

2010 HSC Physics Sample Answers

This document contains ‘sample answers’, or, in the case of some questions, ‘answers could include’. These are developed by the examination committee for two purposes. The committee does this:

- (a) as part of the development of the examination paper to ensure the questions will effectively assess students’ knowledge and skills, and
- (b) in order to provide some advice to the Supervisor of Marking about the nature and scope of the responses expected of students.

The ‘sample answers’ or similar advice are not intended to be exemplary or even complete answers or responses. As they are part of the examination committee’s ‘working document’, they may contain typographical errors, omissions, or only some of the possible correct answers.

Section I, Part B

Question 21

Sample answer:

A consequence of a space vehicle entering the atmosphere at an angle that is too steep is that the vehicle will be heated to an excessive temperature.

If the vehicle enters the atmosphere at an angle that is too shallow, it will bounce off the atmosphere back into space.

Question 22 (a)

Sample answer:

Initial horizontal velocity component is constant: $u_x = x/t = 300/21 = 14.3 \text{ ms}^{-1}$

Question 22 (b)

Sample answer:

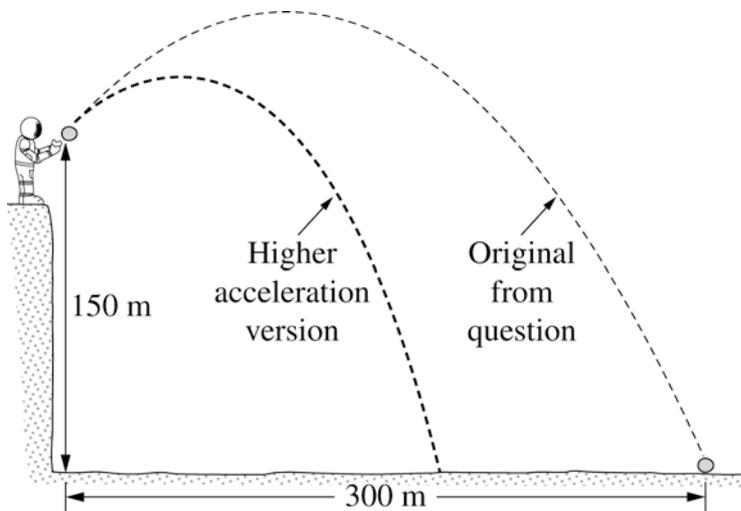
Initial vertical velocity: $y = u_y t + \frac{1}{2} a_y t^2$

$$150 = u_y \times 21 + \frac{1}{2} \times 1.6 \times 21^2$$

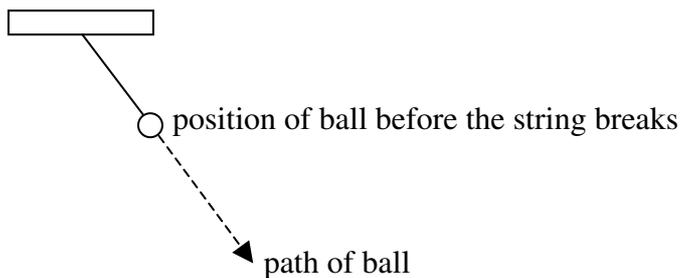
$$\therefore u_y = 9.7 \text{ ms}^{-1}$$

Question 22 (c)**Sample answer:**

The heavy line is a possible path of the stone in a stronger gravitational field.

**Question 23 (a)****Sample answer:**

The train must be accelerating toward the left. It may be moving to the right and slowing down, or moving to the left and speeding up.

Question 23 (b)**Sample answer:**

In the frame of the train the acceleration of the mass is zero, hence there is zero net force. Therefore, apart from the force applied by the string there must be opposing forces. When the string breaks the force exerted by the string is removed and the mass must accelerate in the direction of those opposing forces, which must be along the line of the string.

Question 24***Sample answer:***

Both the Sun and the Earth exert a force on the JWST which is towards the Sun. Therefore the centripetal force on the JWST is greater than that produced by the Sun alone. This means that the orbital speed of the JWST around the Sun is greater than it would be if the Sun alone were producing the centripetal force on the JWST and therefore the period is less than would be predicted from Kepler's law of periods, given that its orbital radius is greater than that of the Earth.

Question 25 (a)***Sample answer:***

The momentum of the burnt fuel is in the direction in which it is ejected and therefore by the law of conservation of momentum, the rocket has an equal momentum change in the opposite direction, resulting in its forward motion.

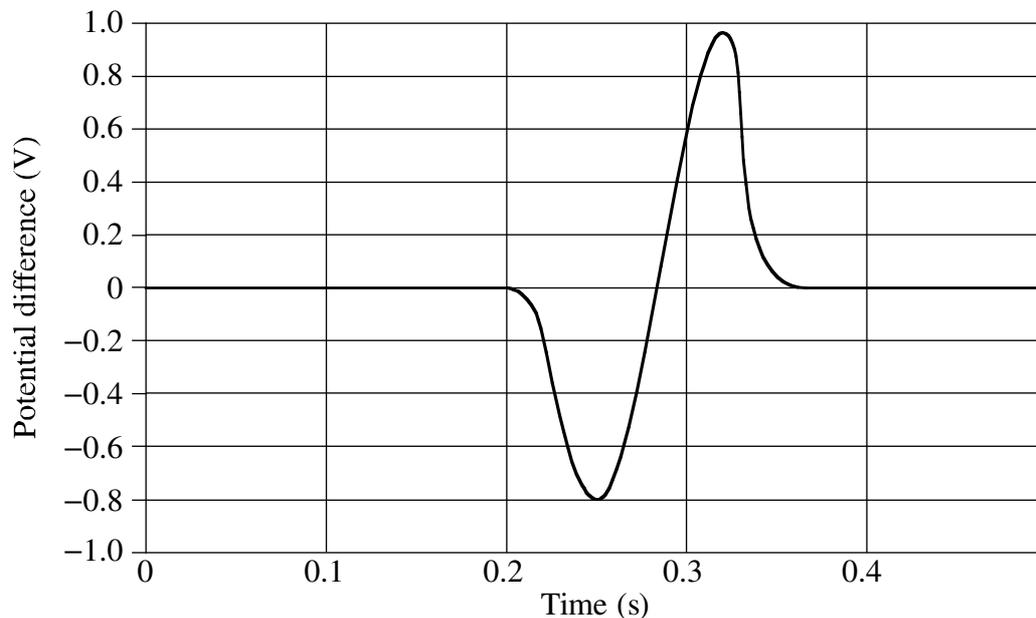
A force is required to propel the fuel in that direction and so an equal and opposite force acts on the rocket, causing it to accelerate in the opposite direction to the ejected burnt fuel.

Question 25 (b)***Sample answer:***

The force produced by the rocket engine on the rocket is constant, however its mass is decreasing as it ejects burnt fuel. Therefore, the acceleration of the rocket and the g-force experienced by the astronaut increases as a result of the increases in acceleration at t_2 versus at t_1 .

Question 26 (a)***Sample answer:***

X is the potential difference as the magnet enters the top of the coil and Y is the potential difference as it leaves the coil. The magnet is accelerating as it falls under the action of gravity and hence the rate of flux change as it leaves the coil is greater than as it enters the coil and hence the voltage has a greater magnitude at Y.

Question 26 (b)*Sample answer:***Question 27***Sample answer:*

Two other applications of superconductors are in maglev trains and for the transmission of electricity through power grids.

Although very few are in commercial operation, maglev trains are in principle capable of transporting people in a faster and more energy-efficient way. Both of these advances are because the maglev principle removes the problem of wheel-track friction at high speeds. The availability of faster transport has an effect on society because it either reduces travel time, allowing higher productivity or more time with family. By reducing wheel-track friction the maglev principle also reduces the energy cost of transport, which has positive benefits for the environment.

Superconducting electricity transmission is currently used for short distances, where a large amount of power must be transmitted or where space for cables is severely limited. This has a positive effect on society because it enables large amounts of power to be transmitted through underground cables in cities without requiring large overhead wires. Because superconducting cables also reduce overall power losses they have positive benefits for the environment too.

Question 28**Sample answer:**

The magnetic field is into the page.

$$F = BI\ell$$

$$B = \frac{F}{I\ell}$$

$$= \frac{9.8 \times 7 \times 10^{-4}}{0.3 \times 0.2} = 0.114\dots\text{T}$$

$$= 0.11 \text{ T to 2 sig. fig.}$$

Question 29**Sample answer:**

One pair of deflection plates must create a horizontal electric field which varies so that it moves the beam in a linear manner repeatedly from left to right. A separate pair of deflection plates has a voltage applied which varies with time, causing the beam to deflect up and down at right angles to the deflection produced by the other pair of plates.

Question 30 (a)**Sample answer:**

Boron has 3 outer shell electrons and germanium has 4 outer shell electrons. When boron atoms are part of the germanium lattice, each boron atom produces a hole since there is one less electron than the number needed to form bonds with adjacent germanium atoms. Semiconductors with holes formed in this manner are p-type semiconductors.

Question 30 (b)**Sample answer:**

The addition of boron increases the conductivity compared to pure germanium because the holes formed act as charge carriers, which are present in greater numbers than the charge carriers present due to electron-hole formation in pure germanium.

Question 31 (a)**Sample answer:**

$$f = c/\lambda = 3.00 \times 10^8 / 1 \times 10^{-6} = 3.00 \times 10^{14} \text{ Hz}$$

$$E = hf = 6.626 \times 10^{-34} \times 3.00 \times 10^{14} = 1.99 \times 10^{-19} \text{ J}$$

Question 31 (b)***Sample answer:***

Photocells rely on the photoelectric effect for their operation. In the photoelectric effect, a photon with sufficient energy (greater than or equal to a threshold called the work function) is able to cause an electron to be ejected from the surface of a metal. These ejected electrons are the photocell current. Longer wavelength light contains lower energy photons, so light with a wavelength longer than the threshold wavelength is not able to eject electrons (= produce a photocell current).

Question 32***Answers could include:***

In order to transport people to Mars the mass of them, their habitat and their spacecraft (including fuel) must be:

1. raised from Earth's surface into orbit around the Earth
2. raised from Earth's orbit around the Sun to Mars' orbit around the Sun (and placed in orbit around Mars)
3. lowered (without crashing) from orbit around Mars to its surface
4. raised from Mars surface → Mars orbit
5. lowered from Mars orbit about Sun → Earth orbit about Sun
6. lowered (without crashing) from Earth orbit → Earth surface

Steps 1, 2 and 4 all involve positive changes in gravitational potential energy, energy that must be supplied by the rocket engines during these stages. Steps 3, 5 and 6 involve negative changes in gravitational potential energy and large positive changes in kinetic energy. To prevent crash landings this kinetic energy must be lost through friction in an atmosphere or by braking using a forward-facing rocket engine. A significant issue is that the fuel needed for the later steps adds to the mass that must be moved in the earlier steps (unless fuel can be made on Mars).

High-speed charged particles from the Sun are dangerous to the people and the instruments in the craft. Because the particles are charged they can be directed using electric and magnetic fields. An electric field could only repel charge of one sign (+ or -) so could not be used, however magnetic fields can be used to move both positive and negative charges. Therefore, in principle a magnetic field could be used to protect the craft from all high-speed charged particles.

Section II

Question 33 (a) (i)

Answers could include:

Any three of elastic, thermal, magnetic, electrical, density.

Question 33 (a) (ii)

Sample answer:

Earth is an oblate spheroid, flatter at the poles and larger at the equator. Measurements of the period of a pendulum would give a longer period at the equator than at higher latitudes, indicating a lower value of g .

Question 33 (a) (iii)

Sample answer:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$\therefore g = \frac{4\pi^2 l}{T^2}$$

For $T_1 = 2.00, T_2 = 2.05$:

$$\frac{g_1}{g_2} = \frac{4\pi^2 l / T_1^2}{4\pi^2 l / T_2^2} = \frac{2.05^2}{2.00^2} = 1.05$$

Question 33 (b)

Sample answer:

Gravity measurements are obtained by conducting a gravimetric survey using a device that measures the local value of the gravitational acceleration. This data can be compared to the expected value by performing three corrections. The latitude correction subtracts the value expected at that latitude at sea level. The free-air correction is then applied to correct for not being at sea level. Finally, the Bouguer correction corrects for the additional rock that produced the altitudinal variation.

After applying these corrections, if the result is non-zero it indicates the presence of something which causes the local density of rock to be different from the average density in the crust. If the result is less than zero there may be an underground cavern, while a result greater than zero may indicate a deposit of a high-density mineral.

Question 33 (c) (i)***Answers could include:***

S waves are shear waves and are transverse, while P waves are compression waves and therefore longitudinal.

Question 33 (c) (ii)***Sample answer:***

- The velocity of both types of waves increases with depth.
- P-waves are faster than S waves.
- Only P waves can propagate in a liquid.

Question 33 (c) (iii)***Sample answer:***

S waves are shear waves and cannot propagate through a liquid. As the outer core of Earth is liquid the S wave cannot propagate as shown.

P waves have a velocity which increases with depth. As the P wave path enters regions of increasing depth (hence increasing wave velocity) the path must bend to the right of the path shown on the original diagram.

Question 33 (d)***Sample answer:***

The original theory of continental drift postulated that the continents moved relative to the sea floor. The initial reluctance to accept this idea was mainly a result of there being no mechanism known to provide the energy needed to move the continents across the sea floor. In contrast the theory of plate tectonics has the continents sitting on crustal plates which include the sea floor and the continents move with those plates, not relative to them.

The mechanism for motion of the crustal plates, known as sea-floor spreading, is the rising of molten mantle rock through crustal plate boundaries, pushing the plates apart. As the molten rock cools the magnetite and haematite components record the direction of the magnetic field at the time and place. Due to random reversals of the magnetic field, rocks solidifying at different times may have different directions of magnetisation.

Extensive mapping of the sea floor with sensitive magnetometers shows alternating regions of magnetisation around plate boundaries. Isotopic dating methods allow the determination of the timing of magnetic field reversals and show that younger rock is nearest the plate boundaries, and older rock further away, demonstrating that crustal plates have moved apart with time as the up-welling molten mantle rock pushes the plates apart. This shows that the crustal plates move apart, the continents moving with the sea floor, and no additional mechanism is needed to move the continents relative to the sea floor.

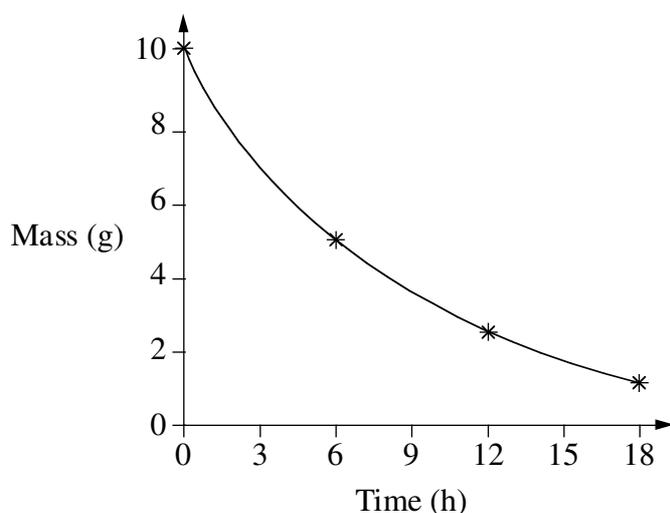
Question 34 (a)**Sample answer:**

A beam of radiation from the X-ray band of the EM spectrum is directed at the hand. The X-rays penetrate the hand. Bone absorbs more X-radiation than soft tissue due to its greater density. The X-rays passing through the hand expose a photographic film, to display the image of the bones.

Question 34 (b) (i)**Sample answer:**

The 6-hour half-life is an advantage because the amount of radioactive material present in the patient's body reduces quickly, presenting the patient with less risk than if the half-life were longer.

A disadvantage of the 6-hour half-life is that the isotope cannot be stored for use. It must be made within a few days at most of the procedure being carried out on the patient.

Question 34 (b) (ii)**Sample answer:****Question 34 (c) (i)****Sample answer:**

Hydrogen is targeted in the MRI process because it has magnetic properties due to its charge and spin which causes it to respond to magnetic fields and radio pulses and because it is abundant in the human body, which is made up mainly of water (H_2O).

Question 34 (c) (ii)**Sample answer:**

An RF oscillator directs RF energy into the body at the Lamor frequency. This causes the magnetic moment of the aligned hydrogen nuclei to precess in phase and absorb the RF energy. The RF oscillator is then turned off. As the moments of the nuclei precess they emit RF which is detected. The hydrogen nuclei relax and lose phase with each other with a rate which is dependent on the type of tissue and its water content. The relaxation values can be localised by using a 3D gradient field and a computer is used to analyse the data from each region in the body, called a voxel, to produce an image.

Question 34 (d) (i)**Sample answer:**

$$Z(\text{muscle}) = \rho v = 1076 \times 1580 \\ = 1.7 \times 10^6 \text{ kg m}^{-2} \text{ s}^{-1}$$

$$\frac{I_r}{I_o} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2} = \frac{(1.7 \times 10^6 - 400)^2}{(1.7 \times 10^6 + 400)^2} \\ = 0.999$$

\therefore 99.9% of the energy is reflected

Question 34 (d) (ii)**Sample answer:**

The Doppler Effect for sound is the apparent change in frequency when the sound is emitted from a source that is moving relative to the detector. In ultrasound (US) Doppler a narrow US beam is directed towards the blood. US reflects off the blood cells and they act as a moving source of US. The reflected US is detected and compared to the source. The difference in frequency gives the speed and direction of the blood flow.

Doppler imaging of the heart can be used to detect malfunctioning valves because in this case the blood is not flowing at the speed and in the direction it would in a normal heart.

Question 34 (e)***Sample answer:***

The doctor should choose PET.

PET uses isotopes that emit gamma radiation from inside the body. The isotope accumulates in areas of high metabolic activity, which is a characteristic of tumours. Therefore the tumour would show up as a bright spot on a PET scan even though it is very small.

CAT uses X-rays which would be effective in penetrating the skull. However CAT scans only show structural information, not function, and have poor ability to distinguish between soft tissues. A small tumour in the brain would be very difficult to see in a CAT scan image.

Ultrasound (US) energy would not be able to image the brain because of the high difference in acoustic impedance between brain tissue and skull bone; very little US energy would pass through into or out of the brain. US images show structure only and do not have the resolution required to observe a 3 mm tumour.

Question 35 (a) (i)***Sample answer:***

HALCA was placed in space in order to create a very long baseline interferometer. The use of a radio telescope in space made possible a much longer baseline than was possible using Earth-based radio telescopes and, since resolution improves with increasing baseline length, the resolution resulting from the simultaneous use of HALCA and ground-based radio telescopes was significantly better.

Question 35 (a) (ii)***Sample answer:***

Infrared radiation is absorbed as it travels through the Earth's atmosphere. More infrared radiation from sources being studied can therefore be detected when it is operated from a high-flying aircraft, providing better measurements of what is intended. Because measurements are also being made in a cooler region than on Earth's surface, the measurements are less subject to interference from ground-based heat sources, again making the measurements more valid.

Question 35 (b) (i)***Sample answer:***

The spectra of stars can provide information about their rotation on their axes and their velocity in a radial direction relative to the observer.

Question 35 (b) (ii)***Answers could include:***

Surfaces of stars are black body radiators and therefore the unique profile of radiation intensity as a function of wavelength allows the temperature of the star's surface to be deduced. The hotter the star's surface temperature, the shorter the peak wavelength intensity produced in the black body spectrum.

Atoms emit radiation when electrons move from high to low energy levels. Since the energy level transitions are unique to each element, the emission lines in a star's spectrum can be used to identify the elements present.

Atoms and molecules absorb radiation when electrons in them are excited to higher energy levels. When a continuous spectrum produced by a black body radiator passes through gases in stellar spectra, dark absorption lines are produced in the spectrum. The lines uniquely identify the atoms or molecules absorbing that radiation, and hence in the star's atmosphere. Corrections need to be made for absorption by gases in interstellar space and by the Earth's atmosphere.

Question 35 (c) (i)***Sample answer:***

The region Z contains white dwarf stars.

Question 35 (c) (ii)***Sample answer:***

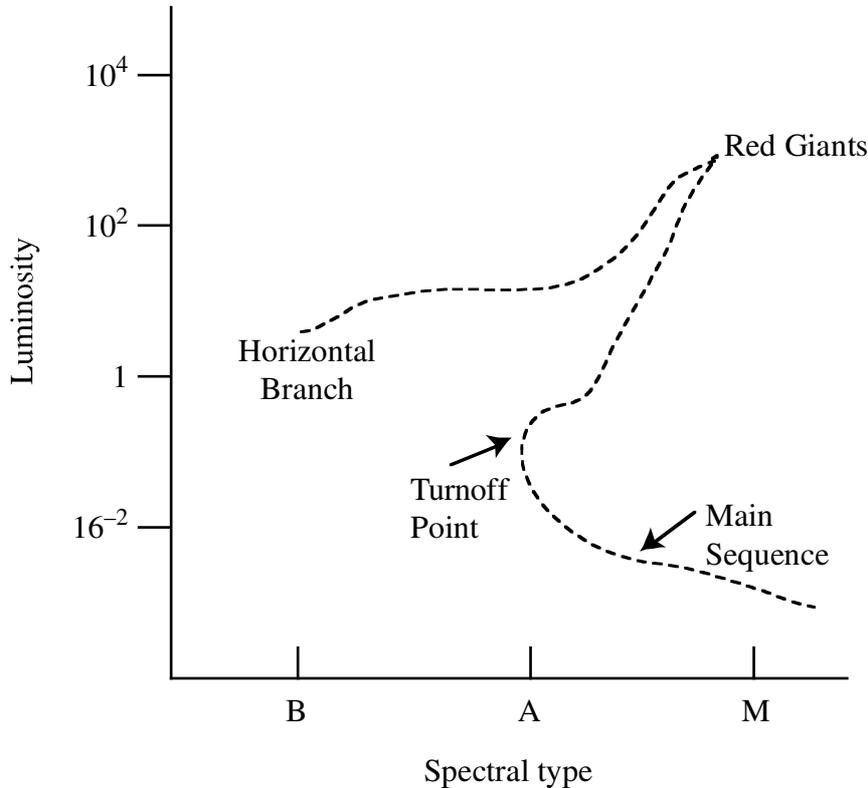
The larger the mass of the star the greater its luminosity. The larger the mass of the star the quicker it burns its fuel, the shorter its lifetime.

Question 35 (c) (iii)***Sample answer:***

The stars at W produce energy by nuclear fusion. The stars at Z release energy as a result of left-over heat – they are glowing embers of dead stars.

Question 35 (c) (iv)

Sample answer:

**Question 35 (d)**

Sample answer:

Three advances in technologies, which have improved our understanding of celestial objects, are larger optical telescopes with active optics, the use of space-based telescopes which can detect wavelengths that cannot penetrate the Earth's atmosphere, and the use of interferometry.

Larger telescopes and active optics have both improved the resolution of telescopes, providing astronomers with more detailed information about stars. For example, binary stars having a very small angular separation can be resolved as a result of this improved technology and so the individual properties of such stars can be measured with improved validity.

The use of space-based telescopes can measure radiation such as X-rays and UV, which cannot pass through the Earth's atmosphere, thus providing a more complete understanding of the behaviour of objects emitting these types of radiation. For example, very hot objects emit significant amounts of radiation in these bands and so more information enables better models for such objects to be developed.

Interferometry using two or more telescopes improves the resolution of images. This is particularly applicable to radio telescopes, but is also being applied using optical telescopes. Better resolved images means that more information about objects being observed is obtained and again, this has improved our understanding of celestial objects.

Question 36 (a)**Sample answer:**

The transition of an electron from a higher energy level E2 to a lower energy level E1 results in the emission of a photon with energy $E_2 - E_1 = hf$.

Similarly, if an electron in energy level E1 absorbs a photon with frequency f, then it will move to the higher energy level E2.

Thus, the energy of the stationary states in Bohr's model of the hydrogen atom determine the frequencies of the photons which can be absorbed or emitted by a hydrogen atom.

Question 36 (b)**Sample answer:**

$$\begin{aligned} 1/\lambda &= 1.097 \times 10^7 (1/4 - 1/16) \\ &= 2.057 \times 10^6 \end{aligned}$$

$$\lambda = 4.86 \times 10^{-7} \text{ m}$$

Question 36 (c)**Sample answer:**

- Every object with momentum mv has an associated De Broglie wavelength $\lambda = h / mv$
- In order for a standing wave to be stable on the electron orbit, an integral number of wavelengths need to fit onto electron orbit.
- The energy levels in a Bohr atom correspond to orbits which can fit 1, 2, 3... complete electron waves onto their orbit.

Question 36 (d)**Sample answer/Answers could include:**

Pauli explained the shape of the β -decay curve by hypothesising the existence of an unobserved particle, the neutrino, which carried away some of the energy released in this nuclear reaction.

He stated that the total amount of energy in the system was conserved:
i.e. the energy of the β -particle + the energy of the neutrino was equal to a constant value.

Question 36 (e) (i)***Sample answer/Answers could include:***

Chadwick theorised that an uncharged particle was released when α particles fused with beryllium nuclei.

He realised that this particle was about the same mass as a proton, and therefore would interact strongly in an elastic collision with a proton, according to the laws of conservation of energy and conservation of momentum. Paraffin contains large numbers of hydrogen atoms, which contain a single proton in their nucleus.

By measuring the recoil energies and momenta of the ejected protons, he was able to determine the properties of the neutrons which were collided with the paraffin.

Question 36 (e) (ii)***Sample answer:***

Neutrons have zero electric charge. Consequently, they are not affected by the electric fields surrounding an atomic nucleus, or by the charges on the electrons surrounding the nucleus. As a result, they strongly penetrate all materials.

Their mass gives them a de Broglie wavelength which makes them ideal for studying materials which have interatomic distances close to that wavelength. Many materials have exactly this characteristic.

Question 36 (f)***Sample answer:***

Three forces operate within a stable atomic nucleus:

- the strong nuclear force (attractive)
- electrostatic forces (repulsive)
- gravitational forces (attractive)

The gravitational attractions within the nucleus are extremely weak, and can be ignored.

In order for a nucleus to be stable, the strong nuclear force needs to be much stronger than the forces of electrostatic repulsion between the positively charged protons in the nucleus.

Question 36 (g)**Answers could include:**

Rutherford:

- gold foil experiment
- determined that atoms have a nuclear structure, and that the nucleus is tiny, dense and positively charged.

Einstein:

- $E = mc^2$ equation

Fermi:

- Neutron bombardment of U-235 caused nuclear fission
- A nuclear chain reaction was possible, where the neutrons released by a fission could cause other nuclei to fission

The atomic bomb is a device, which works by fissioning a large number of atomic nuclei in a short period of time. The resultant mass-energy conversion results in a massive explosion.

Rutherford's measurement of the properties of the atomic nucleus, when coupled with Fermi's experiments on uranium led to the development of the materials needed for an atomic bomb. Einstein's formula allowed scientists to calculate the amount of energy, which could be released by such a device. All three scientists played crucial roles in the invention of this weapon.

The Cold War was one of the most important events in the 20th century and exerted a significant effect on society. One of the most important factors in the Cold War was the existence of huge numbers of atomic weapons on both sides of the conflict. For the first time in human history, man had invented weapons of such power that they had the capability of eliminating life from Earth.

The invention of the atomic bomb, by any measure, had a highly significant effect on our society.

Question 37 (a) (i)**Sample answer:**

Section A of the circuit is a potential divider.

Question 37 (a) (ii)**Sample answer:**

From the graph, the resistance of the thermistor at 60 °C is 4 k Ω .

Using the potential divider equation:

$$V_t = (+5 \text{ V}) \frac{10 \text{ k}\Omega}{10 \text{ k}\Omega + 4 \text{ k}\Omega} = 3.57 \text{ V}$$

Question 37 (a) (iii)**Sample answer:**

Section B of the circuit contains an operational amplifier connected as a comparator, with positive feedback provided by R_3 . In this configuration, the output of the amplifier is equal to the voltage difference between its input terminals multiplied by the (large) gain of the device. R_3 provides positive feedback, which combined with the input resistors introduces hysteresis in the response of the circuit.

Question 37 (a) (iv)**Sample answer/Answers could include:**

The potential divider connected to the inverting input provides a $5\text{V}/2 = 2.5\text{ V}$ reference voltage.

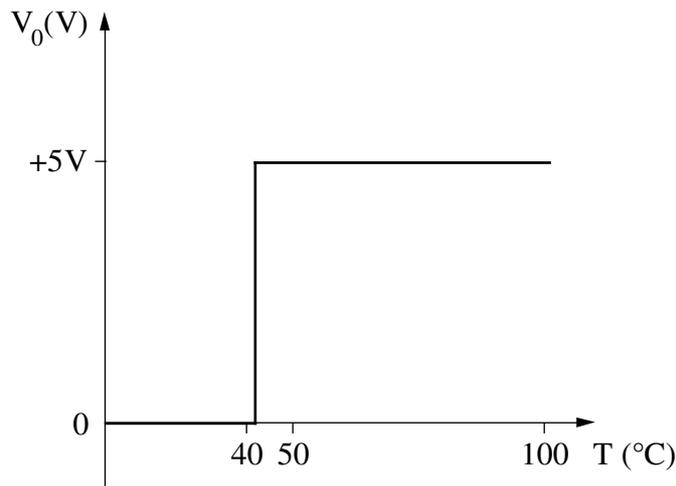
This is the voltage at which the comparator output will switch states.

When the thermistor is at $0\text{ }^\circ\text{C}$ its resistance is much higher than $10\text{ k}\Omega$ and V_i is lower than the 2.5 V reference. The output is then 0 V and R_3 is effectively connected in parallel with the

$10\text{ k}\Omega$ resistor in Section A, with an overall resistance of $1/\left(\frac{1}{10} + \frac{1}{100}\right) = 9.1\text{ k}\Omega$.

The thermistor has a resistance of $9.1\text{ k}\Omega$ at about $42\text{ }^\circ\text{C}$.

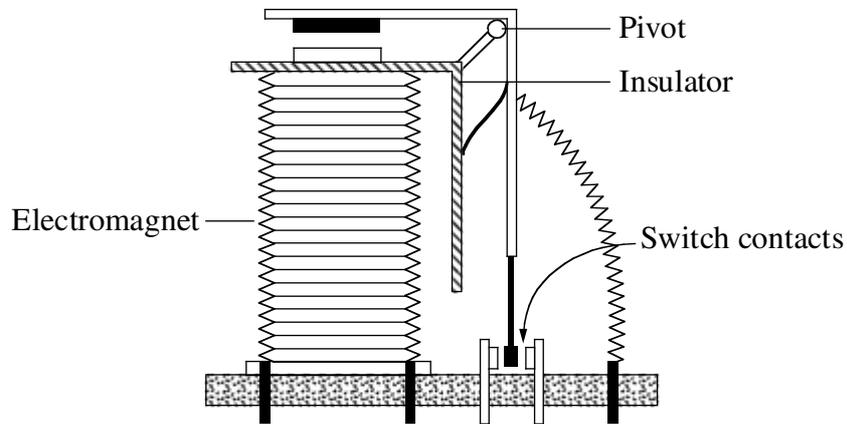
Thus, if the temperature starts at $0\text{ }^\circ\text{C}$ and increases, the output will be 0 V until the temperature reaches $42\text{ }^\circ\text{C}$ and the output becomes 5 V and remains at this voltage.



Question 37 (b)

Sample answer/Answers could include:

A relay contains an electromagnet, a pivot, switch contacts and insulator. When current flows through the electromagnet coil, the contacts are moved via the pivot and the connections are switched.


Question 37 (c)

Sample answer/Answers could include:

I_0	I_1	I_2	O_0
0	0	0	1
0	0	1	0
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	1
1	1	1	1

Question 37 (d) (i)***Sample answer/Answers could include:***

An input transducer measures a property of its environment and provides an electronic output.

Question 37 (d) (ii)***Sample answer/Answers could include:***

An LED emits light in response to an electrical signal thus it is an output transducer.

Question 37 (e)***Sample answer/Answers could include:***

- Developed in the late 1950s, combining multiple electronic devices on one piece semiconductor
- Successive rapid development has resulted in approximate doubling in transistor number/circuit performance/memory capacity every 18 months since then (Moore's Law).
- This rapid development in IC technology has underpinned the rapid development of electronics and electronic applications in general
- This rapid development enables new applications of ICs to be developed year on year, many of which have had significant impact on society, eg:
 - compact low-power radio communication technology (early radios through to current mobile phones and satellites) → local, regional, national and international communication is simple, inexpensive and available to all society, changing the way we interact with each other.
 - electronic/electro-optical network communications systems, eg internet → high-speed worldwide data communications have changed the way people communicate, trade and shop, disrupting old technologies (wired telephone/telegraph, physical shops etc)
 - handheld/lightweight calculators and computers (handheld calculators through to modern PCs and portable computers) → have changed how and where people perform work duties etc
 - guidance systems (GPS) → eased and optimised transport (sea/air/land) issues and led to the development of new technologies (location-specific information delivery).

Once it was established, maintaining this rapid development has required greater and greater scientific input. This had led now to a point where physics is limiting the performance of ICs and a reconceptualisation in the way that ICs and computers are designed is required.

In summary, the rapid development of IC technology has led to a rapid development in electronic technology, many applications of which have very significantly changed how society communicates, works, travels and plays.