BOSTES | BOARD OF STUDIES TEACHING & EDUCATIONAL STANDARDS NSW

2016 HSC Physics
Marking Guidelines

Section I, Part A

Multiple-choice Answer Key

Question	Answer
1	D
2	C
3	C
4	A
5	D
6	D
7	B
8	D
9	B
10	C
11	B
12	B
13	C
14	B
15	A
16	A
17	C
18	C
19	A
20	B

Section I, Part B

Question 21 (a)

Criteria	Marks
• Relates the reason for orbital decay to altitude of orbit	2
• Provides some relevant information	1

Sample answer:

Low-Earth orbit satellites encounter atmospheric drag due to their lower altitude. This drag reduces the orbital velocity causing orbital decay.

Question 21 (b)

Criteria	Marks
• Applies correct method to calculate magnitude and provides correct units	3
• Shows correct substitution into the equation without correct unit conversion OR without correct units	2
• Substitutes into a relevant formula	1

Sample answer:

$$F = \frac{Gm_1m_2}{r^2} = \frac{6.67\times10^{-11}\times6\times10^{24}\times50}{(8000\times10^3)^2} = 312.7N$$

Question 22 (a)

Criteria	Marks
• Identifies any motion of the magnet which would induce an oscillating voltage in coil B	2
• Identifies any motion of the magnet which would induce a voltage in coil B	1

Sample answer:

One end of the bar magnet is moved quickly and repeatedly towards and away from the end of coil B.

Question 22 (b)

Criteria	Marks
• Fully accounts for the features of the graph with reference to the motion of the magnet and the forces acting on it	4
• Relates features of the graph to the motion of the magnet	3
• Links a feature of the graph to a motion of the magnet	2
• Provides relevant information	1

Sample answer:

The magnet falls from rest and accelerates at 9.8 m s^{-2} due to gravity (downward line on graph). As the magnet approaches the disc, eddy currents are induced in the disc due to changes in magnetic flux. A magnetic field due to these currents opposes the change in flux, slowing the descent of the magnet (upward line on graph). It eventually comes to rest on the disc ($v = 0$).

Question 23 (a)

Criteria	Marks
• Correctly explains the role of deflection plates in showing different voltages	3
• Shows some understanding of how deflection plates work	2
• Provides some relevant information	1

Sample answer:

When an electron moves between the deflection plates it experiences a force due to the electric field. An increase in the input voltage increases the voltage across the deflection plates, increasing the electric field and causing more deflection that can be seen on the fluorescent screen.

Question 23 (b)

Criteria	Marks
• Provides correct substitution for the calculation of B with the correct direction	3
• Provides correct substitution to calculate B OR • Equates $F = qE$ and $F = qvB$ and states correct direction	2
• Provides correct direction OR • Provides partial substitution into a relevant equation	1

Sample answer:

$F_E = F_m$

$qE = qvB$

$B = \dfrac{E}{v}$

$B = \dfrac{10}{5.2 \times 10^4}$

$B = 0.0002T$ up the page

Question 24

Criteria	Marks
• Relates the graph to the behaviour of electrons both above and below the critical temperature	4
• Relates the graph to the behaviour of electrons above or below the critical temperature	3
• Links a feature of the graph to the behaviour of electrons	2
• Provides some relevant information	1

Sample answer:

Above T_c, the wire is a normal conductor with electrical resistance due to collisions between electrons and the lattice. Since the lattice vibrates more at higher temperatures, these collisions increase with temperature and lead to higher electrical resistance at higher temperatures.

Below T_c, the wire becomes superconductive. Electrons form Cooper pairs and pass through the lattice without loss of energy, resulting in zero electrical resistance for all temperatures below T_c.

Question 25 (a)

Criteria	Marks
• Provides valid comparison between force and distance in the graphs	2
• Identifies a relationship between force and distance in one of the graphs	1

Sample answer:

Both graphs show that as distance increases, the force decreases. However, in Team A's graph, the force between the masses decreases at a decreasing rate, whereas in Team B's graph, the force decreases at a constant rate.

Question 25 (b)

Criteria	Marks
• Makes an informed judgement of the appropriateness of each data set	3
• Identifies strengths and/or weaknesses of the data set(s)	2
• Provides some relevant information	1

Sample answer:

Team A's data set has a good range but too few measurements for a valid relationship to be deduced.

Team B's data set has sufficient measurements but over an insufficient range of distances for a valid relationship to be deduced.

Question 26

Criteria	Marks
• Identifies applications and explains how they have affected society	5
• Identifies applications and outlines their effects on society	4
• Identifies applications and outlines an effect on society	3
• Identifies applications OR • Outlines an effect on society	2
• Provides some relevant information	1

Sample answer:

Transformers allow the widespread use of electronic devices powered by mains voltages. Such proliferation of electronic devices has had significant effects on society, including rapid communication and data processing resulting in significant changes to the workforce, and the development of a large IT sector.

Transformers allow the efficient distribution of electrical energy over distances, so that consumers may be located at a distance from the point of generation. This reduces the effect of pollution in large cities, improving living conditions and the focus of health programs. It also allows an equitable standard of living to be delivered across the population regardless of location.

Question 27 (a)

Criteria	Marks
• Outlines observations including equipment used	3
• Outlines an observation OR equipment used	2
• Provides some relevant information	1

Sample answer:

Hertz observed that if a glass screen between the spark emitter and the receiving loop antenna was removed, the maximum length of the spark across the air gap of the loop antenna was increased.

Answers could include:

The air gap of the loop antenna was set at the maximum for which a spark across it was maintained. Inserting a glass screen caused the spark to stop.

A diagram is provided showing a spark source and loop antenna with a spark gap with a glass screen between them.

Question 27 (b)

Criteria	Marks
• Shows a thorough understanding of how the investigation of the photoelectric effect changed the understanding of light, including one specific piece of evidence	4
• Relates the investigation of photoelectric effect to the understanding of light	3
• Shows some understanding of the investigation of the photoelectric effect and/or the change in understanding of light	2
• Provides some relevant information	1

Sample answer:

Before the explanation of the photoelectric effect, light was considered to consist of transverse waves of different wavelengths. One experimental result showed that the velocity of photoelectrons did not increase with increased light intensity, but did increase when the frequency of the light was increased.

This was not consistent with predictions of the wave model and could only be explained by considering the light to consist of discrete packets of energy (quanta) where quanta of high frequency light possessed more energy than those of low frequency light.

Question 28

Criteria	Marks
• Explains the change in acceleration of the rocket with reference to the law of conservation of momentum	5
• Links the changes in acceleration of the rocket to the law of conservation of momentum	4
• Shows some understanding of the law of conservation of momentum and/or the acceleration of the rocket	2–3
• Provides some relevant information	1

Sample answer:

The rocket is propelled forwards by expelling gases backwards.

The mutual force acting between the rocket and gases exerts an equal and opposite effect on each. Since this force is applied over the same time interval, the rocket and gases experience equal and opposite changes in momentum, that is, momentum is conserved.

Since the mass of the rocket is decreasing while the force acting on it due to the gases is constant, the acceleration of the rocket increases as it ascends.

Answers could include:

Algebraic analysis.

Question 29

Criteria	Marks
• Provides explanations with reference to electric generators and TWO other technologies	6
• Provides explanations with reference to electric generators and ONE other technology	5
• Links relevant discoveries to electric generators and TWO other technologies	4
• Links relevant discoveries to TWO technologies	3
• Identifies relevant discoveries OR • Outlines one relevant discovery	2
• Identifies a discovery or a technology other than electric generators	1

Sample answer:

Faraday discovered that a change in magnetic flux would induce an emf in a conductor. This discovery led directly to the development of the electric generator.

Physicists discovered that electrons could be made to travel through evacuated tubes. They were deflected by electric and magnetic fields and could cause a fluorescent screen to emit light. The electrons could be manipulated precisely to form an image on the screen leading to the development of television.

Physicists made discoveries about the properties of semiconductors. They exhibited a small energy gap between conduction and valence bands that could be altered by doping. Doped semiconductor combinations (eg PNP) formed devices that behaved in the same way as existing thermionic components, allowing the miniaturisation of computers, and the development of practical computing.

Question 30 (a)

Criteria	Marks
• Applies a correct method to calculate the maximum possible energy released	3
• Provides the main steps	2
• Substitutes into a relevant formula	1

Sample answer:

$$\Delta E = E_{pfinal} - E_{pinitial}$$

$$= \left(\frac{-Gm_1m_2}{r_{final}}\right) - \left(\frac{-Gm_1m_2}{r_{initial}}\right)$$

$$= \frac{-6.67\times10^{-11}\times6.39\times10^{23}\times2}{3376203} - \frac{\left(-6.67\times10^{-11}\times6.39\times10^{23}\times2\right)}{3376204}$$

$$= -7.48 \text{ J (lost by falling mass)}$$

$$\therefore \text{ light bulb released a maximum of 7.48 J of energy}$$

Answers could include:

Assuming g_{mars} is constant over this range,

$$\text{Work} = Fs$$

$$= \frac{Gm_1m_2}{r^2}\times s$$

$$= \frac{-6.67\times10^{-11}\times6.39\times10^{23}\times2\times1}{3376203^2}$$

$$= 7.48 \text{ J}$$

Question 30 (b)

Criteria	Marks
• Explains the difference in behaviour	3
• Provides some reasoning for the change in behaviour	2
• Identifies a change in behaviour	1

Sample answer:

When the switch is open, there is no longer any magnetic effect opposing the falling of the mass, so the mass now falls more quickly.

Answers may include:

Information on Lenz's Law or conservation of energy.

Section II

Question 31 (a) (i)

Criteria	Marks
• Relates what geophysicists do to the seismic data generated by a nuclear explosion	2
• Makes a relevant statement about seismic waves of nuclear origin	1

Sample answer:

Nuclear weapon explosions create a unique seismic signature, which is detected by seismographs. Geophysicists who analyse the seismograms can deduce whether and where a nuclear explosion has occurred and thus can monitor compliance with test ban treaties.

Question 31 (a) (ii)

Criteria	Marks
• Outlines one geophysical method and links an economic benefit to the method	3
• Identifies a geophysical method and a general economic benefit OR • Outlines a geophysical method	2
• Identifies a geophysical method	1

Sample answer:

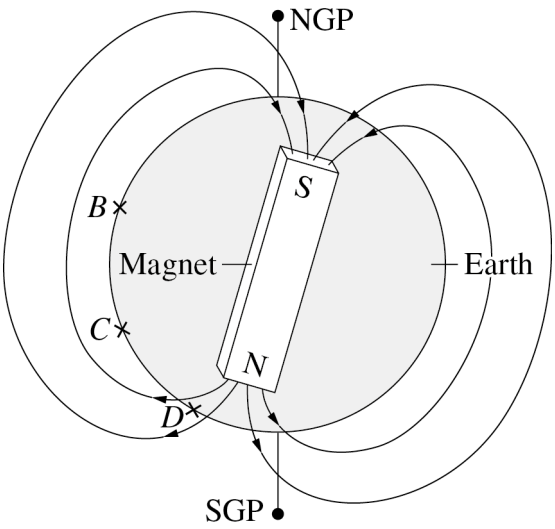
Oil deposits produce gravitational anomalies, which can be measured and used to locate the deposits. Oil extracted from these deposits provides energy for a great range of industries, such as transport. Hence this geophysical method has resulted in great economic benefits.

Question 31 (b) (i)

Criteria	Marks
• Describes a relevant model	3
• Outlines a relevant model	2
• Provides some relevant information	1

Sample answer:

One model that has been used for Earth's magnetic field postulates the existence of a permanent dipole, represented as:



At the equator (B), this model shows Earth's magnetic field being nearly parallel to Earth's surface. This model shows that as the latitude increases, $B \rightarrow C \rightarrow D$, the inclination of the magnetic field to Earth's surface increases.

Question 31 (b) (ii)

Criteria	Marks
• Describes features of Earth's magnetic field	3
• Outlines features of Earth's magnetic field	2
• Identifies a feature of Earth's magnetic field	1

Sample answer:

The Earth's magnetic field changes with time, which is observed in the change of position of the magnetic N/S poles over geologically short times.

Earth's magnetic field is not uniformly symmetrical, since it has some irregularities that are intrinsic due to local variations in composition and density and other irregularities that are extrinsic and change due to effects such as solar wind.

Question 31 (c)

Criteria	Marks
• Explains TWO gravimetric corrections	4
• Identifies TWO gravimetric corrections and gives a reason why a specific gravimetric correction must be made	3
• Identifies TWO gravimetric corrections OR • Gives a reason why a specific gravimetric correction must be made	2
• Identifies a feature of gravimetric analysis	1

Sample answer:

Analysis of gravimetric data must take the altitude at which the measurement was taken into account since the force of gravity decreases with altitude. Correction for this variable is called the free-air correction.

Corrections must also be applied for local variations in rock density and distribution, since these affect the gravimeter data. This is called the Bouguer correction.

Question 31 (d)

Criteria	Marks
• Provides valid inferences with justifications	4
• Provides valid inferences and justifies one of them	3
• Provides valid inferences OR • Provides a valid inference with justification	2
• Provides some relevant information	1

Sample answer:

The same patterns of reversal occur over a shorter distance at location B compared with A, so the rate of seafloor spreading at B is slower than the rate at A. This is based on the assumption that the same extrinsic field changes affect cooling rocks at both locations.

The rate of spreading is the same on either side of the ridge at both locations. This is evidenced by the symmetric patterns on either side of the mid-ocean ridge.

Answers could include:

The non-uniform width of regions with normal/reverse magnetisation may be due to either variation of the seafloor spreading rate or due to variation of the lengths of time between reversals, or both. Further evidence is required to make a better inference.

Question 31 (e)

Criteria	Marks
• Relates features on the seismogram to the behaviour of different types of earthquake waves and Earth's internal structure	6
• Relates features on the seismogram to the behaviour of different types of earthquake waves and/or Earth's internal structure	5
• Links features of the seismogram to waves and/or Earth's internal structure	3–4
• Identifies features on the seismogram OR • Links a feature on the seismogram to a type of wave or Earth's internal structure	2
• Provides some relevant information	1

Sample answer:

Seismograms at *W* and *X* show two events at the stations separated by ~7 minutes and ~11 minutes respectively. The first event in each case is the arrival of the P-waves, followed by the S-wave.

P-waves are longitudinal waves that travel faster than S-waves which are transverse waves. Since *X* is further from the earthquake focus, the arrival time difference between P and S waves is greater at *X*.

S-waves cannot travel through liquids and so there can be no liquid layers extending as far as the line joining the focus and *X*.

The record at *Y* only shows the arrival of the P wave and so it can't be deduced from this record if there's a liquid component between the focus and *Y*, since we don't know if the S-wave was detected at that location.

Answers could include:

The P/S wave records of the seismograph at *X* have a smaller amplitude than the corresponding waves at *W*. This is due to the effect of the inverse square law and absorption of energy by material in the Earth.

Question 32 (a) (i)

Criteria	Marks
• Identifies differences between hard and soft X-rays	2
• Identifies a property of hard or soft X-rays	1

Sample answer:

Hard X-rays have a higher energy than soft X-rays. Hard X-rays have a greater ability to penetrate human body structures than soft X-rays.

Question 32 (a) (ii)

Criteria	Marks
• States reasons for the widespread use of X-rays to image limbs	3
• States a reason for the widespread use of X-rays	2
• Identifies a feature of X-ray imaging	1

Sample answer:

X-ray imaging provides high contrast between soft tissue and bone, at sufficient resolution to detect fractures. X-ray technology is cheaper than most alternatives and does not expose the patient to as much ionising radiation as CT. For these reasons X-ray is widely used to image human limbs.

Question 32 (b) (i)

Criteria	Marks
• Describes the piezoelectric effect and its application in ultrasound	3
• Describes the piezoelectric effect OR its application in ultrasound	2
• Identifies a feature of the piezoelectric effect	1

Sample answer:

The piezoelectric effect is the inter-conversion of mechanical and electrical energy in a crystal. When a potential difference is applied across such a crystal, its shape will alter. Conversely, applying a force to the crystal will result in a potential difference across it.

Since these variations can occur at high frequencies, the piezoelectric effect is ideal for creating and detecting ultrasound waves used for medical imaging.

Question 32 (b) (ii)

Criteria	Marks
• Describes what happens to the intensity at each boundary with the support of calculations	3
• Provides some relevant calculations and/or shows an understanding of what happens	2
• Provides some relevant information	1

Sample answer:

At the first boundary (gel/soft tissue), none of the ultrasound pulse is reflected, since both media have the same acoustic impedance.

At the second boundary (soft tissue/bone), some of the pulse will be reflected, and some will continue into the bone. Quantitatively:

$$\frac{I_r}{I_0} = \frac{\left(Z_2 - Z_1\right)^2}{\left(Z_2 + Z_1\right)^2}$$

$$\frac{I_r}{I_0} = \frac{\left(6.732\times10^6 - 1.632\times10^6\right)^2}{\left(6.732\times10^6 + 1.632\times10^6\right)^2} = 0.3718$$

So, approximately 37% of the pulse is reflected at the soft tissue/bone boundary and approximately 63% of the pulse passes into the bone.

Question 32 (c)

Criteria	Marks
• Contrasts the uses of CAT imaging and Doppler ultrasound imaging, providing an example of how each is used	4
• Outlines a use of each technology	3
• Outlines a use of either technology	2
• Provides some relevant information	1

Sample answer:

Doppler ultrasound is used to examine functional characteristics of the human body, in particular the motion of body structures and fluids. Specific uses of Doppler ultrasound include determining the motion of the heart and determining the motion of blood, particularly near valves or blockages.

In contrast, CAT imaging examines structural characteristics of the human body, at very high resolutions. CAT provides excellent contrast between hard and soft tissues, and also different forms of soft tissue. Specific uses of CAT imaging include the detection of abdominal tumours and the diagnosis of damaged soft tissue such as cartilage.

Question 32 (d)

Criteria	Marks
• Describes how PET scan technique is used in diagnosis with reference to the interaction of positrons and electrons	4
• Outlines how PET scan is used with reference to the interaction of positrons and electrons	3
• Identifies some features of the PET scan technique	2
• Identifies a feature of the PET scan technique	1

Sample answer:

PET imaging is useful in diagnosis because it allows for the use of specific radiopharmaceuticals which can target specific metabolic processes, such as high rates of metabolism associated with cancerous tissues.

During PET imaging, the patient is injected with a radioisotope that releases positrons. These positrons undergo annihilation with nearby electrons in the body, releasing gamma radiation. The patient is surrounded by a circular gamma detector that allows the distribution of the radioisotope within the patient to be computed.

Question 32 (e)

Criteria	Marks
• Explains how principles of physics are applied in MRI	6
• Relates principles of physics to their use in MRI	5
• Describes the use of a principle of physics used in MRI	4
• Describes a principle of physics used in MRI OR • Identifies principles of physics used	3
• Outlines features of MRI OR • Identifies a principle of physics used in MRI	2
• Provides some relevant information	1

Sample answer:

The physical principles related to spin and resonance are applied in MRI.

The magnetic properties of nucleons are related to their spin. Hydrogen is abundant in the human body and has a net spin that is determined by its single proton. During MRI a patient is placed in a strong magnetic field causing the spin directions of the hydrogen nuclei to align and precess about the magnetic field lines at a specific frequency.

Due to the principle of resonance, a radio wave at this frequency will be readily absorbed by the nuclei, causing their precession to become synchronised and some of them to be placed into a high energy state. This is necessary in order to detect the nuclei in subsequent processes.

Answers could include:

- The principle of electromagnetic induction in the detecting coils.
- The principle of superconductors in the field coil.
- The principles of semiconductor operation essential for the operation of computers used in MRI.

Question 33 (a) (i)

Criteria	Marks
• Correctly distinguishes between resolution and sensitivity for optical telescopes	2
• Shows some understanding of sensitivity OR resolution	1

Sample answer:

Resolution of an optical telescope is the ability to distinguish two close objects as separate images.

Sensitivity is the light-gathering power or the ability to detect faint objects for observation. This depends on the area of the mirror or lens of the telescope.

Question 33 (a) (ii)

Criteria	Marks
• Outlines ways	3
• Identifies ways OR • Outlines one way	2
• Provides some relevant information	1

Sample answer:

The resolution of ground-based telescopes can be improved by a number of techniques including active optics, adaptive optics and interferometry.

Active optics uses a slow computer-controlled feedback system to correct for sagging or deformities of large primary mirrors in optical telescopes.

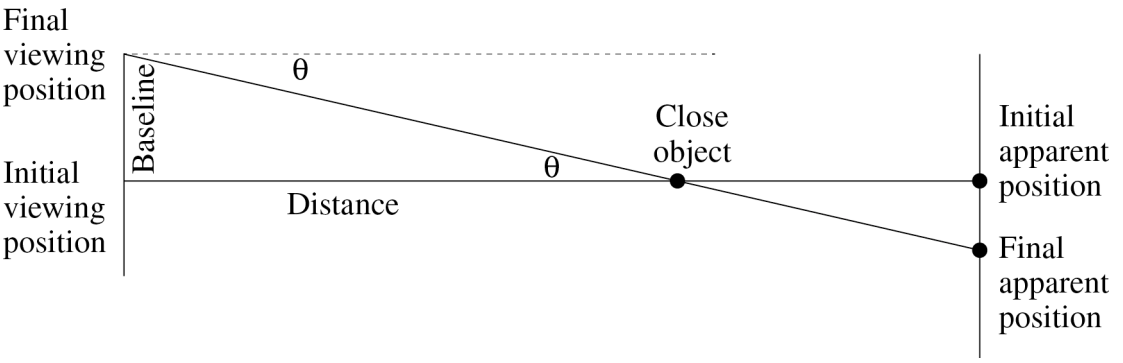
Interferometry uses data (optical or radio) from a number of collectors to produce an interference pattern which is then mathematically analysed to produce an ‘unblurred’ image.

Question 33 (b) (i)

Criteria	Marks
• Provides a correct explanation	3
• Shows some understanding of trigonometric parallax	2
• Provides some relevant information	1

Sample answer:

Trigonometry can be used to calculate the distance to relatively close stellar objects by using their apparent change in position with time, against background distant stars (parallax).



Viewing positions could change as the Earth rotates (diurnal) or as Earth orbits around the Sun (six months).

Distance can then be calculated by:

Distance = Baseline/tan θ

Question 33 (b) (ii)

Criteria	Marks
• Applies correct procedure to calculate the absolute magnitude	3
• Provides some main steps	2
• Substitutes into a relevant formula	1

Sample answer:

$M = ?$ $m = 4.2$ $p = 0.055$ $d = ?$

$$p = \frac{1}{d}$$

$$= \frac{1}{0.055}$$

$$= 18.18 \text{ parsecs}$$

$$M = m - 5\log\left(\frac{d}{10}\right)$$

$$= 4.2 - 5\log\left(\frac{18.18}{10}\right)$$

$$= 4.2 - 1.298$$

$$= 2.9$$

Absolute magnitude is 2.9

Question 33 (c)

Criteria	Marks
• Describes the use of spectral analysis to determine chemical composition and surface temperature of stars	4
• Outlines features of spectra related to composition and surface temperature	3
• Makes some reference to spectra to identify composition AND/OR temperature	2
• Provides some relevant information	1

Sample answer:

Particles in the atmosphere of stars absorb specific frequencies of light allowing the elements and molecules to be identified. Hence chemical composition can be determined.

The presence of molecules, neutral atoms or ionised atoms in a star are determined by its temperature. These can be detected in the absorption spectrum, allowing their temperature to be deduced.

Answers could include:

Information on Wien's Law.

Question 33 (d)

Criteria	Marks
• Explains how the study of different types of variable stars has contributed to the understanding of celestial objects	4
• Outlines features of different types of variable stars and relates a feature to the understanding of celestial objects	3
• Identifies features of variable stars OR • Relates a feature of variable stars to the understanding of a celestial object	2
• Provides some relevant information	1

Sample answer:

The period–luminosity relationship of Cepheid variables allows their distances from Earth to be deduced. Knowing this distance, inferences about celestial objects near the Cepheid can be made, such as absolute magnitude and relative age of star clusters.

Features of binary and multiple star systems, such as orbital period, mass and relative size, can be deduced from their extrinsic variations in brightness.

Answers could include:

Use of variables to identify exoplanets.

Question 33 (e)

Criteria	Marks
• Relates processes that occur during stellar evolution to the non-uniform distribution of stars on the H–R diagram	6
• Relates processes that occur during stellar evolution to the distribution of stars on the H–R diagram	5
• Relates processes that occur in stars to their position on the H–R diagram	4
• Describes processes that occur in stars OR • Relates a process that occurs in stars to their position on the H–R diagram OR • Describes characteristics of stars in the main regions on the H–R diagram	3
• Describes a process that occurs in stars OR • Identifies regions on the H–R diagram	2
• Provides some relevant information	1

Sample answer:

Stars on an H–R diagram are non-uniformly distributed into distinct groups dependent on processes which occur during their evolution.

The primary source of energy in stars on the main sequence is hydrogen fusion.

In the next evolutionary stage for most stars, helium fusion is the main source of energy. These belong to the group known as red giants.

The next evolutionary stage for most stars is characterised by gravitational collapse during which gravitational potential energy is converted to radiant energy. These belong to the group known as white dwarfs.

Since the transition from one process to another occurs quickly relative to time spent in each group, fewer stars are distributed in areas outside of these groups on the H–R diagram.

Answers could include:

- Reference to other groups such as protostars, supergiants
- Sketch of H–R diagram
- Reference to properties of stars related to their distribution within particular groups
- Globular and open clusters.

Question 34 (a) (i)

Criteria	Marks
• Identifies TWO nucleons and states a difference	2
• Provides some relevant information	1

Sample answer:

The two types of nucleons are neutrons and protons. Protons are positively charged whereas neutrons have no charge.

Question 34 (a) (ii)

Criteria	Marks
• Explains the stability in terms of two forces	3
• Explains the stability due to one force OR • Links stability to two forces	2
• Provides some relevant information	1

Sample answer:

Protons carry a positive charge so that there is electrostatic repulsion that occurs between the protons in the nucleus.

The strong nuclear force is needed to hold the nucleus together. It occurs between proton–proton, neutron–neutron and protons–neutrons. It is a short range force that is strongly attractive when the nucleons are 0.5 to 1.0 the diameter of a proton apart; anything outside this range will be repulsive.

Question 34 (b) (i)

Criteria	Marks
• Outlines features	3
• Outlines one feature or identifies features	2
• Provides some relevant information	1

Sample answer:

Bohr's model cannot explain why some spectral lines were observed to be more intense than others; it does not explain why some transitions were favoured over others.

With more sensitive instruments, other lines were observed known as hyperfine lines. This indicates there is some splitting of the energy level that Bohr's model cannot explain.

Question 34 (b) (ii)

Criteria	Marks
• Applies correct procedure to calculate n_i	3
• Provides some main steps	2
• Substitutes into a relevant formula	1

Sample answer:

$$\frac{E}{hc} = \frac{1}{\lambda} = R\left(\frac{1}{{n_f}^2} - \frac{1}{{n_i}^2}\right) \text{ therefore, } \frac{1}{{n_i}^2} = \frac{1}{{n_f}^2} - \frac{E}{hcR}$$

$$\frac{1}{{n_i}^2} = \frac{1}{2^2} - \frac{4.089\times10^{-19}}{6.626\times10^{-34}\times3\times10^{8}\times1.097\times10^{7}} \text{ so } \frac{1}{{n_i}^2} = 0.06248 \text{ therefore,}$$

$$n_i = \sqrt{\frac{1}{0.06248}} = 4$$

Question 34 (c)

Criteria	Marks
• Describes both Pauli's and Heisenberg's ideas and how they changed the Bohr model	4
• Describes both Pauli's and Heisenberg's ideas and outlines a change made by either Pauli or Heisenberg	3
• Describes either Pauli's or Heisenberg's ideas OR • Outlines a change to Bohr's model	2
• Provides some relevant information about Pauli's or Heisenberg's ideas	1

Sample answer:

Pauli introduced the last quantum number associated with spin. His exclusion principle states that no two electrons can have the same quantum number. This changed Bohr's model by limiting the number of electrons that can exist in each shell.

Heisenberg's uncertainty principle states that if you know the accurate position of the particle then you cannot know its momentum accurately. If you can determine its momentum accurately than you cannot specify its position accurately. This changed Bohr's shell to an orbital probability cloud since precise measurements cannot be made.

Question 34 (d)

Criteria	Marks
• Relates evidence from accelerators and detectors to development of the standard model	4
• Describes the purpose of accelerators and detectors in identifying subatomic particles or the development of the standard model	3
• Describes the purpose of accelerators and detectors OR • Describes the standard model	2
• Provides some relevant information	1

Sample answer:

High energy collisions in particle accelerators produced many different types of subatomic particles which had not been previously observed. Properties of these particles, such as momentum and charge, could be deduced from measurements made using a range of detectors.

The standard model was developed to provide a framework for understanding these new particles. It also predicted the existence of particles which were subsequently produced and detected, providing further evidence to support the standard model.

Question 34 (e)

Criteria	Marks
• Relates Fermi's work to applications of nuclear physics and their effects on society	6
• Relates the work of Fermi to application(s) and effect(s) on society	5
• Relates the work of Fermi to any application and its effect on society	4
• Describes the work of Fermi, identifies an application and an effect on society	3
• Identifies an application and its effect on society OR • Identifies applications OR • Describes the work of Fermi	2
• Provides some relevant information	1

Sample answer:

Fermi made experimental observations of nuclear reactions in the first nuclear fission reactor. He was able to determine the requirements for a controlled chain reaction, leading to the development of stable nuclear reactors.

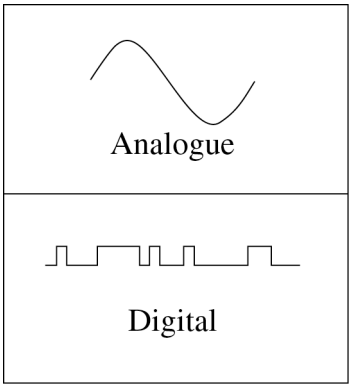
Nuclear reactors are used for the production of electricity using fission. This provides an alternative reliable supply of energy for a significant number of people in many countries.

Nuclear reactors are also used to produce radioisotopes. These may be used in medical imaging and in the treatment of cancer, enhancing healthcare.

Question 35 (a) (i)

Criteria	Marks
• Shows voltage outputs of both analogue and digital signals	2
• Identifies an analogue or digital signal	1

Sample answer:



Question 35 (a) (ii)

Criteria	Marks
• Describes an advantage of electric circuits and an advantage of electronic circuits	3
• Describes an advantage of either electric or electronic circuits	2
• Identifies an advantage of electronic circuits OR electric circuits	1

Sample answer:

Electronic circuits can work with tiny voltages and currents and can be miniaturised to allow large amounts of processing in a small volume.

Electric circuits can carry large amounts of electrical energy, making them ideal for transfer of energy to power various devices. Electric circuits are much more simple and cannot process signals in the same way as electronic circuits.

Question 35 (b) (i)

Criteria	Marks
• Compares all features	3
• Compares some features	2
• Provides some relevant information	1

Sample answer:

This op amp does not have ideal properties. An ideal amplifier has infinite open loop gain and infinite input impedance, while this op amp has a very high open loop gain.

The output impedance of an ideal amplifier is zero, but this op amp has a relatively low but not insignificant output resistance.

An ideal amplifier has an infinite bandwidth, but this amplifier has a limited bandwidth.

Question 35 (b) (ii)

Criteria	Marks
• Draws correct circuit diagram with correct feedback resistor	3
• Draws a relevant circuit and/or shows understanding to calculate the value of feedback resistor	2
• Provides some relevant information	1

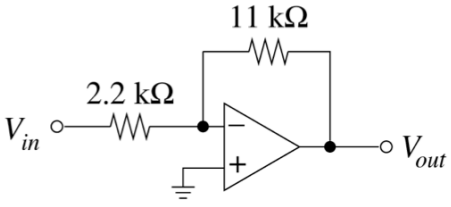
Sample answer:

$$\frac{V_{out}}{V_{in}} = \frac{R_f}{R_i}$$

$$\frac{-10}{2} = \frac{-R_f}{2.2}$$

$$R_f = 2.2 \times \frac{10}{2}$$

$$R_f = 11k\Omega$$



Question 35 (c)

Criteria	Marks
• Completes a relevant truth table and determines correct voltages for each input	4
• Provides correct truth table OR • Determines input voltages using an incorrect truth table	3
• Partially completes the truth table	2
• Shows a basic understanding of truth tables	1

Sample answer:

A	*B*	*C*	*Output*
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	0
1	1	1	1

The output would be low only when inputs *A* and *B* are between 2U–5V and input *C* is less than 0.8 V.

Answers could include:

A low voltage can be any value $0 \leq V \leq 0.8$
A high voltage can be any value $2 \leq V \leq 5$

Question 35 (d)

Criteria	Marks
• Explains advantages of using integrated circuits over individual transistors in electronic devices	4
• Outlines the advantages OR explains an advantage of integrated circuits over individual transistors	3
• Identifies features of integrated circuits and/or individual transistors	2
• Provides some relevant information	1

Sample answer:

Many individual transistors are needed to perform even simple calculations. Therefore, early computers using transistors were bulky, less powerful and less reliable than their integrated circuit counterparts. The integrated circuit consists of many tiny transistors all built onto the one silicon chip. This allows modern computers to be more compact, efficient and cost-effective when compared with previous technology based on individual transistors.

Question 35 (e)

Criteria	Marks
• Explains THREE changes	6
• Identifies THREE changes that need to be made and explains at least two	5
• Outlines changes that need to be made	4
• Identifies changes that need to be made and outlines at least one	3
• Identifies changes that need to be made OR • Outlines a change that needs to be made	2
• Provides some relevant information	1

Sample answer:

Use a Relay – The fan is stated as 240 V. This would require a current and voltage greater than what can be supplied by an electronic circuit. In this case, a relay should be used in place of the fan and the fan can be driven by a separate circuit through the relay.

R_1 should be 5 kΩ – Op amp in open loop configuration will act as comparator. It will switch between high and low when the input voltage equals the reference voltage. In this case, the reference voltage is 7.5 V due to R_2 and R_3 being equal. However the input voltage will never match this as R_1 is too great. To match 7.5 V, R_1 should be equal to the required thermistor value. From the graph the thermistor will be 5 kΩ at 30° so R_1 should also be 5 kΩ.

Swap the positions of R_1 and the thermistor. Since the resistance decreases with temperature, an increase in temp will tend to pull down the input voltage. This means the fan will be on below 30° and switch off above 30° which is the opposite of what is required. Swapping R_1 and the thermistor would rectify this.

Answers could include:

- Adjusting the reference voltage by changing the values of either R_2 and R_3 to suit the R_1 / thermistor voltage divider
- Swapping the two inputs of the op amp.

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Mapping Grid

Section I
Part A

Question	Marks	Content	Syllabus outcomes
1	1	9.3.4.2.1	H7, H9
2	1	9.3.3.3.3	H4, H7
3	1	9.4.1.2.3, 9.4.1.3.3	H9
4	1	9.4.4.3.1	H3
5	1	9.4.1.3.3	H9
6	1	9.2.4.2.6	H10
7	1	9.3.2.2.7	H7, H9
8	1	9.3.2.3.1/2, 9.3.2.2.3/4	H7, H9
9	1	9.3.2.2.5/6	H7, H9
10	1	9.2.4.2.9	H6
11	1	9.4.2.2.6, 9.4.2.3.4	H10
12	1	9.4.1.3.2, 9.4.1.2.3	H9
13	1	9.4.2.2.6	H10
14	1	9.2.2.3.5	H6
15	1	9.4.3.3.4	H7
16	1	9.3.2.2.3/4, 9.4.1.2.5	H7, H9
17	1	9.2.2.2.1, 9.2.4.3.2	H6, H9
18	1	9.2.1.3.3, 9.2.2.2.8	H6
19	1	9.2.4.2.9	H6
20	1	9.3.1.2.3, 9.3.1.3.3	H7, H9

Section I
Part B

Question	Marks	Content	Syllabus outcomes
21 (a)	2	9.2.2.2.11	H9
21 (b)	3	9.2.3.3.2	H9
22 (a)	2	9.3.2.3.2	H9
22 (b)	4	9.3.2.3.4, 9.2.1.3.3	H9
23 (a)	3	9.4.1.2.9	H9
23 (b)	3	9.4.1.3.3	H9
24	4	9.4.4.2.5/4/3	H7
25 (a)	2	9.2.3.2.2, 9.2.3.3.2, H14.1a	H6, H14
25 (b)	3	9.2.3.2.2, 9.2.3.3.2, H14.1c	H6, H14
26	5	9.3.4.2.1/7	H4
27 (a)	3	9.4.2.2.1	H1

Question	Marks	Content	Syllabus outcomes
27 (b)	4	9.4.2.1.1, 9.4.2.3.2	H2
28	5	9.2.2.2.7	H6
29	6	9.2, 9.3, 9.4	H3
30 (a)	3	9.2.1.2.3	H6
30 (b)	3	9.3.2.2.5	H7

Section II

Question	Marks	Content	Syllabus outcomes
Question 31		**Geophysics**	
31 (a) (i)	2	9.5.5.2.2	H4
31 (a) (ii)	3	9.5.5.2.1	H3
31 (b) (i)	3	9.5.4.3.1, 9.5.4.3	H9
31 (b) (ii)	3	9.5.4.2.1/2	H9
31 (c)	4	9.5.2.2.8	H1
31 (d)	4	9.5.4.3.2	H14
31 (e)	6	9.5.3.3.3	H12
Question 32		**Medical Physics**	
32 (a) (i)	2	9.6.2.2.2	H8
32 (a) (ii)	3	9.6.4.3.4	H4
32 (b) (i)	3	9.6.1.2.2	H7
32 (b) (ii)	3	9.6.1.2.6	H13
32 (c)	4	9.6.4.3.4, 9.6.1.3.3	H3
32 (d)	4	9.6.3.2.3/4/5	H3
32 (e)	6	9.6.4	H3
Question 33		**Astrophysics**	
33 (a) (i)	2	9.7.1.2.3	H8
33 (a) (ii)	3	9.7.1.2.5	H3
33 (b) (i)	3	9.7.2.2.2	H3
33 (b) (ii)	3	9.7.4.3.1	H12
33 (c)	4	9.7.3.2.5	H8
33 (d)	4	9.7.5.2.3, 9.7.5.2.4	H4
33 (e)	6	9.7.6.3.1/2/3	H13
Question 34		**From Quanta to Quarks**	
34 (a) (i)	2	9.8.3.2.1	H2
34 (a) (ii)	3	9.8.3.2.7/8	H9
34 (b) (i)	3	9.8.1.3.4	H10
34 (b) (ii)	3	9.8.1.3.3	H7, H12
34 (c)	4	9.8.2.3.1	H1
34 (d)	4	9.8.4.2.4/5	H2
34 (e)	6	9.8.3, 9.8.4, 9.8.3.2.5/9/10, 9.8.4.2.2, 9.8.4.3.1	H3, H4

Question	Marks	Content	Syllabus outcomes
Question 35		**The Age of Silicon**	
35 (a) (i)	2	9.9.2.3.1	H8
35 (a) (ii)	3	9.9.2.2.1	H7
35 (b) (i)	3	9.9.6.2.1, 9.9.6.2.4	H2
35 (b) (ii)	3	9.9.6.2.8, 9.9.6.2.7, 9.9.6.3.3	H7
35 (c)	4	9.9.5.2.1, 9.9.3.1, 9.9.5.3.2	H7
35 (d)	4	9.9.1.2.2	H3
35 (e)	6	9.9.4.2.1, 9.9.3.2.5, 9.9.3.3.2, 9.9.2.2.5, 9.9.6.2.6	H7