportunity to increase energy efficiency in power distribution. Electricity goes along hundreds of kilometres of cables between power stations and consumers, and a significant part of the energy loss is due to resistance in the cables. Superconductor technology will virtually eliminate this loss, but the present no superconductors are suitable for long distance transmission. Another source of losses is transformers in every substation, which also have significant heat losses due to resistance, as well as sound vibration and electromagnetic loss. Superconductors can assist in minimising substation losses, and some superconductor installations are being used in substations and interconnection points. Overseas, increased efficiency in cooling systems can also help control the resistance in transformers. As better superconductive materials are developed, the loss in power transmission could be improved dramatically.

Question 27 (7 marks)

In an experiment to investigate the photoelectric effect, light is shone onto a silver surface and the resulting maximum electron kinetic energy is measured and recorded.

Light wavelength (nm)	Electron kinetic energy (eV)
250	0.25
215	1.08
187	1.90
167	2.73
150	3.56

- (a) Determine the frequency of the highest energy photons used in the experiment. 2

$$E = hf \quad f = \frac{c}{\lambda}$$

$$E = 6.626 \times 10^{-34} \times \frac{3 \times 10^8}{150 \times 10^{-9}}$$

$$= 1.3252 \times 10^{-18} \text{ J}$$

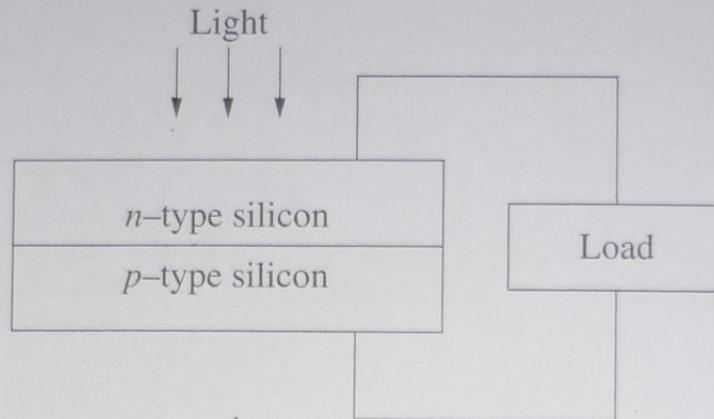
- (b) What effect would changing the intensity of the light have on the measured electron kinetic energy? 1

None.

Question 27 (continued)

- (c) With reference to the photoelectric effect, and the semiconductors shown in the diagram, explain the operation of a solar cell.

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~~As light hits the~~ As light hits the semi-conductors, the energy of the photons is transferred into electrons in the semiconductor (the photoelectric effect). The electrons are conducted through the semiconductors as their doping gives ~~the~~ positive electron holes and free electrons forcing the electrons to move around the circuit as long as new electrons are being freed by the light energy.

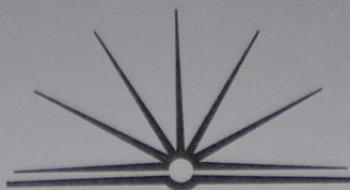
End of Question 27

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Examination

PHYSICS

8

WRITING BOOKLET

Section	Part	Question Number
11		29

Date

4th November 2009

Number of booklets
used for this question

1

Instructions

- Write your Centre Number and Student Number at the top of this page and of each page that you use.
- In the boxes provided write the name and date of this examination, and the number(s) of the question(s) attempted in this booklet.
- If you have not attempted the question, you must still hand in the Writing Booklet, with the words 'NOT ATTEMPTED' written clearly on the front cover.
- Write the number of each question or part in the margin at the beginning of each answer.
- Write using black or blue pen.
- Write on the ruled pages only. You may use the unruled pages for rough work.
- You may ask for an extra Writing Booklet if you need more space.
- Do NOT remove any pages from this booklet.
- You may NOT take any Writing Booklets, used or unused, from the examination room.

$$r = 7.0 \times 10^6 \text{ m}$$

$$v = 8.1 \times 10^3 \text{ m s}^{-1}$$

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

$$= \frac{65610000}{7 \times 10^6}$$

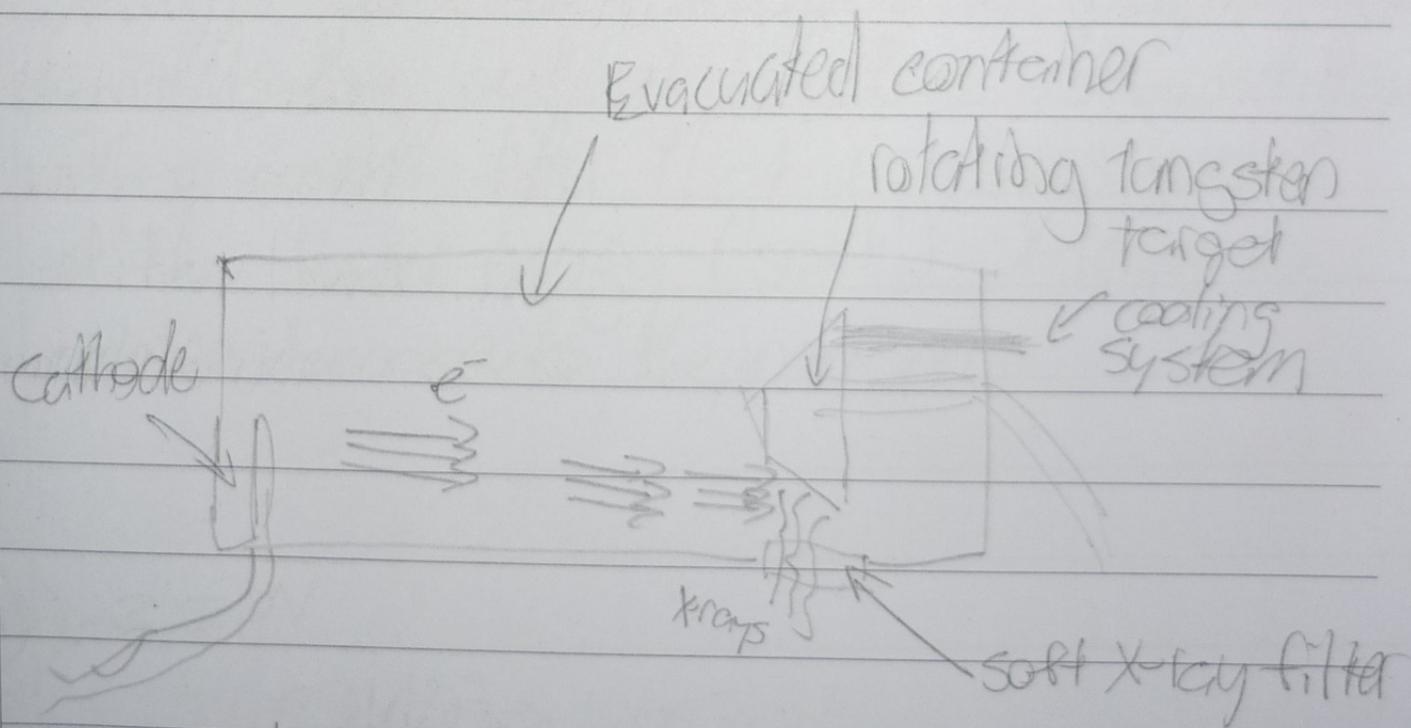
$$= 9.373 \text{ m/s}^2$$



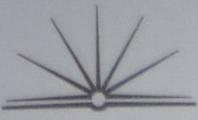
Question 29

a) i) A contrast medium, eg. a barium meal, will absorb X-rays better than soft tissue like the small intestine. By ingesting the contrast medium, the small intestine will become visible on the X-ray image when the contrast medium is digested. The higher density of the atoms results in their increased X-ray absorption.

ii)



Medical X-rays are produced using an assembly similar to a cathode ray tube. Electrons are emitted from the cathode



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ii)

due to a high voltage electric current. The electrons are accelerated towards a tungsten target at the other end of the chamber, and when they collide with the target, ^{some} electrons in the tungsten atoms will move to higher energy levels. As those electrons relax in to their normal energy levels, ^{some of} the excess energy is released as X-rays. Some of these X-rays will proceed towards the output window, which is fitted with a small filter that removes some of the lower energy ('soft') X-rays to minimise damage to the patient.

b) i) $Z = PV$
 $= 1.53 \times 10^3 \times 1.05 \times 10^3$
 $= 1606500$

b) ii) More of the pulse will be reflected back towards the transducer.

iii) Piezoelectric crystals can be used as a producer and receiver of ultrasound waves due to the piezoelectric effect. When an electric potential is placed across a piezoelectric crystal, the crystal changes shape. By placing an alternating current across the crystal, the crystal will ~~produce~~ vibrate and thus produce sound, or ultrasound, waves. Conversely, a change in the shape of the crystal creates a potential, and by passing a current through, vibrations can be detected. Therefore, passing an AC through a crystal of the right frequencies ($> 20\text{kHz}$) creates ultrasound waves, and the reflected waves change the current and can be detected by the equipment. Using a bank of piezoelectric transducers, the full ultrasound image can be created.

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c) i) ^{validity of} The claim made in this statement is debatable. CAT scans are useful for producing relatively high resolution images that can see soft tissue injuries. If the patient has an undiagnosed soft tissue problem, a CAT scan can diagnose it and appropriate treatment can be taken. These issues include brain injuries, cancerous growths and other serious issues. However, CAT scans use relatively high doses of ionising X-ray radiation, and for this reason doctors generally recommend against taking scans without justification such as already-known symptoms. Whilst the radiation dose from a CAT scan is unlikely to cause serious harm, it should be avoided where possible. Whilst the statement is partially true in the sense that a CAT scan can detect certain injuries, it is generally false - most people suffering from injuries will have already consulted their doctor and taken appropriate measures, and unnecessarily scans cause more harm than good.



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c) ii) This image was produced using a radioactive chemical tracer (such as carbon-14) tagged to glucose molecules. When the radioisotope is tagged to a bodily compound, it becomes a radiopharmaceutical. Chemically, the substance is kept similar to the original substance so it will be absorbed in the same way. The patient ingests the substance, and the tagged glucose is absorbed. The radioisotope decays inside the body, releasing a positron and an electron for each decaying atom. When the positron and electron collide, they annihilate each other, resulting in total conversion to electromagnetic radiation. Two gamma rays are released, pass through the body and are detected by the PET scanner. Over the course of several hours, the intensity of rays coming from each part of the body can be determined, resulting in an image like that shown.

d) Magnetic resonance imaging (MRI) is an imaging process that relies on the properties of certain atoms that 'spin', and the fact that a magnetic field ~~can~~ and EM radiation can change the spin. When producing an MRI image, the patient is placed inside a large magnetic field, usually $> 0.5T$, generally created using superconducting electromagnets. This lines up the spin of the atoms in the body. Given a particular isotope and magnetic field, there is a certain frequency of radiation (the Larmor frequency) that causes the atoms to precess in such a way that they 'topple' over. As the patient moves through the MRI machine, small 'gradient' magnets are used to 'isolate' slices of the patient by changing the Larmor frequency.

The machine calculates the appropriate Larmor frequency for the isotope ^{and area} being targeted (normally hydrogen-1), and a wave of ~~the~~ that frequency is sent through, causing the atoms to tip over.

When the wave stops, the atoms return to their normal position releasing radio waves as they relax. These waves are detected by the MRI machine, and are used to calculate the density of the isotope in that part of the body. The resultant density values are processed by a computer which generates high-resolution cross-section images. By showing the density of the atoms, the doctor can identify different parts and diagnose any damage.