Neap:

HSC Trial Examination 2007

Physics

Solutions and marking guidelines

Section I

Part A

Answer and explanation	Syllabus content and course outcomes	
Question 1 **A** Using the equations of motion: $v = u + at$ gives the velocity after 1 second as 9.8 m s^{-1} after 2 seconds as 19.6 m s^{-1}. Similarly, $\Delta y = u_y t = \frac{1}{2} a_y t^2$ gives a displacement after 1 second of 4.9 m and after 2 seconds of 19.6 m.	9.2.2	H6
Question 2 **C** At an angle of 45°, the initial vertical velocity of $v \sin 45°$ is equal to the initial horizontal velocity of $v \cos 45°$. Range is determined by the factor $\sin 2\theta$, which has a maximum value of 1 when θ is 90°, i.e. θ must equal 45°. For any other angle the result will have a shorter range.	9.2.2	H6, H9
Question 3 **D** Using Kepler's third law equation and substituting the correct values gives an orbital radius of 1.2×10^9 m.	9.2.2	H6, H9
Question 4 **A** The gravitational potential energy is negative and decreases in magnitude as r increases. Assuming the rocket is accelerating, the kinetic energy will be positive and increasing until the rocket stops firing. The graph which best displays these concepts is alternative **A**.	9.2.1	H9
Question 5 **C** If a planet had lower gravitational field strength (i.e. lower acceleration due to gravity) then it would have to have a mass equal to or less than the Earth's mass and a radius larger than the Earth's radius.	9.2.1	H2, H14
Question 6 **C** Looking from the left end, the direction of the B field is clockwise around the wire, thus the north pole of the magnet would move out of the page and the south pole into the page.	9.3.1	H9
Question 7 **B** $B = \frac{F}{Il}$ $= \frac{0.25}{16 \times 5 \times 10^{-2}}$ $= 0.3125$ T	9.3.1	H9
Question 8 **A** A mass connected to springs and on low-friction bearings is an ideal torsional pendulum. The aluminium loop brings it to rest rapidly, without friction. The meter shouldn't carry enough current for heating, so **B** is not the correct answer. Any rigid material could supply strength, so **C** is not the correct answer. Aluminium has no effect on the magnetic field, so **D** is not the correct answer.	9.3.2	H7, H9
Question 9 **D** If there were any 'back emf', it would oppose the motion, so **A**, **B**, and **C** are incorrect. The ammeter has low resistance, allowing current to flow that opposes the motion of the magnet (by Lenz's law).	9.3.2	H7, H9

Part A (Continued)

Answer and explanation	Syllabus content and course outcomes
Question 10 **A** $\frac{V_p}{V_s} = \frac{n_p}{n_s}$ $\frac{240}{12} = \frac{480}{n_s}$ $n_s = 24$	9.3.4 H7, H9
Question 11 **B** $E = \frac{V}{d}$ $= \frac{150}{1.0 \times 10^{-2}}$	9.4.1 H9
Question 12 **D** $E = hf$	9.4.2 H9
Question 13 **C** Atoms are stable, while all other options produce electromagnetic radiation.	9.4.1 H6
Question 14 **A** Silicon is difficult to purify (so **B** is not the correct answer) and aluminium and carbon are not semiconductors (so **C** and **D** are incorrect).	9.3.3 H9
Question 15 **A** Shadows require straight-line rays.	9.3.1 H2, H9

Part B

Sample answer	Syllabus content, course outcomes and marking guide
Question 16	
(a) initial vertical velocity $= v\sin\theta$ $= 20\sin 37°$ $= 12 \text{ m s}^{-1}$	9.2.1 H6, H9 • Correct answer using suitable equation . . 1
(b) Maximum height occurs when $v = 0$. Using $v_y^2 = u_y^2 + 2a_y\Delta y$ $\Delta y = \dfrac{0^2 - 12^2}{2 \times 9.8}$ $= 7.35$ $= 7.4$ m	9.2.1 H6, H9 • Correct calculation of maximum height using suitable equation. . . . . 3 • Incorrect calculation of maximum height using suitable equation. . . . . 2 • Incorrect calculation of maximum height using suitable equation. 1
(c) time of flight = 2 × time to reach maximum height $= 2 \times \dfrac{v-u}{a}$ $= 2 \times \dfrac{0-12}{9.8}$ $= 2.45$ s horizontal range $= \Delta x$ $= u_x t$ $= v\cos(\theta)t$ $= 20\cos 37° \times 2.45$ $= 39$ m	9.2.1 H6, H9 • Correct calculation of time to reach maximum height using suitable equations and correct determination of maximum range. . . . . 2 • Correct calculation of time to reach maximum height using suitable equations OR • Incorrect determination of time to reach maximum height and a determination of maximum range based on that error 1
Question 17	
(a) The orbital velocity of a satellite is the velocity at which it orbits another body. It is also the minimum velocity required to maintain a satellite in a given orbit about another body.	9.2.2, 9.2.3 H6, H9, H13 • A statement that fully explains the term 'orbital velocity' 1
(b) The centripetal force between the Earth and the Sun is the force of gravitational attraction between the two. The magnitude of this gravitational force is proportional to the product of the masses of the Sun and the Earth and inversely proportional to the square of their distance of separation. The direction of the force on the Earth is always towards the Sun as the Earth revolves around it.	9.2.2, 9.2.3 H6, H9, H13 • Correctly relates the centripetal force to the force of gravity AND • Clearly explains the magnitude and direction of the force. . . . . 3 • Correctly relates the centripetal force to the force of gravity OR • Clearly explains the magnitude and direction of the gravitational/centripetal force . . . . 2 • Mentions centripetal force OR • Mentions gravity but doesn't discuss its magnitude or direction. 1

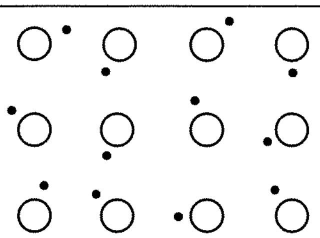
Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
(c) Using $F = \frac{mv^2}{r} = \frac{Gm_1m_2}{r^2}$ gives $v^2 = \frac{Gm_2}{r}$ $v = \sqrt{\frac{Gm_2}{r}}$ $= \sqrt{\frac{6.67 \times 10^{-11} \times 2.0 \times 10^{30}}{1.50 \times 10^{11}}}$ $= 3.0 \times 10^4 \text{ m s}^{-1}$	9.2.2, 9.2.3 H6, H9, H13 • Uses correct equations to calculate the correct value of orbital velocity .... 2 • Uses correct equations to calculate an incorrect value of orbital velocity 1
Question 18	
(a) The slope of the graph is equal to the product of the gravitational force and the radius squared. Thus by dividing the slope by the product of the masses we can obtain a value of the universal gravitational constant, G. slope $= Fr^2$ $= Gm_1m_2$ $G = \frac{Fr^2}{m_1m_2}$	9.2.1 H2, H9, H11 • Correctly determines the slope of the graph and explains how it can be used in calculating G .... 2 • Relates a correct concept of the slope of the graph. 1
(b) Newton's law of universal gravitation states that the force of gravitational attraction between any two bodies is inversely proportional to the square of their distance of separation. The graph shows this relationship over a number of plotted points.	9.2.3 H2, H9, H11 • Comprehensively explains the relationship between the data and Newton's law of universal gravitation................. 3 • Relates the relationship between the data and Newton's law of universal gravitation clearly.......................... 2 • Outlines the relationship between the data and Newton's law of universal gravitation OR • States Newton's law of universal gravitation clearly.......................... 1
Question 19	
When the proton is travelling at 75% (which is a significant fraction) of the speed of light, observers will detect substantial changes in its mass and length. Using the relativistic equations $l_v = l_0\sqrt{1 - \frac{v^2}{c^2}}$ and $m_v = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$, we see that its mass will be observed to increase to 1.51 times the rest mass and its length will contract to 0.66 times the rest length (but only in the direction of its motion). The proton will also be subject to time dilation (i.e. time for the proton will move more slowly relative to the observers the greater its velocity). Observers will measure that events occurring in the rapidly moving frame take longer to occur.	9.2.4 H1, H6, H7 • Comprehensive description in both qualitative and quantitative terms of mass increase, length contraction and time dilation .... 3 • Reasonable description in both qualitative and quantitative terms of mass increase, length contraction and time dilation..... 2 • Brief description in either qualitative or quantitative terms of mass increase, length contraction and time dilation 1

Part B (Continued)

Sample answer		Syllabus content, course outcomes and marking guide
Question 20		
(a)	Motors B and C	9.3.1 H9 • For both answers correct 1
(b)	Motors A and C	9.3.5 H9 • For both answers correct 1
(c)	Motor A: Induction motors only run on AC. Motor B: Permanent magnets mean that reversing the current reverses the motor. It only vibrates on AC. Motor C: Field coils and armature both reverse field direction at the same time on AC, so torque is always in the same direction.	9.3.1, 9.3.5 H14 • Identifies that Motor A needs AC and the Motor B needs DC . . . . 2 • Identifies that Motor A needs AC OR • Identifies that Motor B needs DC 1
Question 21		
(a)	It reduces high voltage to lower voltage for distribution to homes.	9.3.4 H9 • States that the device changes the voltage 1
(b)	One process is resistance heating in the winding wire, which depends on the load. Another is core heating from eddy currents and hysteresis losses. This depends on design, not on loading.	9.3.4 H7, H9 • Two correctly identified heat sources . . . 2 • One correctly identified heat source 1
(c)	Those one the left side are for the high-voltage input, those on the right for the lower-voltage output.	9.3.3 H9 • Identifies different voltages as the reason for the difference 1
(d)	Westinghouse and Tesla used AC power, while Edison used DC. Transformers only work with AC power.	9.3.3 H9, H14 • Identifies that Westinghouse and Tesla used AC and Edison used DC AND • States that transformers will only work with AC . . . . 2 • Identifies that Westinghouse and Tesla used AC and Edison used DC OR • States that transformers will only work with AC 1
Question 22		
(a)	Motor A uses 0.5 A when not loaded. When it is driving something else, the current will be higher. The voltage and current from B were not measured at the same time. We don't know what the voltage and current would be when connected up to a battery. Energy will be lost from the system as heat, therefore we can't put more energy back into the battery than is being taken out.	9.3.1, 9.3.3 H9, H12, H14 • Identifies three errors or incorrect assumptions . . . . 3 • Identifies two errors or incorrect assumptions . . . . 2 • Identifies one error or incorrect assumption 1
(b)	The motors would probably spin slowly, and not necessarily in the right direction. If the connections to one were reversed they would spin rapidly.	9.3.1, 9.3.3 H7, H14 • A reasonable explanation consistent with part (a) . . . . 2 • A reasonable explanation not consistent with part (a) 1

Part B (Continued)

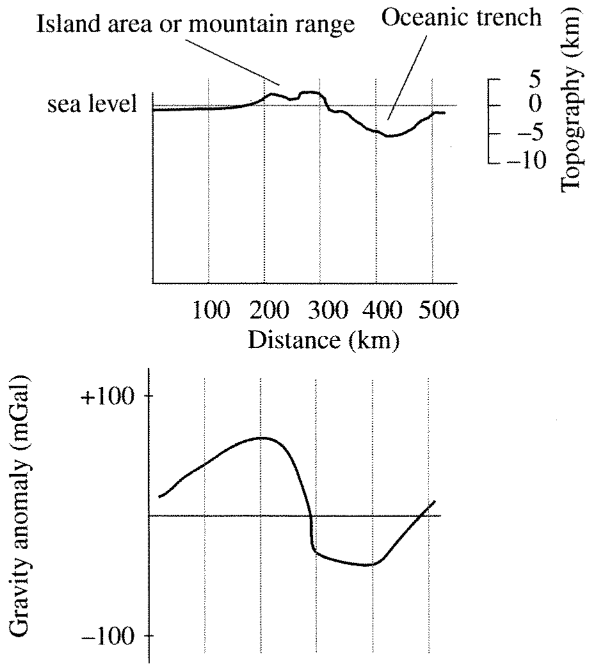
Sample answer	Syllabus content, course outcomes and marking guide
Question 23	
(a) Lights, toaster, washing machine	9.3.5 H7, H9, H13 • Lists three appliances that convert electrical energy into other forms of energy . . . . . . 3 • Lists two appliances that convert electrical energy into other forms of energy . . . . . . 2 • Lists one appliance that converts electrical energy into other forms of energy 1
(b) Lights: Incandescence through resistance heating, or fluorescence discharge, or LED. Toaster: Heating of high-resistance wire. Washing machine: Interaction of current and magnetic field.	9.3.5 H7, H9, H3 • Two correct descriptions of conversion. . 2 • One correct description of conversion. . . 1
Question 24	
The direction of the magnetic deflection of cathode rays indicated that they were negatively charged. However, they could not be deflected by electric fields, indicating they had no charge. In addition, cathode rays passed through thin gold foil without making any holes. These suggested that cathode rays were electromagnetic radiation.	9.4.1 H9, H10 • Fully outlines the inconsistencies and explains their interpretation . . . . .4 • Partially outlines the inconsistencies and partially explains their interpretation . . . . .3 • Fully outlines the inconsistencies. . . . . . . .2 • States an inconsistency or states the two interpretations 1
Question 25	
(a) A beam of X-rays was directed at a single crystal of a metal. The electrons 'reflected off' the crystal and an interference pattern was detected using photographic film. Calculations allowed the atomic spacing to be determined.	9.4.3, 9.4.4 H2, H9, H13 • Fully and clearly outlines the method . . . 2 • Partially outlines the method OR • Outline is not clear. 1
(b)  The metal consists of a lattice of single atoms with outer electrons which can move freely around inside the lattice. When an electric field is applied, the electrons move through the lattice in the opposite direction to that of the field.	9.4.3, 9.4.4 H2, H9, H13 • Diagram shows regular spacing of nuclei and free electrons, with a complete description of conduction. . . . . 3 • One feature missing from diagram or description incomplete. . . . . 2 • Complete diagram OR • Complete outline of conduction. 1

Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
Question 26	
Hertz's discovery of radio waves involved the following. An induction (spark) coil was connected to two terminals between which sparks occurred when the coil was operating. A nearby coil of wire with one small gap, not connected to the induction coil. When the induction coil sparked, Hertz observed sparks across the gap in the other coil. He found that the spark frequency in the coil of wire was the same as that of the induction coil. He also discovered that these waves could be reflected, refracted and polarised. By electrically connecting the coil to the terminal of the induction coil, he found an interference pattern, which allowed him to find the wavelength of the radio waves. Then, using $v = f\lambda$, he could calculate the velocity of the radio waves.	9.4.2 H9, H13 • All five points present in description, and a complete description of the calculation of v .... 6 • One point missing, or an incomplete description of the calculation of v .... 5 • Two points missing, or one point missing and an incomplete description of the calculation of v.... 4 • Three points missing, or two points missing and an incomplete description of the calculation of v.... 3 • Four points missing, or three points missing and an incomplete description of the calculation of v.... 2 • Four points missing and an incomplete description of calculation of v, or a complete description of the calculation of v only .. 1
Question 27	
Thomson's experiment used both magnetic fields created by coils acting as electromagnets and electric fields created by plates to deflect electrons. These are also used in TV tubes. Magnetic fields deflect electrons at 90° to the magnetic field, while electric fields deflect electrons at 180° (parallel) to the electric field. Thomson used both types of field simultaneously, arranged so they deflected the electrons in opposite directions. By adjusting the field strengths so that the deflections were equal and opposite, he was able to calculate a value for the charge to mass ratio of the electrons.	9.4.1 H2, H3, H9, H13 • Full outline of deflection methods and a correct explanation of Thomson's reason 5 • Full outline of deflection methods and a partial explanation of Thomson's reason OR • Partial outline of deflection methods and a correct explanation of Thomson's reason 4 • Full outline of deflection methods and no explanation of Thomson's reason OR • Partial outline of deflection methods and a partial explanation of Thomson's reason OR • Brief mention of deflection and a correct explanation of Thomson's reason .... 3 • Partial outline of deflection methods and no explanation of Thomson's reason OR • Brief mention of deflection and a partial explanation of Thomson's reason OR • No mention of deflection and a correct explanation of Thomson's reason .... 2 • Brief mention of deflection and no explanation of Thomson's reason OR • No mention of deflection and a partial explanation of Thomson's reason 1

Section II

Question 28 **Geophysics**

		Sample answer	**Syllabus content, course outcomes and marking guide**
(a)	(i)	This can be due to either a variation in the distance from the point on the Earth's surface to the centre of the Earth or a change in density of materials immediately below the point on the Earth's surface.	9.5.2 H3 • Indicates two reasons for variation in Earth's gravitational field . . . . 2 • Indicates one reason for variation in Earth's gravitational field 1
	(ii)		9.5.2 H4 • Correctly draws line graph with gravitational highs and lows mirroring the topography and correctly identifies one topographical feature . . . . 3 • Correctly draws the graph with either high or low mirroring of the topography and correctly identifies one topographical feature . . . . 2 • Correctly draws the graph with either high or low mirroring of the topographical feature OR • Correctly identifies one topographical feature 1
(b)	(i)	Alfred Wegener's theory of continental drift, put forward in the 1920s, was largely dismissed by the scientific community because he failed to offer a convincing argument for how the continents moved. It was not until the IGY that evidence from the ocean floors began to support Wegener's extensive land-based evidence.	9.5.4 H1 • States why Wegener's theory was rejected and indicates change in acceptance after new evidence following the IGY. . . . . 2 • States why Wegener's theory was rejected 1
	(ii)	One piece of geophysical evidence is from the study of the magnetic anomalies in and around mid-ocean ridges. This striped pattern of normal and reverse magnetic polarity, symmetrically distributed on either side of the mid-ocean ridge, helped support the theory of sea-floor spreading. A second piece of geophysical evidence is from the ability to radiometrically date the basalts on the sea floor either side of the ridge and measure their spreading rates.	9.5.4 H1 • Expresses concise and relevant details for two pieces of geophysical evidence. . . . . 4 • Expresses concise and relevant details for one piece of geophysical evidence and includes another piece of evidence without details. . . . . 3 • Expresses concise and relevant details for one piece of geophysical evidence. . . . . . 2 • Expresses details of one piece of geophysical evidence 1

Question 28 Geophysics (Continued)

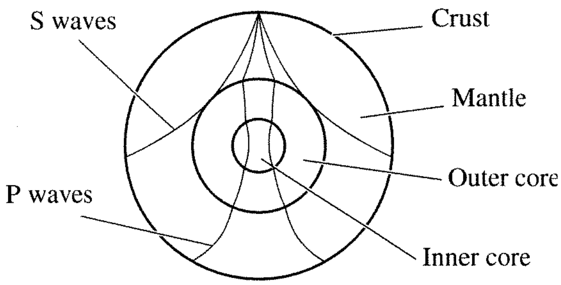
Sample answer

(c) The investigation of the pathways of P and S waves produced by earthquakes in the lithosphere has greatly assisted the scientific community in understanding the layering and composition of the Earth's interior.

With the knowledge that the denser the material the waves travel through the faster they travel, and that S waves do not travel through liquids, science has been able to determine that the density and state of the materials making up the Earth's interior varies, and in fact falls into layers commonly called the crust, the mantle, the outer and the inner core.

P waves refract at each of these boundaries (this is called discontinuation), and at the mantle/outer core boundary (the Gutenberg discontinuity) S waves reflect.

Knowledge of these wave properties has allowed the following layering to be determined, with density increasing with depth and the outer core thought to be liquid.



Syllabus content, course outcomes and marking guide

9.5.3 H2, H3

Criteria	Marks
• Identifies properties of P and S waves (P waves faster than S waves, S waves do not travel through liquid). Links the speed of the waves, their respective reflection and refraction to changes in the density of the material they are travelling through and ultimately to varying composite layers of Earth's interior. Identifies boundaries of density change as discontinuities	7
• Identifies properties of P and S waves (P waves faster than S waves, S waves do not travel through liquid). Links the speed of the waves, their respective reflection and refraction to changes in the density of the material they are travelling through and ultimately to varying composite layers of Earth's interior. Fails to identify discontinuities	6
• Identifies properties, mentioning refraction and reflection. Fails to identify discontinuities and layers.	5
• Identifies properties, mentioning refraction and reflection. Fails to identify discontinuities and layers. Fails to link change and density with changes in speed and composition	4
• Identifies three properties of P and S waves	3
• Identifies two properties of P and S waves	2
• Identifies one property of P and S waves	1

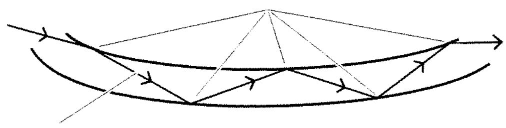
Question 28 Geophysics (Continued)

		Sample answer	Syllabus content, course outcomes and marking guide
(d)	(i)	There are many benefits of using geophysical methods, particularly the reduced cost of exploration and monitoring. Geophysics can help both to identify and to eliminate possible ore bodies prior to the more expensive and time-consuming drilling phase. The use of remote sensing and airborne methods enables exploration over a wider area and in less time. Satellite data can be gathered continuously and over long periods and data can be stored digitally, allowing easy processing and distribution of data. These methods also reduce possible damage to the environment and have the advantage of identifying likely ore bodies which have little or no surface expression or that may be covered by vegetation and sediment.	9.5.5 H3 • Identifies and explains four different benefits .... 4 • Identifies and explains three different benefits .... 3 • Identifies, but fails to explain, four different benefits .... 2 • Identifies up to two different benefits without explanation 1
	(ii)	One property of earth materials that can assist geophysical exploration is their magnetic susceptibility, which is the magnetic response of different materials. Iron-bearing minerals are often found in large quantities associated with other metal ferrous ores.	9.5.1 H3 • Successfully identifies a geophysical property and provides characteristics of the property that assist geophysical exploration methods .... 2 • Successfully identifies a geophysical property 1
	(iii)	The airborne magnetometer survey, which identifies anomalies in the magnetic field.	9.5.5 H1 • Successfully identifies an appropriate geophysical method 1

Question 29 **Medical Physics**

		Sample answer	Syllabus content, course outcomes and marking guide
(a)	(i)	The Doppler effect is the apparent change in frequency when there is relative motion between the source of the reflected wave (i.e. the individual red blood cells which are moving towards and away from the receiver) and the observer (i.e. the transducer). Applications: To locate blockages which cause blood flow to slow down in arteries. To monitor the hearts of foetuses. To diagnose ruptures and/or lesions in vascular tissue. To locate leakages in heart valves.	9.6.1 H8, H13 • Correct description of the Doppler effect AND • Correct identification of one cardiac problem that can be detected with Doppler ultrasound. . . . . 2 • Correct description of the Doppler effect OR • Correct identification of one cardiac problem that can be detected with Doppler ultrasound. 1
	(ii)	$Z = \rho v$ $= 1076 \times 1580$ $= 1700000$ kg m^{-2} s^{-1} OR 1.7 rayl $\frac{I_r}{I_o} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$ $= \frac{(400 - 1700000)^2}{(400 + 1700000)^2}$ $= 0.999$ $= 99.9\%$ Ultrasound would not be recommended for use on the lungs because only 0.1% of the incident signal is available to probe the lungs.	9.6.1 H8, H13, H14 • Correctly determines value of Z AND • Correctly determines value of I_r to I_i ratio AND • Gives appropriate recommendation. . . . . 3 • Correct value of Z AND • Gives appropriate recommendation. . . . . 2 • Correct value of Z OR • Gives appropriate recommendation. 1

Question 29 **Medical Physics (Continued)**

Sample answer	Syllabus content, course outcomes and marking guide
(b) (i) Total internal reflection  Incident light ray The outside of the optic fibre have a higher refractive index than the interior, which causes light impinging on the walls to undergo total internal reflection. The fibres are very long and thin, so that light entering will always meet the side of the fibre with an angle greater than the critical angle. This means that the light is reflected inside the fibre repeatedly until it emerges at the other end.	9.6.2 H13 • Correctly labelled diagram AND • Provides detailed explanation of how total internal reflection applies to the apparatus .... 3 • Correct diagram AND • Identifies that total internal reflection is involved .... 2 • Correct diagram OR • Identifies that total internal reflection is involved 1
(ii) In a coherent bundle, the arrangement of fibres at one end is identical to the arrangement at the other end. The coherent bundle is used to transmit an image focused onto one end of the bundle to the other end where it can be viewed with an eye-piece or a camera. The fibres of the incoherent bundle at one end do not match the other end and these fibres are used to transmit light from a light source at one end to illuminate the organ being examined at the other end inside the patient's body.	9.6.2 H13 • Detailed explanation of the role and structure of coherent and incoherent bundles .... 3 • Identifies role and structure of both type of bundles .... 2 • Identifies the role and structure of the coherent bundle OR • Identifies the role and structure of the incoherent bundle 1
(c) CT: creates cross-sectional and 3-D images of organs; although patients are subjected to higher doses of radiation, the images produced are of a higher quality; digital CT images can be enhanced, manipulated and rapidly exported to other physicians to aid diagnosis; better soft-tissue analysis and the ability to remove elements in the image pathway make for better diagnosis. PET: provides images of body function, not just its structure (shows physiological function over and above anatomy); advancement in development of different radio-traces allows scans of whole-body chemistry; powerful tool for detecting extremely small cancerous tumours, allowing for early detection and treatment; Although still poses a radiation risk (due to ingestion of radiopharmaceuticals). Conclusion: Each imaging technique reveals different information about structure and function of tissues in a painless, non-invasive and cost-effective manner for patients. Advancements in these imaging techniques have greatly extended the ability of medical practitioners to efficiently detect and subsequently treat medical problems more successfully.	9.6.2, 9.6.3 H4, H13, H16 • Gives a well-structured response detailing the relevance, usefulness and limitations of both CAT scans AND PET scans and provides a clear evaluation of these medical techniques .... 7 • Gives a fairly well structured response on the advantages and limitations of BOTH techniques, but NO evaluation .... 5–6 • Gives a less coherent response that focuses only on the advantages and disadvantages of either CAT scans or PET scans .... 3–4 • Gives a response covering only the advantages OR disadvantages of CAT scans OR PET scans 1–2

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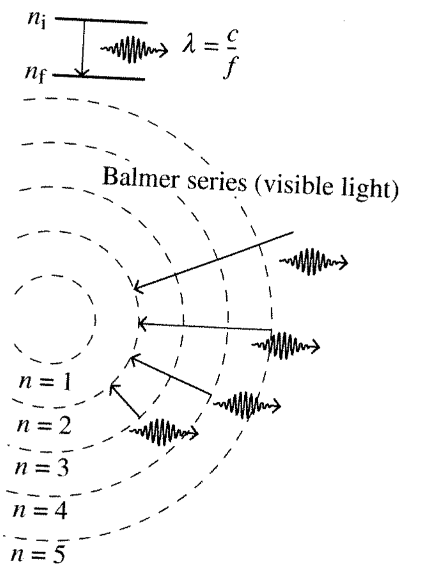
Question 29 Medical Physics (Continued)

		Sample answer	Syllabus content, course outcomes and marking guide
(d)	(i)	Hydrogen nuclei align themselves to the strong external magnetic field and their spin axes precess (at the Larmor frequency) about the axis of the magnetic field. When radio-frequency pulses of increasing frequency are applied, nothing happens until this frequency matches the Larmor frequency of precession. At this frequency, the nuclei absorb energy from the radio-frequency wave (hence the blip on the output signal), flip through 90° and are in a state of resonance.	9.6.4 H7, H8, H9, H13 • Clearly describes the alignment and precession of nuclei AND • Explains the resonance of nuclei at the Larmor frequency AND • Relates the absorbed energy to the output signal . . . . 3 • Provides a reasonable description of precession AND • Provides a reasonable description of the resonance of nuclei . . . . 2 • Identifies that the resonance of nuclei occurs at the Larmor frequency. 1
	(ii)	After removal of the radio-frequency pulse, the resonating hydrogen nuclei flip back to their lower energy states and emit weak radio signals in the process. The different relaxation times of nuclei of different tissues are captured and processed, and the digital information is used by the computer to create the magnetic resonance images.	9.6.4 H7, H8, H13 • Explains how energy is released on the relaxation of H_2 nuclei AND • Explains how differences in the relaxation times are digitally processed to produce images . . . . 2 • Explains the relaxation of nuclei OR • Explains how different rates of energy release by nuclei are processed to create images 1
	(iii)	Cancerous tumours are very fast growing and are characterised by relatively high concentrations of blood. These cancerous tissues are therefore very water bound and vascular, and this is picked up on T1-weighted images, especially if a contrast agent (such as gadolinium compound) is added. In this way excellent resolution and contrast of abnormal growths and normal tissue is obtained in magnetic resonance images.	9.6.4 H8, H13 • Explains the different relaxation times and numbers of nuclei of cancerous and normal tissue AND • Discusses the digitised contrasting that results when contrasting agents are added . . . . . . 2 • Identifies that cancerous tumours have markedly different relaxation times than normal tissue OR • Relates the variation in relaxation times to the contrast in the MR images 1

Question 30 Astrophysics Sample answer			Syllabus content, course outcomes and marking guide
(a)	(i)	Atmospheric turbulence limits the resolving power of a ground-based telescope. This results in problems when trying to observe multiple star systems, star formation in galaxies, and possible planets outside our solar system. Adaptive optics, using computers to regularly change the shape of mirrored telescopes can reduce the blurring effect of this turbulence. It provides appreciably sharper images and an additional gain in contrast.	9.7.1 H1 • One clearly identified problem AND • One method of overcoming the problem . 2 • One clearly identified problem OR • One method of overcoming a problem . . 1
	(ii)	$D = \frac{1}{p}$ $p = \frac{1}{D}$ $= \frac{1}{30}$ $= 0.033$ arc seconds $D = \frac{1}{p}$ $= \frac{1}{0.001}$ $= 1000$ parsecs With a parallax of 0.001 arc seconds, a telescope can view stars at a distance of 1000 parsecs. This is a considerable increase in observable distance, allowing more observation and collection of data with much greater precision.	9.7.2 H7 • Correct calculation of parallax AND • Comprehensive comparison of the difference between the parallax angles and what they allow to be determined . . . . . . 3 • Correct calculation of parallax AND • Some comparison of the difference between the parallax angles and what they allow to be determined. . . . . 2 • Correct calculation of parallax OR • Brief comparison of the difference between the parallax angles and what they allow to be determined. 1

Question 30 **Astrophysics (Continued)**

Sample answer	Syllabus content, course outcomes and marking guide
(b) (i) The fusion reaction in the core of a star releases vast amounts of light and energy of all frequencies. When atoms are excited, their outer-shell electrons may absorb enough energy to jump to higher-level orbits. They do not stay in the higher orbits, but drop back, releasing the acquired energy as electromagnetic radiation of a frequency characteristic of that particular atom (or element). When a star's spectrum is separated with a prism or diffraction grating, sets of discrete lines are seen. Atoms of a specific element emit a set of discrete wavelengths rather than a continuous spectrum. This atomic spectrum can be used as a key identifier for an element. From the Bohr model: $\Delta E = hf = 13.6\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ eV  Line spectra of elements are matched with absorption spectra from stars to identify which elements are present in stars.	9.7.3 H10 • Comprehensive description of how emission spectra are formed and how they are used to identify elements found in stars AND • A clearly drawn diagram of the process . 3 • A sound description of how emission spectra are formed and how they are used to identify elements found in stars AND • A clearly drawn diagram of the process . 2 • A sound description of how emission spectra are formed and how they are used to identify elements found in stars OR • A clearly drawn diagram of the process . 1
(ii) Stars exhibit spectral emissions which are indicative of the elements within that star. A star's absorption spectrum consists of narrow dark lines of definite wavelengths superimposed on a bright continuum. The darker lines are formed in a cooler layer of low-density gas, the stellar chromosphere, which lies above the hotter photosphere. Much of the information can be determined by comparing these spectra with spectra obtained from blackbodies. By comparing the intensity versus wavelength curves for real stars with those of blackbodies the surface temperature can be obtained. Similarly, comparison of absorption spectra with blackbody spectra can be used to determine chemical composition. These stellar spectra can be used to determine information about the spectral class, luminosity, density, chemical composition and rotational and translational velocities of stars.	9.7.3 H10, H13 • Clear understanding of how three different pieces of information are obtained from stellar spectra . . . . 3 • Clear understanding of how two different pieces of information are obtained from stellar spectra . . . . 2 • Clear understanding of how a single piece of information can be obtained from stellar spectra 1

Question 30 **Astrophysics (Continued)**

	Sample answer	Syllabus content, course outcomes and marking guide
(c)	Variable stars are stars whose luminosity (i.e. their brightness) changes. These changes can range from a fraction of a magnitude to as much as twenty magnitudes over periods of less than a second to years, depending on the type of variable star. There are over 30 000 variable stars known and catalogued, and many thousands more are suspected to be variable stars. A number of reasons have been suggested as to why variable stars change their brightness. Pulsating variables, for example, may expand and contract due to their internal forces changing. An eclipsing binary, on the other hand, may decrease in intensity when it is eclipsed by a faint companion and then brighten when the other star moves out of the way. The different causes of light variation in variable stars provides the driving force for classifying the stars into different categories. Variable stars are classified as either intrinsic, where changes have physical causes such as pulsation or eruption in the star or stellar system, or extrinsic, where changes are caused by the eclipse of one star by another or by the effects of stellar rotation (eclipsing binaries and rotating variables). Research on variable stars provides information about stellar properties such as mass, radius, luminosity, temperature, internal and external structure, composition and evolution. This information can then be used to understand other stars. Cepheid variables have played a pivotal role in determining the distances to distant galaxies and the age of the universe. Supernovae arouse public interest with their powerful explosions (especially, for instance, the great supernova of 1987 that went off in the Large Magellanic Cloud). Other famous stars include the Mira variables or long-period variable stars, and eclipsing binaries. Variable stars have also provided information about the interiors and evolution of stars. They are also extremely useful as distance indicators, allowing astronomers to measure the distance to the clusters and galaxies where they are found. Historically the study of variable stars has changed our understanding of the scale of the Universe.	9.7.5 H3, H4 • Detailed and comprehensive assessment of the importance of variable stars AND • A comprehensive discussion of their use in discovering information about the universe .... 6–7 • Comprehensive assessment of the importance of variable stars AND • A sound discussion of their use in discovering information about the universe .... 4–5 • General discussion of the importance of variable stars AND • Some discussion of their use in discovering information about the universe ...... 2–3 • Some mention of the importance of variable stars OR • A mention of their use in discovering information about the universe 1
(d)	(i) The apparent magnitude of a star is the magnitude that the star appears to have as viewed from the Earth. Its absolute magnitude is defined to be the apparent magnitude the star would have if viewed from a standard distance of 10 parsecs. Using these it is possible to deduce a formula linking the magnitudes to the star's distance from the Earth. $M = m - 5\log\left(\frac{d}{10}\right)$	9.7.4 H13 • Comprehensive description of the relationship between absolute and apparent magnitudes and distance AND • Correct completion of both table values . 3 • Some description of the relationship between absolute and apparent magnitudes and distance AND • Correct completion of one table value... 2 • Description of the relationship between absolute and apparent magnitudes and distance OR • Correct completion of one table value .. 1

Star	*Absolute magnitude*	*Apparent magnitude*	*Distance (pc)*
Sirius	–1.41	–1.44	**10.1**
Deneb	–8.73	**1.25**	990

Question 30 **Astrophysics (Continued)**

	Sample answer	Syllabus content, course outcomes and marking guide
(d) (ii)	Stars form in the dense molecular clouds within galaxies. Gravity is the main force responsible for stellar formation, and the mass of material that forms a star largely determines its life and its ultimate fate. Protostars form when sections of these giant molecular clouds start to collapse. The clouds are initially diffuse enough that they do not contract unless something triggers an increase in the density of some regions within a cloud. This gravitational collapse does not result in a single, massive star. Instead, the cloud tends to fragment into smaller denser regions. These dense regions then collapse due to gravitational attraction between the particles. Individual gas or dust particles move in towards the centre of the collapsing region, losing gravitational potential energy. As the total energy of the system is conserved, the loss of gravitational energy is balanced by an increase in the kinetic energy of the particles. These particles then undergo more collisions, which in turn raises the temperature of the gas. At this stage further collapse is only possible if the cloud can radiate away the thermal energy so that the radiation pressure outwards remains lower than the inward gravitational pull. If the density and temperature in the core of the protostar become high enough, thermonuclear fusion of hydrogen commences.	9.7.6 H6 • Sound description of how stars are formed AND • A clear outline of the physical processes involved .... 2 • Sound description of how stars are formed OR • A clear outline of the physical processes involved 1
(iii)	Photometry is the measurement of the intensity and hence brightness of stars. Photographic methods were commonly used in the first half of the 20th century, but the non-uniformity of the photographic emulsion meant that the attainable accuracy was limited. Also, the emulsions used suffered from reciprocity failure, meaning that doubling the exposure time would not record stars twice as faint. Photoelectric photometers (PEPs) became available in the 1950s. They had the advantages of much greater efficiency (they could measure fainter stars) and accuracy, as well as giving a linear response (i.e. twice as many photons produced twice as much current, up to a limit). Silicon-based solid-state charge-coupled device (CCD) detectors are now in widespread use in photometry. They offer the linear response of a PEP detector with the advantage of measuring many stars simultaneously (i.e. all stars within the field of view). CCDs have up to 90% quantum efficiency and a deep exposure can go many times fainter than a photographic plate taken with the same instrument. Due to the regular pixel arrangement on a CCD (as opposed to the randomly positioned silver halide grains in an emulsion on photographic paper), the photometric errors from a CCD are much smaller and can be much better quantified.	9.7.4 H3 • Sound general comparison of the differences between photo-electric technologies and photographic techniques .... 2 • Gives a brief general comparison of photo-electric technologies and photographic techniques 1

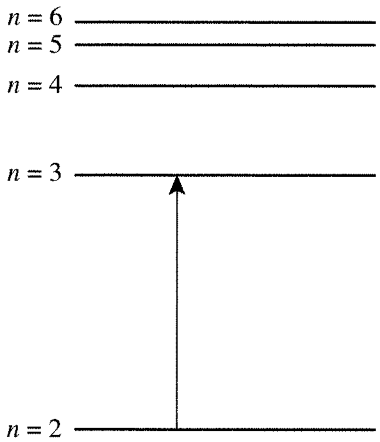
Question 31 From Quanta to Quarks

		Sample answer	Syllabus content, course outcomes and marking guide
(a)	(i)	Bohr's model was limited in that: it was not successful in predicting the spectra of elements with more than one electron in the outer shell; it provided no explanation for the relative intensity of the different spectral lines; it provided no explanation for the Zeeman effect.	9.8.1 H9 • Correctly identifies two limitations ..... 2 • Correctly identifies one limitation 1
	(ii)	$\Delta E = 5.9 \times 10^{-6}$ eV $= 5.9 \times 10^{-6} \times 1.602 \times 10^{-19}$ J $= 9.45 \times 10^{-25}$ J $\Delta E = hf$ $= \frac{hc}{\lambda}$ $\lambda = \frac{hc}{\Delta E} = \frac{6.626 \times 10^{-34} \times 3.00 \times 10^{8}}{9.45 \times 10^{-25}}$ $= 21$ cm	9.8.1 H8, H10 • Correctly determines λ .... 3 • Uses correct formula but makes a mistake in substitution .... 2 • Gives correct value but does not show working 1
(b)	(i)	A cloud chamber was used to create an environment which was both refrigerated (using dry ice) and supersaturated with alcohol vapour (using methylated spirits). The alpha and beta rays were provided by an appropriate radioactive source. Vapour tracks appeared in the chamber because the rays caused ionisation of the air molecules, and alcohol molecules were attracted to and condensed on the ions to form visible vapour tracks indicating the paths of the rays. Some vapour tracks were about 1.5 to 2.5 cm long and were quite intense. These tracks were formed by alpha rays. Some vapour tracks, though clearly defined, were less intense and were 6 to 10 cm long. These tracks were formed by beta rays.	9.8.3 H10 • Correctly describes the experiment, including the need to provide refrigeration and supersaturation with alcohol vapour AND • Correctly explains tracks being formed by the rays ionising air molecules and the charged ions then attracting molecules of alcohol AND • Explains the identification of alpha rays or beta rays .... 3 • Correctly describes the experiment, including the need to provide refrigeration and supersaturation with alcohol vapour AND • Correctly explains tracks being formed by the rays ionising air molecules and the charged ions then attracting molecules of alcohol .... 2 • Correctly describes the experiment, including the need to provide refrigeration and supersaturation with alcohol vapour OR • Correctly explains tracks being formed by the rays ionising air molecules and the charged ions then attracting molecules of alcohol OR • Explains the identification of alpha rays or beta rays 1

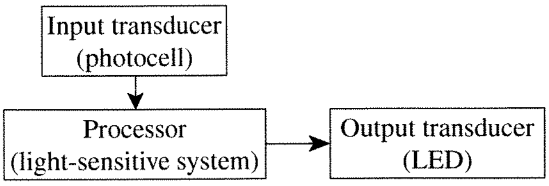
Question 31 From Quanta to Quarks (Continued)

	Sample answer	Syllabus content, course outcomes and marking guide
(b) (ii)	A nucleon is a particle found in the nucleus of atoms. Nucleons include protons and neutrons. Nucleons bind together in a nucleus by means of residual strong interactions. Protons and neutrons have different electrical properties. Protons have a positive elementary charge, while neutrons have no electric charge. The mass of a proton is slightly less than that of a neutron.	9.8.3 H10 • Defines 'nucleon' correctly AND • Contrasts two properties of nucleons.... 3 • Defines 'nucleon' correctly AND • Contrasts one property of nucleons OR • Contrasts two properties of nucleons.... 2 • Defines 'nucleon' correctly OR • Contrasts one property of nucleons 1
(c)	De Broglie's hypothesis states that all matter particles have an associated wavelength, which is inversely proportional to the momentum of the particle. $\lambda = \frac{h}{mv}$ When the idea of standing electron waves was applied to the known radius of orbit of the hydrogen electron, based on the Bohr model, the predicted electron wavelength fitted exactly with the circumference based on the Bohr radius to produce a standing wave for electron stability. Thus the de Broglie hypothesis provided the reason why Bohr's stationary states existed, and clearly showed why electrons do not fall into the nucleus (because only energy levels corresponding to standing waves are occupied). Davisson and Germer accelerated electrons to high speed and then directed the electron beam at a nickel crystal. They then detected and measured the direction at which electrons left the crystal. (A diagram could be used to support the answer.) They found that the electrons were diffracted in the same way that X-rays with the same wavelength as the electrons were diffracted. By measuring the angle of diffraction, knowing the crystal lattice spacing and using Bragg's law they determined the wavelength of the diffracted electrons and found it agreed with the theoretical value calculated using de Broglie's equation $\lambda = \frac{h}{mv}$. This experiment proved not only that electrons behaved like waves, but also that they had the wavelength predicted by de Broglie's theory. These major advances in scientific understanding and technology have changed the direction of scientific thinking by showing that electrons can behave like both waves and particles, not particles alone as was believed before that time.	9.8.2 H1, H8 • Answer demonstrates an extensive knowledge of de Broglie's proposal, how it explains the stability of the electron orbits in the Bohr atom, the experiments of Davisson and Germer and evaluates how major advances in scientific understanding and technology have changed the direction of scientific thinking................. 6–7 • Answer demonstrates a thorough description of de Broglie's proposal, how it explains the stability of the electron orbits in the Bohr atom, the experiments of Davisson and Germer and how they validated the proposal .... 5 • Answer shows a basic knowledge of de Broglie's proposal and the experiments of Davisson and Germer OR • Answer demonstrates a sound knowledge of either de Broglie's proposal or the experiments of Davisson and Germer . 3–4 • Answer shows a limited knowledge of de Broglie's proposal and the experiments of Davisson and Germer OR • Answer shows a basic knowledge of either de Broglie's proposal or the experiments of Davisson and Germer.............. 1–2

Question 31 From Quanta to Quarks (Continued)

	Sample answer	Syllabus content, course outcomes and marking guide
(d) (i)	The diagram shows the energy of the stationary states in which an electron can exist in an atom. The lower the horizontal line, the lower the energy of that state. The length of the vertical arrow gives the energy of photon emitted when an electron falls from an initial state n_i to a final state n_f. n is the principal quantum number.	9.8.1 H10, H14 • Describes the horizontal lines AND • Describes the vertical arrows AND • Identifies the name given to the number n .... 3 • Any two of the above................ 2 • One of the above 1
(ii)	The longest wavelength corresponds to an emitted photon with the lowest energy. Therefore $n_i = 3$, $n_f = 2$. $\frac{1}{\lambda} = R_H\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ $= 1.097 \times 10^7 \times \left(\frac{1}{2^2} - \frac{1}{3^2}\right)$ $= 1523611.1$ $\lambda = 6.56 \times 10^{-7}$ m	9.8.1 H8, H14 • Correctly identifies $n_i = 3$ and $n_f = 2$ AND • Correctly calculates the wavelength .... 2 • Correctly identifies $n_i = 3$ and $n_f = 2$ OR • Correctly calculates the wavelength for chosen n_i and n_f 1
(iii)	Absorption of a photon means an electron moves up from a state with $n = 2$ into a state with $n = 3$. This process can therefore be illustrated by an arrow going up. 	9.8.1 H10, H14 • Correctly outlines the absorption diagram AND • Correctly draws the diagram .... 2 • Correctly outlines the absorption diagram OR • Correctly draws the diagram 1

Question 32 **The Age of Silicon**

		Sample answer	Syllabus content, course outcomes and marking guide
(a)	(i)	Integrated circuits are similar to transistors, in that they are produced with semiconducting materials employing p–n junctions; many integrated circuits and transistors may be incorporated on the same silicon chip; they have similar durability; they operate over the same temperature ranges.	9.9.1 H4 • At least two correct similarities . . . . 2 • One correct similarity 1
	(ii)	Many electronic systems use transducers (devices that convert a signal from one form to another). An input transducer usually changes non-electrical signals into electrical signals (e.g. photocells or solar cells convert light energy into electricity, and may be used for the automatic exposure control in cameras). When processed information is to be converted into a form understood by humans, output transducers are used to convert electrical signals into other forms (e.g. sound in a speaker or light in an LED). In this way, transducers make the connection between an electronic process and the environment.  	9.9.3 H3 • Comprehensive description of an electronic system, including definitions of input and output transducers with a correctly explained example . . . . 3 • Sound description of an electronic system AND • Definitions of input and output transducer OR • A correctly explained example . . . . 2 • Brief description of an electronic system AND • Definitions of input and output transducers OR • A correctly explained example 1

Question 32 **The Age of Silicon (Continued)**

Sample answer

Syllabus content, course outcomes and marking guide

(b) (i) From $V = IR$, $I = \frac{V}{R}$.

For the output voltage to approach 0 V, the transistor must be conducting and the collector–emitter voltage is then 0.2 V.

$$\text{collector current} = \frac{V}{R} = \frac{6.0 - 0.2}{1200} = \frac{5.8}{1200} = 4.8 \text{ mA}$$

If the input voltage is 6 V, the transistor is conducting and the output voltage will be 0.2 V (which is almost 0).

9.9.2 H7

- Correct calculation of the maximum collector current

AND

- A comprehensive explanation of why V_{OUT} is almost equal to 0, based on resistances 3

- Correct calculation of the maximum collector current

AND

- A brief explanation of why V_{OUT} is almost equal to 0 2

- Correct calculation of the maximum collector current

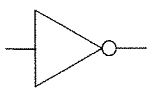
OR

- A brief explanation of why V_{OUT} is almost equal to 0 1

(ii) This circuit utilises a transistor and represents a voltage inverter, which inverts the voltage of the input signal. A NOT gate has one input and one output, and the output signal is inverted. This type of gate is often called an inverter gate. There is an output from the gate when there is no input, and similarly there is no output wherever there is an input.

Input	*Output*
1	0
0	1

NOT gate



9.9.5 H13

- Clear understanding of the operation of this circuit and a NOT gate

AND

- A correctly constructed truth table

AND

- A correct diagram of a NOT gate. 3

- Clear understanding of the operation of this circuit and a NOT gate

AND

- A correctly constructed truth table

OR

- A correct diagram of a NOT gate. 2

- A brief understanding of the operation of this circuit and that of a NOT gate

OR

- A correctly constructed truth table

OR

- A correct diagram of a NOT gate. 1

Question 32 The Age of Silicon (Continued)

	Sample answer	Syllabus content, course outcomes and marking guide
(c)	Semiconducting materials allowed the development of integrated circuits, which gave tremendous advantages over devices such as diodes and transistors. Integrated circuits are similar in construction to transistors in that they are produced using semiconductor p–n junctions. The ability to have a large number of these incorporated on the same silicon chip allowed integrated circuits to eliminate the need for connecting wires, as all components were available to be connected on the silicon wafer and this in turn removed the need for individual connections.	9.9.1, 9.9.7 H4 • Detailed and comprehensive assessment of the advantages and disadvantages of integrated circuits using semiconducting materials, and a comprehensive discussion of physical factors that may limit the growth of computers 6–7
	The introduction of standardised integrated circuits made it practical to manufacture a vast array of electronic devices using relatively few basic building components. Although originally conceived for use in guidance systems for the military, integrated circuits have been used in a wide range of applications since they are far more durable, more compact and faster than separate components. They play an essential role in virtually every field of human activity. Whenever signals containing information are processed or wherever power needs to be controlled a multitude of integrated circuits will be found. They are vital to computers and within communications systems. Additionally, they operate at faster speeds and are more reliable.	• Comprehensive discussion of the advantages of integrated circuits using semiconducting materials, and a sound discussion of physical factors that may limit the growth of computers....................... 4–5 • General discussion of the advantages of integrated circuits using semiconducting materials, and some discussion of physical factors that may limit the growth of computers....................... 2–3
	In computers, integrated circuits have changed the way people work and the number of people actually working (as increased efficiency has reduced the numbers of workers involved). Computers, containing integrated circuits, can be found in almost every workplace, in schools and in most homes.	• Some general advantages of integrated circuits using semiconducting materials, or some mention of physical factors that may limit the growth of computers 1
	There are a number of limits that may become significant in the near future with regard to the growth of computers. The decrease in the size of circuit elements means that quantum effects, such as the de Broglie wavelength of electrons travelling through semiconducting devices, will become a significant factor. The minimum size of components on a silicon chip is limited by the wavelength used to etch them into the chip. To etch smaller devices onto silicon chips will mean that alternative methods will have to be developed. Another factor limiting the production of increasingly smaller devices is the thickness of the insulating layer of silicon dioxide on the surface of the chip.	
	Despite the numerous advantages of integrated circuits, they do have some disadvantages not least of which is their inability to handle high voltage. They operate with and can handle only relatively low voltages and therefore cannot deal with situations involving large amounts of power.	

Question 32 The Age of Silicon (Continued)

		Sample answer	Syllabus content, course outcomes and marking guide
(d)	(i)	Diagram B shows the non-inverting amplifier as it is connected so the input signal goes directly to the non-inverting input (+) and the input resistor (R_A) is grounded. $A = \frac{V_{OUT}}{V_{IN}}$ $= \frac{R_B}{R_A}$ $= \frac{4800\ \text{k}\Omega}{12\ \text{k}\Omega}$ $= 400$	9.9.6 H13 • Correctly identifies circuit diagram and correctly determines the value of the gain 3 • Correctly identifies circuit diagram AND • Correctly uses formula but incorrectly determines the value of the gain .... 2 • Correctly identifies circuit diagram OR • Correctly uses formula but incorrectly determines the value of the gain 1
	(ii)	LEDs are made from semiconducting materials and involve a p–n junction. Such devices are usually constructed of gallium arsenide. They are constructed on a base piece of semiconductor chip with specific impurities added to cause the emission of a particular colour of light. The chip is mounted on and in contact with a reflective metallic base. It is a fusion of a piece of n-type semiconductor with a p-type piece. The junction in an LED is forward biased so that when electrons cross the junction from the n- to the p-type material, the electron-hole recombination process produces light in a process called electroluminescence.	9.9.4 H7 • Sound description of the structure of LEDs and of how light is emitted across the p–n junction. .... 2 • Outline of the structure of LEDs OR • A brief account of how light is emitted across the p–n junction. 1
	(iii)	A light-dependent resistor (LDR) is a device whose resistance changes when the amount of light falling onto it changes. In low light levels, the LDR has a high resistance and allows little current through. In high light levels, the resistance of the LDR is low and it permits much more current through. It is therefore able to affect or be affected by the environment, and can act as an interface between the environment and an electrical system. LDRs are used in light-controlled switches, such as a switch to turn on lights when it gets dark and turn them off when it gets light.	9.9.3 H7 • Comprehensive comparison of the behaviour of an LDR under low light levels and under high light levels with an example of its use......................... 2 • Brief comparison of the behaviour of an LDR under low light levels and under high light levels OR • Brief description of an LDR and an example of its use......................... 1