

**B O A R D O F S T U D I E S**  
N E W S O U T H W A L E S

## **2011 Physics HSC Examination '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.

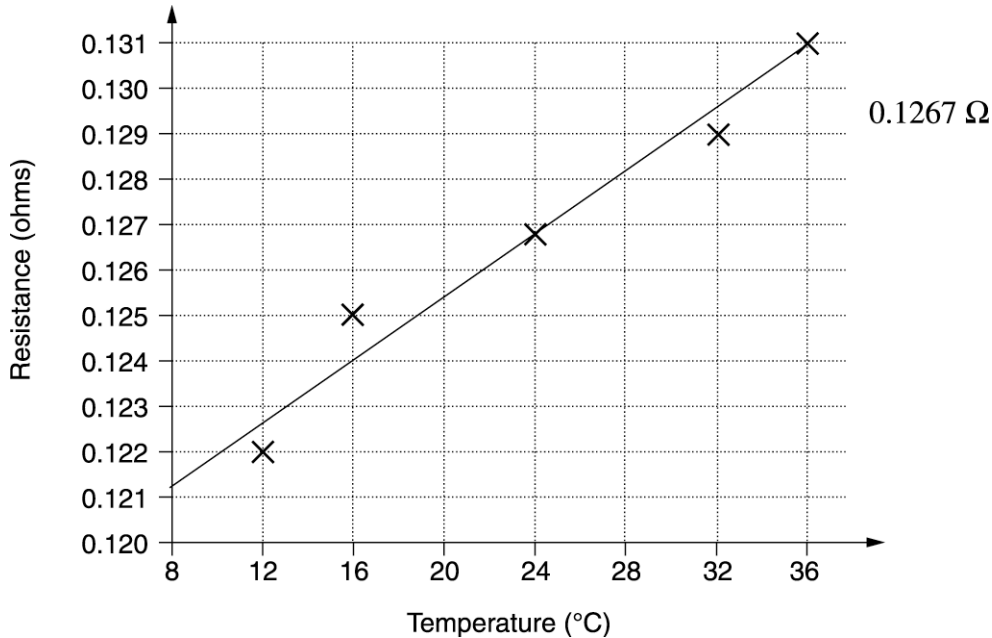
The 'sample answers' or similar advice contained in this document are not intended to be exemplary or even complete answers or responses. As they are part of the examination committee's 'working document', they may contain typographical errors, omissions, or only some of the possible correct answers.

## Section I

### Part B

#### Question 21 (a)

*Sample answer:*



#### Question 21 (b)

*Sample answer:*

This would not be valid, as  $-100^{\circ}\text{C}$  is outside the range for which the model is appropriate. Even if the model were still true at these lower temperatures, if the existing data were used the result would be imprecise, as small inconsistencies in the slope would be magnified by the process of extrapolation.

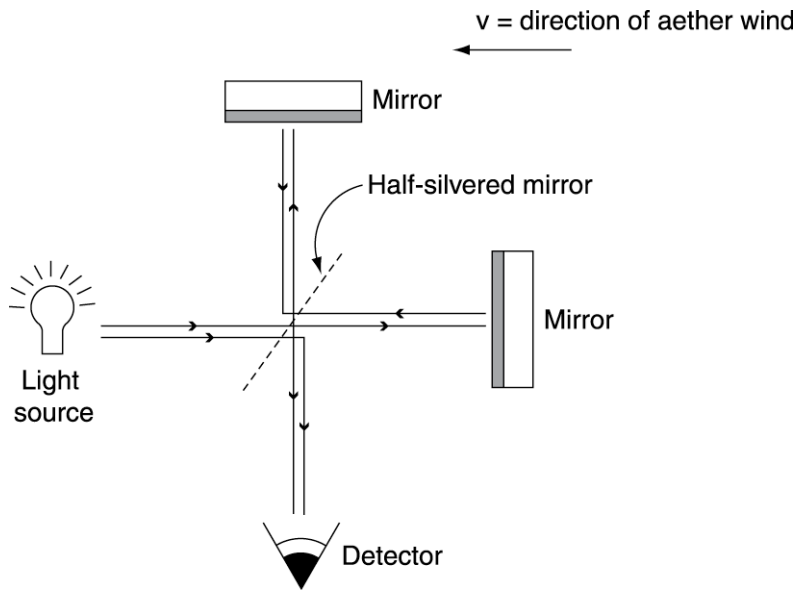
#### Question 22 (a)

*Sample answer:*

Michelson and Morley were attempting to measure the velocity of Earth through the luminiferous aether.

**Question 22 (b)**

*Sample answer:*



The apparatus was mounted on a table that could be rotated. The experiment was repeated after the table was rotated  $90^\circ$ .

**Question 23 (a)**

*Sample answer:*

The gravitational field strength is less, due to an increase in altitude, ie  $W = m g$ .

**Question 23 (b)**

*Sample answer:*

$$\frac{m_s v^2}{r} = \frac{G m_s m_E}{r^2} \therefore v = \sqrt{\frac{G m_E}{r}} = \sqrt{\frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{6.73 \times 10^6}} = 7692 \text{ m.s}^{-1}$$

**Question 23 (c)**

*Sample answer:*

The speed of the satellite will increase as the gravitational potential energy is converted to kinetic energy.

The period of the orbit will be reduced, following Kepler's law that  $\frac{r^3}{T^2}$  is a constant.

**Question 24****Sample answer:**

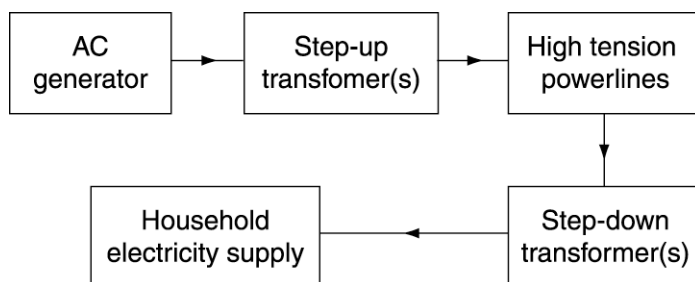
Because the speed of light is constant in all inertial reference frames and is independent of the relative speed of the source and the observer, both the scientist and the observer see the light beam moving towards each of the clocks at the same speed. The different results in their observations are caused by the relativity of simultaneity.

The Earth observer in their inertial frame of reference sees clock A as moving towards the original source of light, hence decreasing the distance the light has to travel, relative to the distance to clock B, which is moving away from the original position of the light. As a result, they see the light arriving at clock A first.

In the scientist's inertial reference frame, the light source is equidistant from the fixed clocks. Therefore, when the light pulse travels from the source to the detectors, it takes an equal time to reach each and the clocks are synchronised.

**Question 25****Sample answer:**

As the magnets fall, they will produce a changing magnetic flux in the walls of both tubes. Lenz's Law says that this will set up a current (eddy current) that will produce a magnetic field to try to oppose this change. This is possible for the magnet A tube, since the eddy current can flow around the complete circumference. This results in a strong braking force on the magnet. For the slotted tube, the eddy currents cannot flow because the slots break the current path and no braking results. This means that magnet B will fall faster and reach the end of the tube first.

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

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

A positive impact of AC generators on the environment is that electrical power is a much more efficient energy source for people than, say, burning timber in a fireplace in a house. Burning timber as a way of generating heat for cooking and for heating a house is very inefficient and produces large quantities of greenhouse gases, as well as health problems for people in the house when they inhale the smoke.

When compared to DC generation, AC generators can be used in conjunction with step-up and step-down transformers to transfer electrical power over greater distances, allowing for generation to take place near the source of energy (coal deposits or dammed water), thus negating the need for many local DC power generator plants and reducing the overall impact on the environment.

However, the efficiencies gained in using AC power generation have resulted in a huge dependence on this form of energy. Consequently, the use of fossil fuels (coal in particular) has increased greatly, leading to AC power generators being a major contributor to CO<sub>2</sub> emissions that are linked to the greenhouse effect and global warming, resulting in effects such as climate change, melting of the ice caps, and sea level rise.

Another negative aspect of AC generators is that the ease of access to energy results in a large amount of waste, eg air conditioners being left on accidentally. As a result, the greenhouse gas emissions from AC generators are considerably higher than they need to be.

**Question 27 (a)****Sample answer:**

$$F = B I \ell$$

$$B = 0.2 \text{ T}$$

$$I = 10.0 \text{ A}$$

$$\ell = 5 \text{ cm} = 5 \times 10^{-2} \text{ m}$$

$$\therefore F = 0.2 \times 10 \times 0.05 \text{ Newtons}$$

$$= 0.1 \text{ Newtons}$$

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

Because of the opposing direction of currents in sides AB and CD, the forces on the two sides are equal and opposite.

The same is true for the pair of sides AD and BC,  $\therefore$  the net force on the coil is zero.

**Question 28 (a)****Sample answer:**

If a bar magnet is brought near a cathode ray beam, the beam will deflect in a way that can only be explained by the hypothesis that cathode rays are composed of a stream of negatively charged particles.

**Question 28 (b)****Sample answer:**

The electrons are initially 'boiled' off a heated cathode and then accelerated towards the anode. The beam is then collimated by an arrangement of electric fields, which focus the beam tightly.

**Question 29 (a)****Sample answer:**

$$E = \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34} \times 3.00 \times 10^8}{450 \times 10^{-9}}$$
$$= 4.42 \times 10^{-19}$$

$$\text{Number of photons} = \frac{1 \times 10^{-3}}{4.42 \times 10^{-19}}$$
$$= 2.26 \times 10^{15}$$

**Question 29 (b)****Sample answer:**

The energy of red light photons is far lower than the energy of blue light photons. Hence, the 1 W blue beam has fewer photons per second passing through it than the 1 W red beam.

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

Because there are more lattice vibrations at 60 K, there is a greater chance of the electrons hitting the lattice,  $\therefore$  losing energy, and hence the sample has a higher resistance.

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

At 18 K the metal has reached its critical temperature where lattice vibrations are such that when electrons travel past positively charged ions in the lattice, the lattice distorts slightly. This distortion of the lattice is associated with phonons being emitted. The result is the formation of an effective net positive charge. A second electron is attracted to the effective net positive charge, forming Cooper pairs, which are able to pass through the lattice unimpeded.

## Section II

### Question 31 (a)

*Sample answer:*

Earthquakes can lead to tsunamis. Seismic monitoring networks can predict the time of arrival of tsunamis at various coastlines, hence giving people in affected areas time to evacuate. These networks use instruments such as seismometers to detect vibrations of the solid components of Earth's surface.

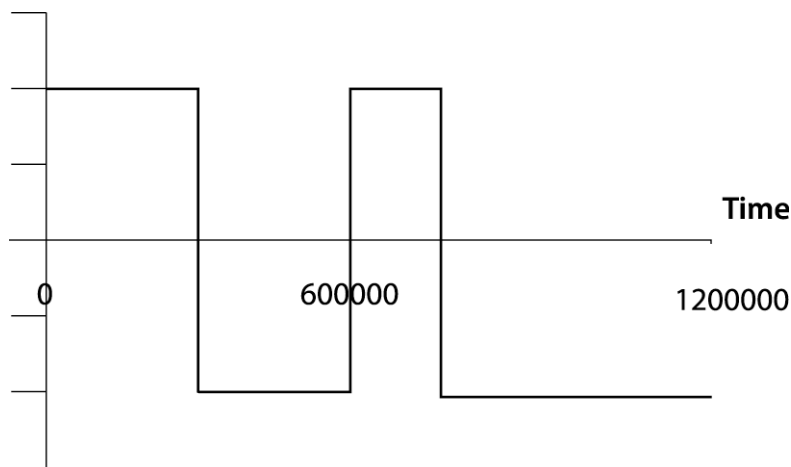
### Question 31 (b) (i)

*Sample answer:*

Magnetic anomaly profiles indicate regions of crust below the sea that formed with differing magnetic polarities. These differing regions can be dated using radiometric methods. The dating information can be linked with the spatial separation of these regions to determine the role of spreading.

### Question 31 (b) (ii)

*Sample answer:*



### Question 31 (c) (i)

*Sample answer:*

We used two different wavelengths of light to illuminate various strips of cardboard of different colours. We observed that some strips of different coloured cardboard were readily distinguishable when illuminated by one wavelength, but not by the other. This illustrates how different surfaces have different absorption or reflection properties.

**Question 31 (c) (ii)****Sample answer:**

After a bushfire, some areas will have vegetation grow back. The reflectivity of the areas will be different from those where the vegetation has not grown back. Observations in visible light by sensors on orbiting satellites can observe these areas and can be used to determine the extent of the regrowth as it progresses.

**Question 31 (d) (i)****Sample answer:**

At different latitudes there will be different linear velocities of the surface due to rotation, which will lead to a small change in the apparent  $g$  value. Of greater impact will be the non-spherical shape of Earth. At lower latitudes we will be further from the centre of Earth, hence the value of  $g$  will be lower than it is at the poles.

**Question 31 (d) (ii)****Sample answer:**

Gravity surveys provide information about how the local gravitational field differs from that expected after correcting for latitude, altitude and the presence of rocks above the level of the geoid.

Resource deposits may have densities that differ significantly from the average density of Earth's surface. Therefore, the value of the field revealed in the survey will differ from the expected value.

If the field is higher than expected, there may be a high-density deposit such as iron ore or copper. If the field is lower, it may indicate the presence of a low-density deposit such as oil or gas.

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

The two main types of seismic waves are P waves and S waves. P waves are longitudinal or compression waves. These can travel through both solids and liquids. S waves are shear waves. These are transverse waves and cannot travel through liquids. P waves travel faster than S waves.

Earth has a solid crust and mantle surrounding an outer core, which is liquid. Inside the outer core is an inner solid core.

The speed for a given type of wave varies with the density and temperature of the material it travels through. By observing the times at which the different waves arrive at a surface network of seismometers after there has been an earthquake, we can deduce information about the path followed and the temperature and density of the material encountered along that path.

In particular, when an earthquake occurs at some point of the surface there will be locations on the other side of the planet where no S waves arrive. This is due to the presence of the liquid outer core. At angles less than  $104^\circ$  from the epicentre, there will also be a P wave shadow zone due to refraction of the P waves at the boundary between the mantle and the outer core. Within the P wave shadow zone will be some weak P waves. This is due to refraction at the boundary between the liquid outer core and the solid inner core.



**Question 32 (a) (i)****Sample answer:**

This is an A scan. It provides information on the distance between different tissues in the body.

**Question 32 (a) (ii)****Sample answer:**

The proportion of the ultrasound reflected at a boundary is determined by the difference in acoustic impedance of the tissues. Since bone has a much higher acoustic impedance than soft tissue, at *Y* it will reflect more ultrasound than it does at the soft tissue interface at *X*.

**Question 32 (a) (iii)****Sample answer:**

$$\frac{I_r}{I_o} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2} \quad Z_1 = 1.56 \times 10^6 \text{ kg m}^2 \text{ s}^{-1}$$
$$Z_2 = 1.04 \times 10^3 \text{ kg m}^{-3} \times 1580 \text{ ms}^{-1}$$
$$= 1.64 \times 10^6 \text{ kg m}^2 \text{ s}^{-1}$$
$$= \frac{(1.64 - 1.56)^2}{(1.64 + 1.56)^2} = \left( \frac{0.08}{3.2} \right)^2 = \frac{1}{1600} = 0.06\%$$

**Question 32 (b) (i)****Sample answer:**

X-rays are produced by converting the kinetic energy of fast-moving electrons into EM radiation. When the electrons meet the metal target in the X-ray tube, they decelerate, producing X-rays. This occurs in two ways:

- braking (Bremsstrahlung) radiation, which is produced by slowing the electron down
- characteristic radiation, which occurs when an electron from the inner shell of the tungsten atom is knocked out by the approaching electron. An outer shell electron takes the place of the inner shell electrons, producing an X-ray photon of a particular frequency.

**Question 32 (b) (ii)****Sample answer:**

Photograph *A* shows a two-dimensional image of a three-dimensional structure, whereas photograph *B* shows a two-dimensional slice through the body.

Photograph *B* provides information about soft tissue, whereas photograph *A* does not. Both photographs *A* and *B* show the structure of the bones of the ribs.

**Question 32 (c)****Sample answer:**

A brain tumour is a region of high metabolic activity due to the rapid cell division. As a result, there is more water (hydrogen nuclei) than in the surrounding brain tissue. MRI scans are a map of hydrogen (proton) density and therefore a brain tumour will show as a brighter spot. MRIs are therefore an effective tool for distinguishing brain tumours from surrounding tissues.

**Question 32 (d)****Sample answer:**

To observe internal organs using an endoscope, both a light source and a means of transmitting an image are required.

An incoherent bundle of optical fibres is not arranged in any specific order and is used to transmit light into the body. The fibres in a coherent bundle have fixed positions and can therefore transmit an image.

**Question 32 (e)****Sample answer:**

Research into radioactive isotopes has identified a number of important properties, including half-life, gamma rays and functioning, that have led to the development of medical technologies such as bone scans and PET scans.

Both of those technologies produce images of body function from gamma rays detected by gamma ray cameras. Radioisotopes, which produce gamma rays, are used because gamma rays can penetrate out of the body without causing ionisation of molecules in cells. The gamma rays are emitted from radioisotopes with an appropriate half-life. The half-life must be long enough for the radioisotope to be metabolised, but not so long that body tissue may be damaged (6–8 hours is ideal).

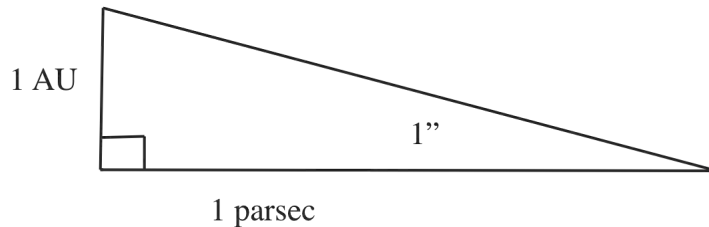
Bone scans rely on radioisotopes, such as technetium-99m, which emit gamma rays and which allow the production of a scan of the metabolic activity of the region. Hotspots indicate a higher uptake of the isotope and are frequently associated with diseases such as bone tumours and with stress fractures.

An understanding of the production of positrons by certain isotopes (eg fluorine-18) and their matter-antimatter annihilation with electrons to produce a pair of gamma ray photons is the basis of a PET scan. PET scans using F-18 are very important in scanning the brain. FDG contains F-18 and the body treats FDG like glucose. The brain uses a lot of glucose and hence FDG can be used to show the functioning of the brain.

Increased understanding of the properties discussed above has therefore resulted in the development of important technologies that provide information about bodily processes and improve the detection of disease.

**Question 33 (a) (i)**
**Sample answer:**

A parsec is the distance from the Sun to an astronomical object at a distance such that the (mean) orbital radius of Earth (1 AU) subtends an angle of 1'' of arc (arcsec).


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

The sensitivity of a telescope relates to its light-gathering power. As Galileo was viewing the Moon, which is bright when viewed from Earth, sensitivity was not important. Resolution was important, as higher resolution allowed more details to be seen. The higher the resolution, the more convincing the features would be. This would show that the heavenly objects did not have to be perfect, as had been believed.

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

Resolution can be improved using interferometry, a method of gathering and combining the light from more than one telescope to obtain greater detail. Computers allow the combination of light to be achieved accurately.

**Question 33 (b) (i)**
**Sample answer:**

The net fusion reaction of stars at both W and Z converts 4 hydrogen nuclei into 1 helium-4 nucleus. The predominant reaction in star W is the CNO-cycle, a process that proceeds far more rapidly than the proton-proton chain reaction, which predominates in star Z.

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

$$M = m - 5 \log_{10} \left( \frac{d}{10} \right) \quad M = -2; d = 135 \text{ pc} \quad \therefore -2 = m - 5 \log_{10} \left( \frac{135}{10} \right) \quad \therefore m = 3.65$$

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

$$\frac{I_A}{I_B} = 100^{\left(\frac{M_B - M_A}{5}\right)} \quad \therefore \frac{I_A}{I_B} = 100^{\left(\frac{6 - -2}{5}\right)} = 1585 \quad \text{A star at W is 1600 times brighter than a star at Z.}$$

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

A Cepheid is a variable star that changes in brightness due to the periodic expansion and contraction of its surface layers, as it is not in equilibrium. Cepheids vary their light output, hence their brightness, by some change within the star itself. As this is a physical change within the star, it is classified as an intrinsic variable. Eclipsing binary stars are variable stars whose light curves change periodically when one of the stars within the system eclipses the other. Extrinsic variables are those in which the light output varies due to processes external to the star itself. The eclipsing of another star is an external process and therefore an eclipsing binary is an extrinsic variable.

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

The H-R diagram plots luminosity, which is obtained through photometry, against colour or spectral type, which is obtained by looking at the spectra of a star measured by spectroscopy. The H-R diagram is a good example of combining spectroscopy and photometry.

The H-R diagram allows us to determine such information as the distance to stars that are too far away to be measured by trigonometric parallax. Using the H-R diagram and a technique known as spectroscopic parallax, the distance to more distant stars can be determined. By using photometry and spectrometry, we can get a more accurate distance ladder for the Universe. To determine the age of star clusters, we look at the turn-off point for the zero age main sequence on an H-R diagram. And by studying different star clusters, much can also be inferred about the evolution of stars.

Using photometry, the masses of stars can only be determined by studying binary stars. By comparing types of stars (found by spectroscopy) to known mass stars, a mass luminosity relationship was established and hence the mass for more stars can be determined.

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

Phosphorus-32 is used to measure the rate at which phosphorus is taken up by a plant. Phosphorus is an important plant nutrient.

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

- The higher the number of fuel rods inserted into the reaction vessel, the faster the rate of the reaction.
- A moderator slows neutrons, making it more likely for these neutrons to be captured by a fissionable nucleus.
- Control rods absorb neutrons. The larger the number of control rods inside the reaction vessel, the fewer the neutrons and the slower the rate.
- Most modern nuclear reactors do not change the amount of moderator in the reaction vessel. Consequently, the rate of reaction in a nuclear reactor will increase when:
  - more fuel rods are inserted
  - control rods are removed.The rate will decrease when:
  - fewer fuel rods are inserted
  - control rods are added.

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

Energy is released because the mass of the products of this reaction is less than the mass of the reactants.

This 'missing' mass is converted to energy through the equation  $E = mc^2$ .

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

	<i>Gravitational</i>	<i>Electrostatic</i>	<i>Strong</i>
<i>Strength</i>	Low	High	Very high
<i>Direction</i>	Attractive	Repulsive	Attractive
<i>Range</i>	Infinite	Infinite	Very short

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

$$\begin{aligned}\lambda &= \frac{h}{mv} \\ &= \frac{6.626 \times 10^{-34}}{0.156 \times 20} \\ &= 2.12 \times 10^{-34} \text{ m}\end{aligned}$$

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

- Tritium contains 1 proton, 2 neutrons and 1 electron.
- Protons contain 2 up and 1 down quark.  
Neutrons contain 1 up and 2 down quarks.
- $\therefore$  a tritium atom contains 4 up quarks and 5 down quarks and 1 lepton (the electron).

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

Heisenberg developed one of the first mathematical formulations of quantum mechanics, in terms of matrices. He is perhaps best known for the Heisenberg Uncertainty Principle, which states that there are absolute limits on the accuracy of the measurement of an object's momentum and position (or energy and time).

Pauli developed the Pauli Exclusion Principle, which states that no two particles can have the same set of quantum numbers. He also developed an explanation of  $\beta$  decay that postulated the existence of the neutrino. Neutrinos were detected experimentally many years later.

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

Many experiments have provided data that, applied to mathematical models, have improved our understanding of the atom.

Niels Bohr applied the quantum ideas developed by Max Planck and Albert Einstein to the spectrum of the hydrogen atom. He postulated that if an electron orbited a nucleus so that its orbital angular momentum was an integral multiple of  $h/2\pi$ , then there would be no emission of electromagnetic radiation by the atom.

This allowed Bohr to interpret earlier equations that calculated the wavelength of lines in the hydrogen spectrum, in terms of a physical model. The wavelength of a photon ( $\lambda$ ) produced when an electron dropped from a higher ( $n_1$ ) to a lower ( $n_2$ ) energy level was given by

$$\frac{1}{\lambda} = R \left( \frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \text{ and the energy of the photon by } \epsilon = \epsilon_1 - \epsilon_2.$$

A deeper analysis of the experimental evidence reveals some shortcomings in Bohr's model (postulates): for example, his model was unable to explain the spectra of larger atoms, the relative intensity of spectral lines, the existence of fine structure, and the Zeeman effect.

Louis de Broglie's model of 'matter waves' was developed before any experimental evidence had been collected. De Broglie stated that the wavelength of any object of mass ( $m$ ) and

velocity ( $v$ ) was given by  $\lambda = \frac{h}{mv}$ .

Several years later, Clinton Davisson and Lester Germer diffracted electrons and were able to confirm the validity of de Broglie's equation.

Two key aspects of our current understanding of the atom – the hydrogen spectrum and de Broglie wavelengths – support the statement that mathematical models, validated by experimental evidence, have improved our understanding of the atom.

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

$I_\phi$	$I_l$	$I_\phi$
0	0	0
0	1	1
1	0	0
1	1	0

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

An open loop op-amp circuit is one in which there is no feedback path from the output to the input circuits. The op-amp circuit here does not have a feedback path, so therefore this is an open loop configuration.

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

Potential divider:

$$V_{\text{in}} = \left( \frac{10 \text{ k}\Omega}{23 \text{ k}\Omega + 10 \text{ k}\Omega} \right) V_{\text{batt}}$$

**Question 35 (d)***Sample answer:*

The LED lights up when  $O_\phi = 0$ .

$\therefore$  the LED is off when  $\phi_\phi = 1$

From the truth table, this happens when  $I_0 = 0$  and  $I_1 = 1$

This happens when  $V_{\text{in}}$  is less than the voltage on the junction between the 20 and 90 resistors:

$$V_{\text{in}} < \left( \frac{90 \text{ k}\Omega}{(90 + 20 + 390) \text{ k}\Omega} \right) 5\text{V}$$

$$V_{\text{in}} < 0.9\text{V}$$

AND when  $V_{in}$  is greater than the voltage on the junction between the  $390\text{ k}\Omega$  and  $20\text{ k}\Omega$  resistors:

$$V_{in} > \left( \frac{(20 + 90)\text{ k}\Omega}{(90 + 20 + 390)\text{ k}\Omega} \right) 5\text{V}$$

$$V_{in} > 1.1\text{V}$$

Using the potential divider equation, this corresponds to

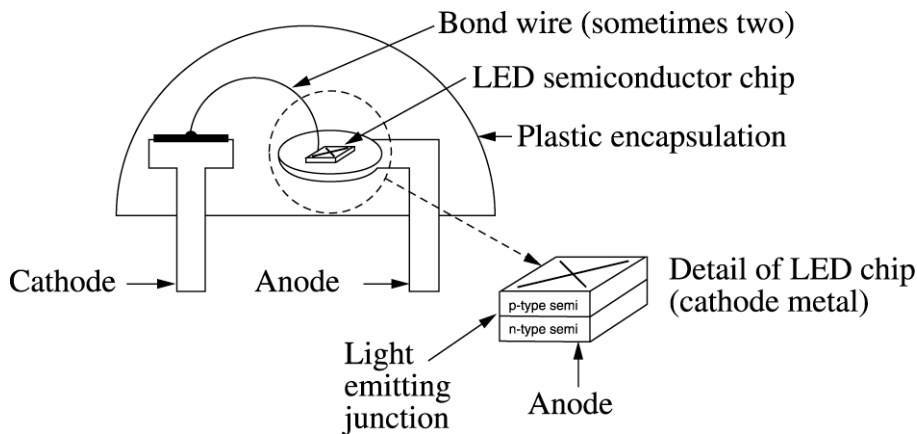
$$V_{in} < \left( \frac{(10 + 23)\text{ k}\Omega}{10\text{ k}\Omega} \right) 0.9\text{V}$$

$$V_{in} > \left( \frac{(10 + 23)\text{ k}\Omega}{10\text{ k}\Omega} \right) 1.1\text{V}$$

So the LED lights up to  $\begin{cases} 0 < V_{in} < 3.0\text{V} \\ 3.6 < V_{in} < 5.0\text{V} \end{cases}$

### Question 35 (e) (i)

*Sample answer:*



### Question 35 (e) (ii)

*Sample answer:*

One advantage of LEDs for household lighting is that they are more efficient at converting electricity into light than other light sources, such as incandescent light bulbs.

One disadvantage of LEDs for household lighting is that they are more expensive to manufacture than other light sources, such as incandescent light bulbs.



**Question 35 (f)****Sample answer:**

First, silica melts in such a way that it is easy to form it into long optical fibres. This is clearly a desirable property.

Second, silica has a refractive index that makes it easy to clad the fibre in such a way as to keep the light in the fibre and make it easy to get light into the end of the fibre.

Third, silica can easily be doped with certain materials to increase its optical non-linearity and therefore make it useful in active optical systems, such as fibre amplifiers.

**Question 35 (g)****Sample answer:**

In order to increase the power of computers, the integrated circuit industry has steadily developed technology to make the circuit elements of ICs smaller and smaller and, in parallel, faster and faster.

This is because a reduction in the size of the elements (transistors) means that a greater number can be manufactured on the same area of silicon, resulting in an increase in processing ability and/or memory capacity.

This work to reduce size is in parallel with developments that enhance the speed of IC circuits. If the IC circuits can switch currents on and off faster, then computers are able to process digital information faster, enhancing processing power. The sizes and speeds of IC circuits are related but are not completely dependent on each other.

As the size of IC circuit elements is reduced, quantum effects become more and more important. One example is that the operation of transistors in ICs typically relies on a thin insulating layer to block current flow. However, as this thin insulating layer is made thinner, its thickness becomes comparable to a few atomic spacings. Quantum effects mean that electrons can 'jump' or tunnel through the layer, defeating its purpose and disrupting the IC's operation.

As this limitation is reached, a new way of enhancing processing power must be developed. Otherwise, progress in computer design will stop. This will force a reconceptualisation of the way computers are designed, with possible outcomes being quantum-based computers.