BOARD OF STUDIES
NEW SOUTH WALES

2012 HSC Physics
'Sample Answers'

When examination committees develop questions for the examination, they may write 'sample answers' or, in the case of some questions, 'answers could include'. The committees do this to ensure that the questions will effectively assess students' knowledge and skills.

This material is also provided to the Supervisor of Marking, to give some guidance about the nature and scope of the responses the committee expected students would produce. How sample answers are used at marking centres varies. Sample answers may be used extensively and even modified at the marking centre OR they may be considered only briefly at the beginning of marking. In a few cases, the sample answers may not be used at all at marking.

The Board publishes this information to assist in understanding how the marking guidelines were implemented.

The 'sample answers' or similar advice contained in this document 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 (a)

Sample answer:

[Investigation could use different methods, including being based on a pendulum or timing a falling mass.]

A computer-based timing system should be set up using a sensor to measure how long it takes for a mass to fall to the ground from several heights between 0.5 m and 3.0 m. To increase reliability several readings for each height should be recorded. The results should be plotted on a time^2 vs height graph. The acceleration due to gravity is equal to 2 x the reciprocal of the slope of the line of best fit.

Question 21 (b)

Sample answer:

The known value (measured using more accurate equipment) should be looked up for my location, as published, for example, on the National Measurement Institute website and compared to the measured value. The closer the measured value is to the reference value, the more accurate it is.

Question 21 (c)

Sample answer:

The same measurement (using the same procedure) should be repeated at each height several more times. Statistically this would reduce the uncertainty in the average of all the results for each height.

Question 21 (d)

Sample answer:

The difference between each of the measurements and the average reading for each height the object was dropped from should be compared. If there is a large variation in the readings (relative to the average value) then the data is not very reliable.

Question 22 (a)

Sample answer:

The magnetic field around the bar magnet passes through the turns of the coil, resulting in a certain enclosed magnetic flux. An emf is induced when the coil is moved because the enclosed magnetic flux decreases as the coil is moved away from the magnet. Since the coil terminals are short-circuited, this emf will cause a current to flow.

Question 22 (b)

Sample answer:

As the coil is moved away, initially the reading on the balance becomes less and then it goes back to 42.42 g. The induced current in the coil that results from the change in flux produces a magnetic field that tends to maintain the flux through the solenoid. The field due to the induced current in the coil has a south pole at the bottom of the coil, resulting in a force of attraction on the magnet causing the force and, therefore the reading on the balance due to the bar magnet to decrease. As the coil is moved further away, the interaction between the magnet and the coil effectively disappears and the reading on the balance returns to 42.42 g.

Question 23

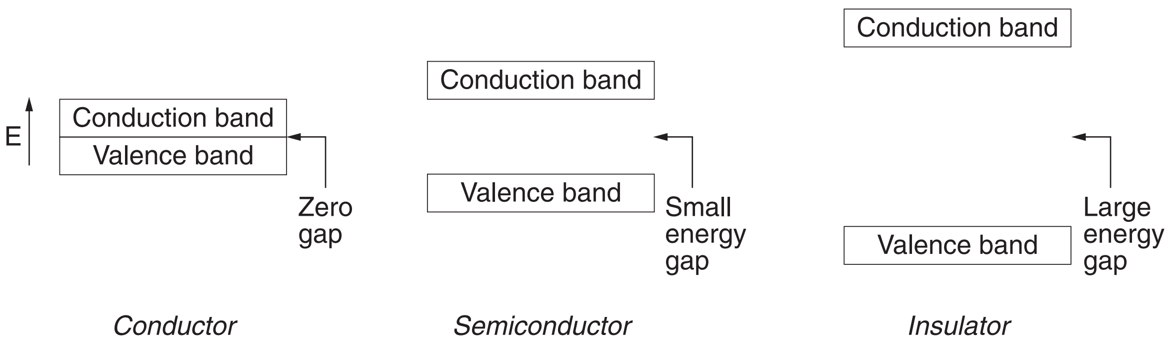
Sample answer:

The mass at the top of tower B is in geostationary orbit since it is at the correct height above Earth and travelling at the same rotational speed as Earth. Therefore, when it is released it will not fall and will not move relative to tower B.

In contrast, the mass at the top of tower A is not in geostationary orbit since it is sitting on the rotation axis of Earth and therefore has zero orbital velocity. This means that it will fall directly towards Earth. Since the mass starts out at such a high altitude, the acceleration due to gravity starts off lower and increases as the mass falls (approaching 9.8 m s^{-2} as it nears Earth's surface). This means that this mass falls with an increasing acceleration until it reaches the atmosphere.

Question 24 (a)

Sample answer:



Question 24 (b)

Sample answer:

At any temperature above absolute zero, some electrons in the valence band of a semiconductor are excited into the conduction band, creating a corresponding hole in the valence band.

An applied potential causes electrons in the conduction band to move in the opposite direction to the applied electric field and holes in the valence band to move in the direction of the electric field. This is a current.

Question 25 (a)

Sample answer:

Transistor circuits are smaller than thermionic devices and are less fragile as they are not made of glass.

Question 25 (b)

Sample answer:

Transistors have had a significant positive effect on society. The development of transistors led to the development of microchips that are used in a wide range of communication devices and technologies, such as satellites.

Microchips have led to the development of cheap and compact consumer products, such as mobile phones. This has made these devices accessible to large members of the population and enabled people to communicate flexibly throughout the day and from any location.

Microchips have been incorporated into computers to provide fast processing speeds and have revolutionised society through the near-instantaneous transfer of information via the internet. This has transformed the business world, allowing financial trading to be instantaneous, and has led to new and increased social interactions between people in society such as Facebook.

Satellites enable weather to be monitored and allow us to predict natural disasters so that people and property can be protected. The use of transistors in electronic devices has radically shaped society.

Question 26

Sample answer:

Design A
Power loss is (120 – 100) MW = 20 MW over the low-voltage transmission line

Design B
Voltage drop along power line, V = 8 kV
Power loss along power line, $P = V^2/R = 8000^2/40 = 1.6$ MW

Design C
Power use along transmission line = 100 km × 30 kW/km = 3 MW

Design B is the best way of transmitting power from the power station to the substation because it results in the least total power loss/use of the three processes.

Question 27

Sample answer:

$$u_x = u\cos 60° = \frac{u}{2}$$

$$u_y = u\sin 60° = \frac{\sqrt{3}u}{2}$$

$$45 = \left(u_x\right) t \Rightarrow t = \frac{45}{u_x} = \frac{90}{u}$$

$$\Delta y = \left(u_x\right)t - \frac{1}{2}at^2 = 34$$

$$\rightarrow 34 = \left(\frac{\sqrt{3}}{2}u\right)\left(\frac{90}{u}\right) - \frac{1}{2}(9.8)\left(\frac{90}{u}\right)^2$$

$$34 = 45\sqrt{3} - \frac{39690}{u^2}$$

$$\rightarrow u = \sqrt{\frac{39690}{45\sqrt{3} - 34}}$$

$$= 30m / s$$

Question 28 (a)

Sample answer:

The special theory of relativity predicted that a clock would run slower if it were moving relative to an observer. The GPS navigation system corrects for this slowing of the atomic clocks on satellites used in the system. This evidence supports the theory of relativity because if the theory were not correct, its application in this context would result in a system that did not work.

Question 28 (b)

Sample answer:

A theory is validated when it agrees with observations and is consistent with the results of scientific/controlled experiments designed to test specific aspects of the theory. Validation of a theory is complete when it can be used to make predictions that can be tested and demonstrated to be correct.

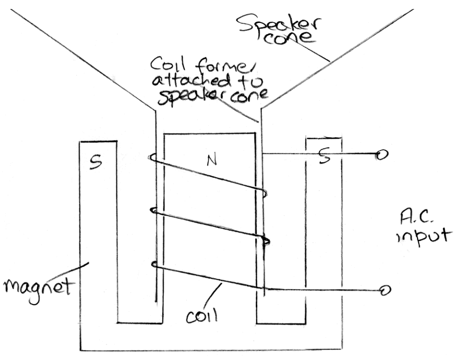
Question 28 (c)

Sample answer:

$l = l_0$ multiplied by the square root of $(1-v^2/c^2)$ = 40 cm × 0.994987 = 39.8 cm

Question 29

Sample answer:



When a current passes through the wire in the coil, a force is exerted on it because the current has a component perpendicular to the magnetic field direction – this is the motor effect. By passing AC through the coil, the force produced on the coil causes it to oscillate, moving the speaker cone correspondingly to produce sound waves. The pitch of the sound can be altered by changing the AC frequency and the volume of the sound can be increased by increasing the current through the coil.

Question 30 (a)

Sample answer:

The two charged particles have opposite charges.

Question 30 (b)

Sample answer:

The paths are circular because the force produced by the magnetic field on the moving charge is constant in magnitude and always perpendicular to the particles' velocities, and these are the conditions necessary for circular motion to be produced by a force.

Question 30 (c)

Sample answer:

The greater the mass of a particle travelling through a magnetic field, the greater the radius of curvature of its path, other variables being unchanged. The greater the charge of the particle, the smaller the radius of curvature of its path.

Section II

Question 31 – Geophysics

Question 31 (a)

Sample answer:

Cayenne is closer to the equator than the location where the period of the pendulum clock was calculated. Earth is not spherical, the equatorial diameter being greater than the polar diameter. Hence the force of gravity is less at the equator due to this effect, increasing the period of the pendulum in Richer's clock.

The rotation of the Earth on its axis produces a centripetal acceleration, which decreases the net force acting on the pendulum, which also acts to increase the period of the pendulum.

Question 31 (b) (i)

Sample answer:

Earth's magnetic field changes over time because it is the result of several interacting and changing components, including movement of charged particles in Earth's interior and movement of the Earth's crust, which contains magnetised materials as well as ocean currents and solar effects. Because all of these factors change with time, so does Earth's magnetic field.

Question 31 (b) (ii)

Sample answer:

This model is not consistent with observations of Earth's magnetic field and conventions used to represent magnetic fields, so the model is incorrect. The Earth's magnetic field is not aligned exactly with the axis of rotation as shown in the model. The model uses a large bar magnet, but temperatures inside the Earth are too high to allow for the existence of a permanently magnetised material such as iron. The model is incorrect because the polarity of the magnet producing the field lines is inconsistent with the direction of the lines of Earth's magnetic field, which themselves are in the correct direction in the model.

Question 31 (c) (i)

Sample answer:

The line C1 shows the time of arrival at successive geophones, at increasing distances from the shot, of the sound which has travelled along the surface of the Earth.

The curve C2 shows the time of arrival at successive geophones of sound energy reflected off a boundary between two layers of different rock material in the Earth's crust.

Question 31 (c) (ii)

Sample answer:

For both P waves and S waves, speed increases as the density of rocks increases and since density increases slightly with increasing pressure at greater depths, this is reflected in a general increase in each distinct section of the two graphs as depth increases.

S waves travelling through the solid outer layer of the Earth encounter a boundary and change in the nature of the solid crust at a depth of about 1000 km, resulting in a decrease in the gradient of the graph (the rate of change of velocity with depth). S waves, being transverse waves, cannot travel through liquids and so the graph for these waves ends at a depth of 3000 km, the beginning of the liquid core of the Earth.

The P waves' behaviour changes at a depth of 1000 km for the same reason as did the S waves. P waves can travel through liquids because they are longitudinal waves. At approximately 3000 km, the velocity of P waves decreases dramatically because the elastic properties of the liquid core are so different from the elastic properties of the solid layers above. However at depths greater than 3000 km, the velocity of P waves continues to increase due to the increase in pressure with depth.

Question 31 (d) (i)

Sample answer:

The symmetry of the pattern of magnetic anomalies is evidence that the crust is moving away from the mid-ocean ridges on both sides of the ridge and that new crust is forming from molten rock originating beneath the ridge.

The existence of these boundaries where spreading is taking place provides key evidence for the plate tectonic theory.

The age of the rocks in each magnetically homogeneous region can be determined using dating methods based on radioactive isotopes. This reveals a symmetrical pattern of magnetic anomalies on either side of the mid-ocean ridge, which is consistent with the production of new crust at the mid-ocean ridge boundary.

Question 31 (d) (ii)

Sample answer:

The GPS satellite network continually transmits radio waves to ground-based receivers. Each receiver can use this signal to precisely measure the latitude, longitude and altitude of the receiver. Repeated measurements over time by receivers placed on different plates provides evidence that the plates are moving in the directions predicted by plate tectonic theory.

Question 31 (e)

Sample answer:

Remote sensing refers to the gathering of data about the Earth, based on measurements taken from a distance away from it through the use of technologies on board satellites or aircraft. Data is derived from measurements taken using sensors that detect electromagnetic radiation, magnetism and the effects of gravity.

Electromagnetic radiation in the near-IR and IR regions that is emitted from the land or water, can be used to deduce variations in temperature of these surfaces because differences in temperature produce differences in the emitted near-IR and IR wavelengths. Visible light reflected from the Earth can be used to make inferences about rocks, soils, pollution and the density and nature of vegetation on the Earth. The latter is possible because different plants reflect different wavelengths of the em spectrum. Monitoring vegetation is important in making measurements to predict crop yields, detect diseases and measure vegetation changes due to land use and climate changes.

Magnetic measurements made remotely can be used to make inferences about the existence of minerals. These are carried out using magnetometers and sensitive quantum devices called SQUIDS. These can be on board a satellite or plane, and are also sometimes trailed behind a plane to minimise interference.

Gravity measurements can be deduced from orbital changes of satellites. Other types of remote sensing detectors can measure radiation, such as gamma radiation, originating from radioactive isotopes in the Earth’s crust. Different isotopes produce different spectra, allowing identification of their sources.

Question 32 – Medical Physics

Question 32 (a) (i)

Sample answer:

The production of a CAT scan requires the processing of large amounts of data using complex mathematical algorithms. The processing of the data requires the use of computers, which were not cheap enough nor commonplace enough to use prior to the development of microchip-based computers in the 1970s.

Question 32 (a) (ii)

Sample answer:

A PET scan provides information about the chemical/metabolic processes taking place in a tissue whereas a CAT scan provides structural information.

Question 32 (a) (iii)

Sample answer:

In PET, positron-electron annihlation produces two gamma rays travelling in opposite directions, whereas CAT uses X-rays that are produced when electrons are accelerated in a cathode ray tube. Their energy is converted to X-rays when they collide with heavy metal atoms in a target electrode and decelerate.

Question 32 (b) (i)

Sample answer:

Energy is absorbed by the precessing hydrogen nuclei from the Larmor frequency radio waves, which flips some of the hydrogen nuclei to a higher energy level.

Question 32 (b) (ii)

Sample answer:

The strong magnetic field used to align hydrogen nuclei for MRI is produced by superconducting electromagnets. Without developing an understanding of superconductivity in the 20th century, it would not be possible to create magnetic fields strong enough for use in MRI imaging.

Large amounts of data have to be processed to produce an MRI image from the raw data. Without the development of computers based on an understanding of the physics of semiconductors, it would not be possible to analyse the data to produce the images.

Question 32 (c)

Answers could include:

To be medically useful, radioactive isotopes must have a half-life that is long enough to allow them to accumulate in the target organ, so that an image can be produced, yet short enough so that the exposure of the person to radioactivity is minimised to reduce harm to the patient. For example Tc-99m that has a half life of 6 hours is used in bone scans.

Radioisotopes must also emit appropriate types of radiation, eg technetium-99m produces gamma radiation. Alpha and beta particles do not penetrate the body and are unsuitable for use as medical radioisotopes. But gamma rays do penetrate the outside the body and can be used for imaging.

Question 32 (d)

Sample answer:

An endoscope uses optical fibre technology to both illuminate and image internal organs through a long narrow instrument. An incoherent or unordered bundle of small optical fibres can be used to transmit light to the end of the endoscope since no image is being formed and the arrangement of fibres doesn’t matter. An ordered/coherent bundle of small optical fibres then used to transmit the image from the end of the endoscope back to the user since the fibre bundle must maintain the image for viewing. The small optical fibres in either type of bundle use total internal reflection to transmit light from one end to the other.

Question 32 (e)

Sample answer:

Ultrasound can be used to produce images that show the location and size of different tissues, including soft tissues and organs in the body. It can also be used to identify tumours in tissues, because they have a different acoustic impedance from the normal tissue. Ultrasound is used to produce images of the development of a foetus, which can be used to help determine whether its development is normal.

Ultrasound can be used to measure bone density by passing it through a bone, such as the heel bone. Diseased bone absorbs sound differently from healthy bone, so differences in absorption can be used to diagnose bone disease, such as osteoporosis.

Doppler ultrasound is used to produce images showing movement in the body and this is useful in measuring blood flow in large vessels and in the heart. Doppler ultrasound can be used to diagnose heart disorders such as faulty valves.

The wavelength of the ultrasound used is long, compared to electromagnetic waves, and this limits the resolution of ultrasound images. The weakness of the reflected ultrasound as well as the complex effects resulting from reflection at irregular tissue boundaries and refraction of the ultrasound also limits the quality of the image produced.

Ultrasound is strongly reflected by bone, so it cannot be used to produce images of parts of the body which lie behind bone, such as the adult brain.

Question 33 – Astrophysics

Question 33 (a) (i)

Sample answer:

Apparent measurements are actual observations made, while absolute measurements are calculated at a standard distance. Their use allows stars to be compared in terms of their intrinsic brightness or other characteristics.

Question 33 (a) (ii)

Sample answer:

Photometric measurements can be made directly using the light from stars whereas spectroscopic data is obtained by filtering or splitting the light from stars and making observations or measurements at different wavelengths.

The earliest data about stars was gathered using the human eye, later with the aid of a telescope. This was replaced by photography then by photoelectric devices including photomultiplier tubes, photodiodes and CCDs.

Filters were initially used to obtain spectroscopic data about stars. The brightness of stars was initially measured at filtered UV, blue and green wavelengths. Later, red and infrared bands were included.

Prisms were first used to split starlight into a spectrum that could be analysed. Later, diffraction gratings replaced prisms for this purpose.

Question 33 (b) (i)

Sample answer:

The resolution of images produced by ground-based optical astronomy is limited by the diameter of the mirror (or lens) of the telescope. Resolution increases with diameter, but technical and engineering limitations exist in creating large mirrors with sufficiently accurate dimensions that are unaffected by their environment, eg temperature variations. Resolution is also limited by atmospheric disturbances.

Question 33 (b) (ii)

Sample answer:

The atmospheric effects that limit the resolution of optical telescopes are reduced by locating optical telescopes at high altitude, so there is less air above the telescope, and in places where the atmosphere is colder and therefore more stable. Optical telescopes are housed in buildings with interior temperatures the same as the outside temperature to minimise distortions of thermal origin, such as the mirror expanding or convection in the air. Modern telescopes use flexible mirrors controlled by servomechanisms to correct for atmospheric distortion and therefore improve their resolution. This is called adaptive optics. The resolution can also be improved by using a larger diameter mirror.

Question 33 (c) (i)

Sample answer:

Main sequence star → Red giant → Planetary nebula → White dwarf
Star > 3 solar masses → Supernova → Neutron star
Star > 5 solar masses → Supernova → Black hole

Question 33 (c) (ii)

Sample answer:

Hydrogen is the most abundant element in most stars and in the universe. Hydrogen fusion occurs in stars having masses up to that of the Sun through the proton–proton chain to produce helium.

In heavier main sequence stars, the CNO cycle takes over. Helium burning results in elements up to iron being produced in stars. In this process, helium nuclei are fused with other nuclei to form heavier elements, eg carbon + helium → oxygen.

Elements heavier than iron are produced in supernovae under conditions of extreme temperature and density of nuclei.

Question 33 (d) (i)

Sample answer:

The position of a nearby star relative to the fixed background of relatively distant stars is measured and this is repeated 6 months later when Earth is at the opposite side of its orbit around the Sun. The change in angular position of the near star is called parallax and the angular change, 2p, is related to the distance to the nearby star by $d = 1/p$, where the distance is in parsecs and the parallax angle p is in arcseconds. (a diagram may be used to clarify the process)

Question 33 (d) (ii)

Sample answer:

Most stars are too distant to show any measurable angular shift due to the Earth's orbital motion and so parallax cannot be measured and used to calculate distance.

Question 33 (e)

Sample answer:

Star A is a yellow main sequence star in the middle of its life, predominantly H-burning at a temperature of approximately 7000 K.

Star B is a white dwarf at the end of its life in which minimal fusion reactions occur. It has a temperature of approximately 9000 K.

Together they form a visual binary system in which one moves in front of the other reducing the total amount of light visible, thereby reducing brightness. The time for one full cycle of this is 40 years.

For Star A, from the H-R diagram, the absolute magnitude M is +2.5.

Using the distance modulus formula:
$M = m - 5 \log (d/10)$
$2.5 = 0.35 - 5 \log (d/10)$
$d = 3.7$ pc

Therefore, the distance of the system from Earth is 3.7 parsecs.

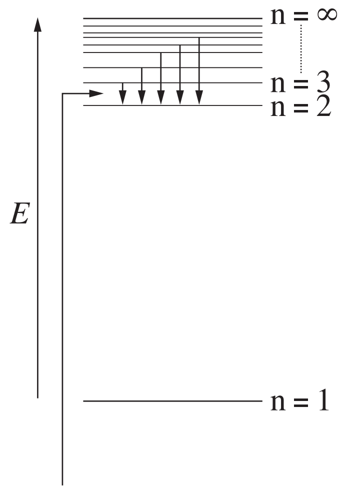
Using $m1 + m2 = (4 \pi^2 r^3)/(G T^2)$
$= (4 \pi^2 (2.2 \times 10^9)^3)/((6.67 \times 10^{-11}) (40 \times 365.25 \times 24 \times 60 \times 60)^2)$
$= 1.59 \text{ x } 10^{30}$ kg

So, the combined mass of the system is 3.95×10^{30} kg.

Question 34 – From Quanta to Quarks

Question 34 (a) (i)

Sample answer:



The arrows indicate the electron transitions from n > 2 to n = 2 levels. The energy change here gives the characteristic wavelength of each time in the Balmer series via $E = hf = \frac{hc}{\lambda}$

Bohr postulated that the electronic levels of the hydrogen atom (labelled n = 1, 2, 3…) are characterised by quantized angular momentum values (l = 0,1…, n-1) in turn resulting in quantized energy values. He explained the Balmer series as electronic transitions between n > 2 and n = 2 levels. The diagram shows that, as an electron moves from a high n level to the lower n = 2 level, the change in energy is emitted as a photon. Since the levels have certain fixed values, the wavelengths of the photons that are emitted are also fixed.

Question 34 (a) (ii)

Sample answer:

Although the R-B model explained the hydrogen emission spectrum very well it could not explain the wavelengths/photon energies of the light emitted by heavier elements.

It was also observed that the wavelengths/photon energies of the light emitted by hydrogen and other elements could be influenced by an external magnetic field – this is called the Zeeman effect. The R-B model of the atom could not explain this effect.

Question 34 (b) (i)

Sample answer:

Three key conditions are required to produce an uncontrolled nuclear reaction:

1. A block of an isotope with nuclei that spontaneously fission when they absorb a neutron
2. Each fission reaction should produce, on average, more than 1 free neutron per fission
3. The shape of the block of isotope and the kinetic energy of the released neutrons should be such that, on average, more than one fission occurs per previous fission event

Question 34 (b) (ii)

Sample answer:

Natural radioactivity occurs when the total mass of the daughter nucleus and emitted particles is less than that of the parent nucleus → the difference in mass is converted into the kinetic energy of the products.

Question 34 (c)

Sample answer:

Based on the work of de Broglie we know that a beam of neutrons with a known kinetic energy and hence momentum, has a certain characteristic wavelength. This wave character means that the regular repeating lattice of the nuclei in the metal crystal will diffract the neutron beam. Because the neutrons are neutral they are not affected by the electrons in the crystal and only scatter from the nuclei.

Question 34 (d) (i)

Sample answer:

The proton contains three quarks, two up and one down. The neutron also contains three quarks, two down and one up. The mass of the up and down quarks is very similar, which means that the total masses of the proton and neutron are very similar. The electronic charges of the up and down quark are +2/3 e and –1/3 e respectively. The combination of up and down quarks in the proton leads to a +1 charge, whereas in the neutron this leads to 0 net charge.

Question 34 (d) (ii)

Sample answer:

Scientists use particle accelerators to accelerate electrons (charged particles) at very high energies before crashing them into a target. Using information about the spread and direction of the scattered particles they can deduce information about the matter.

Question 34 (e)

Sample answer:

Conservation laws have played a key role in the development of many ideas in atomic physics:

- The ideas of the conservation of momentum and energy were essential to the development of Bohr's model of the atom: he used the conservation of energy to explain how the atomic emission lines of hydrogen are generated.
- The conservation of mass–energy allows us to understand why radioactive decay occurs and to also understand the stability of the nuclei.
- Chadwick inferred the existence of the neutron by studying the 'visible' components of nuclear reactions and using the conservation of momentum to determine what was not 'visible' in his experiments.
- Likewise, Pauli used the conservation of mass–energy to infer the existence of the neutrino in beta decay processes.

Thus, the use of conservation laws has been critical to many key discoveries in atomic physics and even today the ideas of conservation of momentum and mass–energy are used to understand the results from experiments such as the Large Hadron Collider.

Question 35 – The Age of Silicon

Question 35 (a) (i)

Sample answer:

The diagram shows an electronic circuit. This can be understood because its operation principally relies on the use of voltages and currents to represent signals rather than to transfer power.

Question 35 (a) (ii)

Sample answer:

The thermistor is an input transducer since it measures an external property. R2 is an output transducer since it is used to heat the metal block thereby affecting its environment.

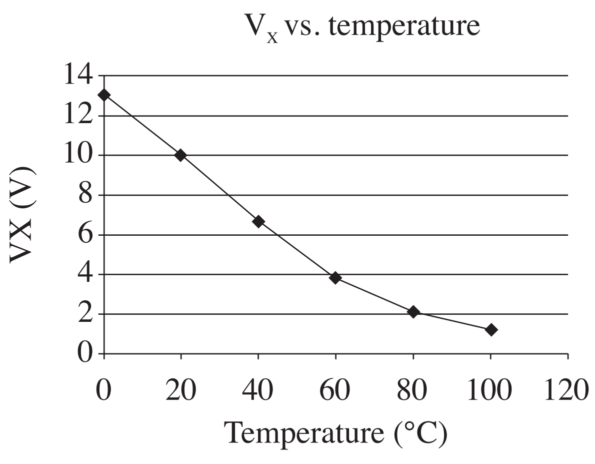
Question 35 (a) (iii)

Sample answer:

R1 (12 kΩ) and the thermistor form a potential divider circuit (we can assume that the input resistance of the opamp is infinite).

So, at a temperature T the potential at X is:
$V_X = (15\text{ V})[(R_{thermistor})/(R_{thermistor} + 12 \times 10^3\,\Omega)]$

So, at T = 0 ºC $V_X = 13.0$ V
T = 40 ºC $V_X = 6.63$ V
T = 80 ºC $V_X = 2.14$ V



Question 35 (a) (iv)

Sample answer:

The opamp circuit in Section A is set up in a closed-loop configuration with R4 supplying negative feedback. Overall the circuit amplifies the difference between the voltages present as the inverting and non-inverting inputs, taking into account the current fed from the output to the inverting input via R4. The resulting operation of the circuit means that the opamp amplifies the difference in voltage between V_X (from the thermistor voltage divider) and the fixed reference divider, with the negative feedback reducing the effective gain of the opamp circuit.

Question 35 (a) (v)

Sample answer:

Neglecting the effect of R4 initially, we see that the amplifier will apply a voltage to R5 until Vx exceeds the reference voltage provided by the fixed voltage divider or R3 and R2. At this point the output will go to zero. The effect of the negative feedback (R4) is to reduce the gain of the amplifier, leading to a slower change in output voltage with increasing Vx near the threshold.

The reference voltage from R2 & R3 is:

V_{ref} = (15 V)[(R2)/(R3 + R3)] = (15 V) (1/3) = 5 V

Vx will be 5V when $R_{thermistor}$ = 0.5 x R1 = 6.0 kΩ
Looking at the provided plot, this occurs when T ~ 45 ºC

Question 35 (b)

Sample answer:

A relay should be used when there is a need to switch a large current infrequency since relays are slow but can switch very large currents. Conversely, a large transistor should be used to switch large currents when they need to be switched at high frequencies.

Question 35 (c)

Sample answer:

I_0	I_1	I_2	0_0
0	0	0	0
1	0	0	1
0	1	0	1
1	1	0	1
0	0	1	0
1	0	1	0
0	1	1	0
1	1	1	0

Question 35 (d)

Sample answer:

The development of modern electronics has been strongly influenced by both our understanding of the properties of materials and the development of complex manufacturing techniques.

The obvious example is the integrated circuit. As our understanding of semiconductor material properties (eg Si, GaAs, including doping) has increased, we have been able to design faster, smaller and lower-powered integrated circuits. However, these advances would not have been possible without the ability to construct these tiny and intricate devices reliably. This has been made possible by the development of the complex manufacturing techniques (vacuum systems, industrial robots, ion implanting, clean rooms etc) that are used in the huge and complex integrated circuit fabrication facilities used today.

The integrated circuit is not the only place this relationship exists. The construction of modern electronics requires all of the electronic parts (including passive devices) in a circuit to be extremely small but still have the functionality and accuracy of the much larger electronic parts of a decade or more ago. For example, this requires new materials (dielectrics metals etc) to construct physically tiny but high capacitance and stable capacitors, which must also be constructed extremely accurately (using complex manufacturing techniques such as thin film deposition) in order to maintain the accuracy of their value. Even the circuit boards, plastics cases and coated-glass touch screens used to make modern electronics have advanced greatly through a better understanding and manipulation of their material properties.

So, we see that the advancement of modern electronics is strongly related to advances in understanding and the manipulation of the properties of materials and also to our ability to use these materials in increasingly complex manufacturing systems.