BOARD OF STUDIES
NEW SOUTH WALES

HIGHER SCHOOL CERTIFICATE EXAMINATION

1996

SCIENCE

3/4 UNIT

PAPER 2—ELECTIVES

3 UNIT CANDIDATES: Time allowed—One hour and a half
4 UNIT CANDIDATES: Time allowed—Three hours
(Plus 5 minutes' reading time)

DIRECTIONS TO CANDIDATES

3 Unit Candidates

- Attempt TWO questions. These questions may be chosen from ANY Group.

4 Unit Candidates

- Attempt FOUR questions. These questions MUST be chosen from AT LEAST THREE Groups.

All Candidates

- Each question is worth 25 marks.
- Answer each question in a *separate* Elective Answer Book.
- Write your Student Number and Centre Number on the cover of each Elective Answer Book.
- Write the Course, Elective Name, and the Question Number on the cover of each Elective Answer Book.
- You may ask for extra Elective Answer Books if you need them.
- A Data Sheet and Periodic Table are provided as a tear-out sheet at the back of this paper.
- Board-approved calculators may be used.

CONTENTS

GROUP 1—BIOLOGY ELECTIVES

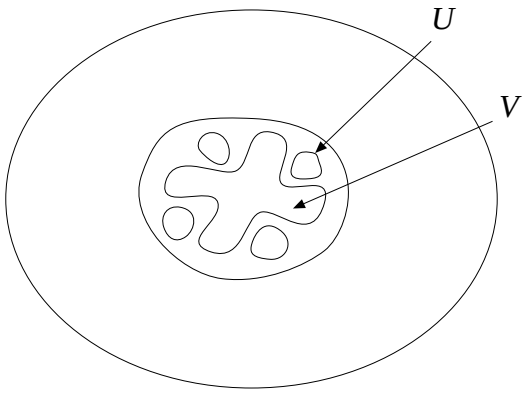
QUESTION 1. Flowering Plants and Mammals

(a) (i) Define transpiration. **4**

(ii) List THREE changes in environmental factors that would lead to an increase in the rate at which transpiration occurs.

(b) Name ONE plant hormone that is involved in the growth of plants towards light. Describe the action of that hormone. **3**

(c) This question refers to the following diagram. **3**



TS ROOT OF YOUNG PLANT

(i) Name the tissues labelled *U* and *V*.

(ii) State the function of each of the tissues labelled *U* and *V*.

(d) Use a labelled flowchart to explain how a mammal responds to an environmental stimulus. **3**

(e) (i) What are TWO features that leaf mesophyll and mammalian lungs have in common? **4**

(ii) Explain how each of these features is essential for the biological function of flowering plants and mammals.

Question 1 continues on page 4

QUESTION 1. (Continued)

(f) The table below shows the normal concentration of various substances in two body fluids. **6**

Substance	*Concentration in blood plasma* (%)	*Concentration in urine* (%)
Water	99	96
Salts	0·72	1·5
Glucose	0·10	0·00
Amino acids	0·05	0·00
Urea	0·03	2·0

(i) Explain why the concentration of each substance differs between blood plasma and urine.

(ii) What processes occur in the kidney to form urine?

(g) Carbon dioxide is fifty times more soluble in blood than it is in water at the same temperature. Account for this difference in solubility. **2**

QUESTION 2. Reproduction and Genetics

(a) Genetic engineering is a technique that can be used to manipulate the genetic material in organisms. **3**

(i) Describe TWO applications of this technique.

(ii) Explain ONE problem that could be caused by the use of this technique.

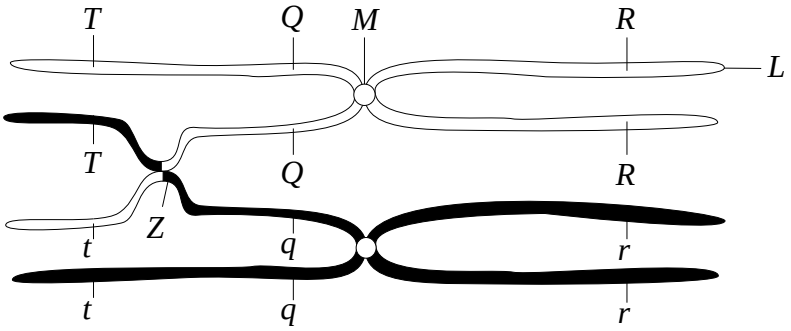
(b) State ONE way in which reproduction in viruses is: **2**

(i) *similar* to reproduction in plants and animals;

(ii) *different* from reproduction in plants and animals.

(c) What are the advantages of asexual reproduction to an organism? **2**

(d) **7**



The diagram shows a pair of chromosomes during cell division. *QRT* and *qrt* refer to alleles.

(i) What are the structures labelled *L* and *M*?

(ii) What process is occurring at *Z*, and what is its significance?

(iii) What is the name of this type of cell division?

(iv) Draw in your Answer Book the chromosomes in the gametes arising from this cell division.

(v) Will the frequencies of alleles *QRT* and *qrt* in the offspring obey Mendelian ratios? Explain your answer.

Question 2 continues on page 6

QUESTION 2. (Continued)

(e) In a particular species of beetle, the wing-covers may be either red or black. Wing-cover colour is determined by a single gene. Four pairs of virgin beetles were chosen from a laboratory population and mated to investigate the inheritance of wing-cover colour. Each female lays many eggs. **5**

The crosses and results were as follows:

Cross	*Parents*	*Progeny*
I	red × black	All black
II	black × black	75% black; 25% red
III	red × red	All red
IV	black × black	All black

(i) What is the genetic basis of wing-cover colour in this species?

(ii) Give the possible genotypes of all parents and progeny for:

1. Cross I;

2. Cross III.

(iii) For Cross IV, what further experiment(s) would need to be carried out to determine the genotype(s) of the parents?

(f) In vitro fertilisation (IVF) is a technology applied to human fertility. **4**

(i) What is meant by the term ‘in vitro’?

(ii) What medical problems may be overcome by using IVF?

(iii) Briefly describe the steps carried out in IVF.

(iv) What is one problem or concern regarding the use of IVF in humans?

(g) (i) What is the function of DNA? **2**

(ii) What features of the structure of the DNA molecule enable it to carry out its function?

QUESTION 3. Micro-organisms and Disease

(a) List: **3**

(i) THREE *similarities* between fungi and bacteria;

(ii) THREE *differences* between fungi and bacteria.

(b) The discovery of micro-organisms was aided by developments in technology. **2**

(i) Give ONE example of a technology that led to the discovery of micro-organisms.

(ii) Describe how the technology was used in the discovery.

(c) A pathologist is required to identify the cause of a skin disease. What procedures and tests would she need to carry out in order to: **5**

(i) identify the micro-organism concerned?

(ii) confirm that the micro-organism caused the disease?

(d) In what ways do the functions of *B* cells and *T* cells differ? **2**

(e) (i) What is meant by 'passive immunity'? **2**

(ii) How might passive immunity be used in medicine?

(f) (i) Name: **4**

1. ONE bacterial disease in humans;

2. ONE fungal disease in humans;

3. ONE viral disease in humans.

(ii) Select ONE of the diseases you have named, and describe how this disease may be transmitted from one person to another.

(iii) Give TWO methods that might be used to prevent the spread of this disease.

Question 3 continues on page 8

QUESTION 3. (Continued)

(g) The body responds to infection by a pathogenic micro-organism by rapidly producing antibodies. **2**

(i) What process leads to the rapid rise in antibodies?

(ii) How does this initial response differ from a response to infection by the same micro-organism six months later?

(h) When livestock are imported from overseas they may have to spend a period in quarantine. **3**

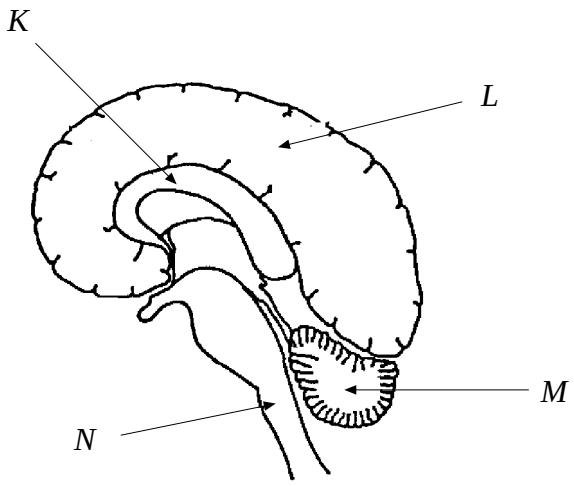
(i) What is the purpose of the quarantine period?

(ii) Quarantine is an expensive and prolonged process. What alternatives to quarantine could be proposed, and what are their disadvantages?

(i) How is it possible for an organism to be a carrier of a disease (that is, be able to transmit the disease, but not show symptoms of it)? **2**

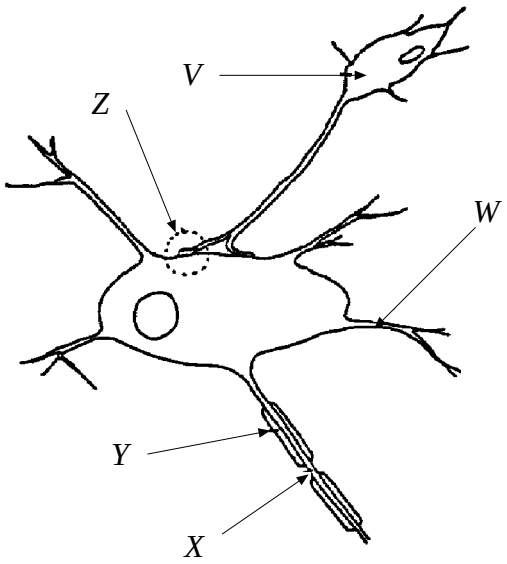
QUESTION 4. Coordination and Control

(a) This question refers to the following diagram of the human brain. **4**



In a table, give the name and function of each of the organs labelled *K*, *L*, *M*, and *N*.

(b) The diagram below shows two neurones in the central nervous system. **4**



(i) Name the structures *V, W, X, Y,* and *Z*.

(ii) Describe the process occurring at *Z* during the transmission of a nerve impulse.

(c) When grown in the garden, chrysanthemums flower in autumn. **4**

(i) What environmental stimuli might be responsible for inducing flowering?

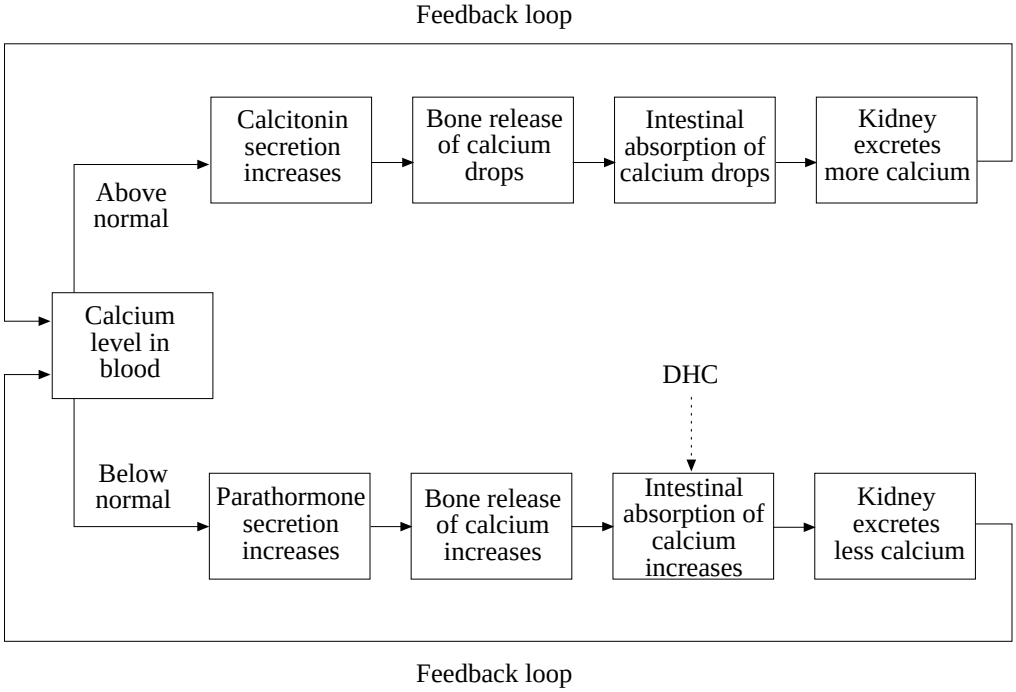
(ii) Design an experiment that would enable you to identify the stimulus for flowering in chrysanthemums.

Question 4 continues on page 10

QUESTION 4. (Continued)

(d) The diagram shows the processes involved in regulation of blood calcium levels in humans. **3**

'Biology: a human approach', Sherman & Sherman, Oxford Uni Press, 1983, p310.



Ultraviolet radiation from the Sun acts on a substance present in the skin to produce a substance called Vitamin D_3. This enters the bloodstream, is carried to the liver, and then becomes dihydroxycalciferol (DHC) which promotes the uptake of calcium from the intestine and aids in the deposition of calcium salts in the bones.

In what respects does Vitamin D_3 behave as a hormone?

(e) State ONE similarity and ONE difference between the action of hormones and the action of nerves. **2**

(f) (i) Describe a situation in which a biological process is controlled by the interaction between at least two hormones. Include the names of the hormones. **5**

(ii) Describe the role of each hormone involved in this interaction.

(iii) How does the interaction between these hormones determine the overall effect?

(g) Ethene is a widely distributed plant hormone. **3**

(i) Name ONE role of ethene in plants.

(ii) In what ways does ethene differ from other plant and animal hormones?

GROUP 2—CHEMISTRY ELECTIVES

QUESTION 5. Energy

Include physical states in all equations.

(a) (i) Calculate the standard enthalpy of formation of gaseous ammonia, NH_3, from the average bond enthalpies given. **3**

Bond	*Enthalpy* (kJ mol^{-1} at 25°C)
H—H	436
N—H	391
N≡N	945

(ii) The standard enthalpy of formation of solid glucose, $C_6H_{12}O_6$, is -1273 kJ mol^{-1}.

Write the thermochemical equation that represents the standard enthalpy of formation of glucose.

(b) (i) Write a balanced equation for the complete combustion of: **6**

1. liquid octane;

2. liquid ethanol.

(ii) 1. Discuss the problem associated with the partial combustion of octane.

2. Account for the fact that partial combustion of ethanol does not usually occur.

(iii) Use the data in the table to compare the standard enthalpy of combustion *per kilogram* of octane with that *per kilogram* of ethanol.

Compound	*Molar mass* (g mol^{-1})	*Enthalpy of combustion* ($-\Delta H_c$) (kJ mol^{-1})
Octane	114·2	5470
Ethanol	46·1	1367

Question 5 continues on page 12

QUESTION 5. (Continued)

(c) A tank holds 500 kilolitres of water at 20°C that must be heated to 80°C using propane gas as a fuel. The heat liberated on complete combustion of propane gas is 2220 kJ mol^{-1}. Assuming that only 75% of the heat generated during combustion is used to heat the water, what volume of propane gas, measured at 101.3 kPa and 298 K, is needed? **3**

(d) The thermite reaction has been used for welding massive steel structures. The reaction is **4**

$$Fe_2O_3(s) + 2Al(s) \rightarrow 2Fe(s) + Al_2O_3(s).$$

(i) Calculate the standard enthalpy change for the thermite reaction, given that

$$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s) \qquad \Delta H^0 = -3352 \text{ kJ}$$

$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s) \qquad \Delta H^0 = -1648 \text{ kJ}.$$

(ii) How much energy is liberated per gram of Fe_2O_3 used?

(iii) The enthalpy of fusion of iron is 14 kJ mol^{-1}. Write the thermochemical equation for this process.

(e) (i) Draw a *fully labelled* diagram of a galvanic cell involving zinc and silver half-cells. **5**

(ii) Write the overall equation for the cell reaction.

(iii) Calculate the standard e.m.f. for the cell at 25°C.

(iv) Briefly state how an electrolytic cell could be made involving zinc cells and silver cells.

(v) Write the half-equation for the reaction that occurs at the anode in the electrolytic cell.

QUESTION 5. (Continued)

(f) (i) Calculate the standard enthalpy change, ΔH^0, for each of the following reactions, using the data in the table. **4**

Substance	ΔH_f^0 (kJ mol^{-1})
$K_2O(s)$	–363
$KOH(aq)$	–482
$H_2O(g)$	–242
$H_2O(l)$	–286
$CO(g)$	–111
$CO_2(g)$	–394

1. $4K(s) + O_2(g) \rightarrow 2K_2O(s)$;

2. $2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$;

3. $2K(s) + CO_2(g) \rightarrow K_2O(s) + CO(g)$.

(ii) Two types of fire extinguishers are:

- water
- carbon dioxide.

Which, if either, of these fire extinguishers would be appropriate for a fire involving potassium? Explain your answer.

QUESTION 6. Atomic Structure and the Periodic Table

(a) Describe the contributions of each of the following scientists to our knowledge of atomic structure. Include in your answer a brief description of the relevant experiments they performed. **6**

(i) J. J. Thomson.

(ii) Ernest Rutherford.

(iii) James Chadwick.

(b) (i) Describe the basis of Mendeleev's classification of the elements. **4**

(ii) On what basis are the elements arranged in the modern periodic table?

(iii) Why are elements with atomic numbers 3 to 10 placed in the second period of the periodic table?

(iv) What is a lanthanide?

(c) The groups in the periodic table exhibit trends in their properties. **5**

For the halogens (group 7), describe and explain:

(i) the trend in melting-points;

(ii) the similarities in chemical reactivity;

(iii) the differences in chemical reactivity.

QUESTION 6. (Continued)

(d) (i) An element was identified as having the following electronic configuration: **6**

$$1s^2\ \ 2s^2\ \ 2p^6\ \ 3s^2\ \ 3p^6\ \ 4s^1$$

1. Name the element.

2. To which group does it belong?

(ii) Francium (Fr) does not occur naturally, and only very small amounts have been available for study. However, the behaviour of francium and its compounds can be predicted from its position in the periodic table.

1. How does the atomic radius of francium compare with the atomic radius of sodium? Explain your answer.

2. Write the balanced equation for the reaction of francium with water.

3. Write the formula for francium chloride and predict the type of bonding, stating the reason for your answer.

4. Would aqueous solutions of francium compounds conduct an electric current? Explain your answer.

(e) (i) Define the term 'orbital'. **2**

(ii) Sketch an *s* orbital and a *p* orbital.

(f) Both nitrogen and phosphorus belong to Group 5 of the periodic table. Explain why phosphorus forms a pentachloride, PCl_5, as well as a trichloride, PCl_3, but nitrogen only forms a trichloride, NCl_3. **2**

QUESTION 7. Carbon Chemistry

(a) (i) An alkanol with the formula $C_5H_{11}OH$ has several isomers. **7**

Name and draw the structural formula of an isomer of $C_5H_{11}OH$ that is:

1. a secondary alkanol;

2. a tertiary alkanol.

(ii) Name and draw the structural formula of the organic substance produced when the secondary alkanol in part (a) (i) is dehydrated.

(iii) For a primary alkanol with the formula $C_5H_{11}OH$:

1. state the reagents you would use to convert it to an acid;

2. write the equation for the reaction.

(iv) Explain why ethanol is more soluble in water than any of the alkanols with formula $C_5H_{11}OH$.

(b) Ethanol reacts with propanoic acid. **2**

(i) Write the equation, using structural formulae, to represent this reaction.

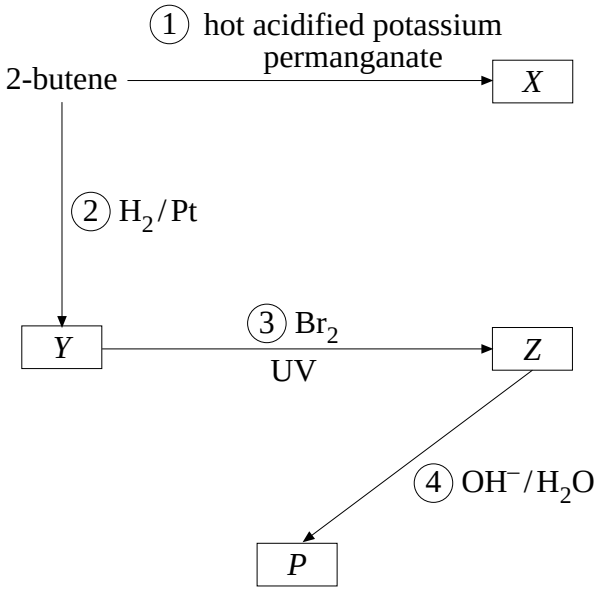
(ii) State ONE safety precaution necessary when using ethanol.

(c) Copy and complete the following table in your Answer Book. **3**

Name of compound	*Formula*	*Application/use*
Glycerol		
	HC≡CH	
Butane		

QUESTION 7. (Continued)

(d) **6**



(i) Write equations for reactions ①, ②, ③, and ④.

(ii) Name each of the compounds *X*, *Y*, *Z*, and *P*.

(e) State the trend in boiling-points of straight-chain saturated hydrocarbons. Account for this trend. **2**

(f) Write a balanced equation for the fermentation of glucose. **1**

(g) (i) Write the equation, using structural formulae, to represent the hydrolysis of an ester. **2**

(ii) Define the term ‘saponification’.

(h) (i) Name and draw the structural formula of an aromatic hydrocarbon compound. **2**

(ii) State a use for this compound.

GROUP 3—GEOLOGY ELECTIVES

QUESTION 8. Regional Geology

In this elective, you have studied *one* of the following regions.

- North-western Fold Belt
- Central and Southern Fold Belt (northern areas)
- Central and Southern Fold Belt (southern areas)
- New England Fold Belt
- Sydney Basin
- Clarence–Moreton Basin
- Great Australian Basin
- Murray Basin.

(a) (i) Name the region you have studied for this elective. **4**

(ii) Name ONE other region that has a boundary with the region you have studied.

(iii) What type of geological structure occurs at the boundary between the two regions?

(iv) Which of these two regions contains the older rocks?

(v) What is the age of the oldest rocks in the region you have studied?

(b) (i) Name an igneous rock in the region you have studied. **7**

(ii) What is the age of the igneous rock you have described?

(iii) Describe the boundary relationship between this igneous rock and surrounding sedimentary or metamorphic rocks.

(iv) How does the igneous rock affect the landscape in the region where it outcrops?

(c) (i) Name a structural feature found in the region you have studied. **8**

(ii) What type of structure is it?

(iii) What does this structure indicate about events in the geological history of the region?

(iv) Draw a *labelled diagram* to show the main components of structural features of the type you have named in part (i).

QUESTION 8. (Continued)

(d) For a geological resource (mineral deposit, fossil fuel, groundwater system, or industrial rock) of economic importance to the region you have studied: **6**

(i) Name the resource and describe its location.

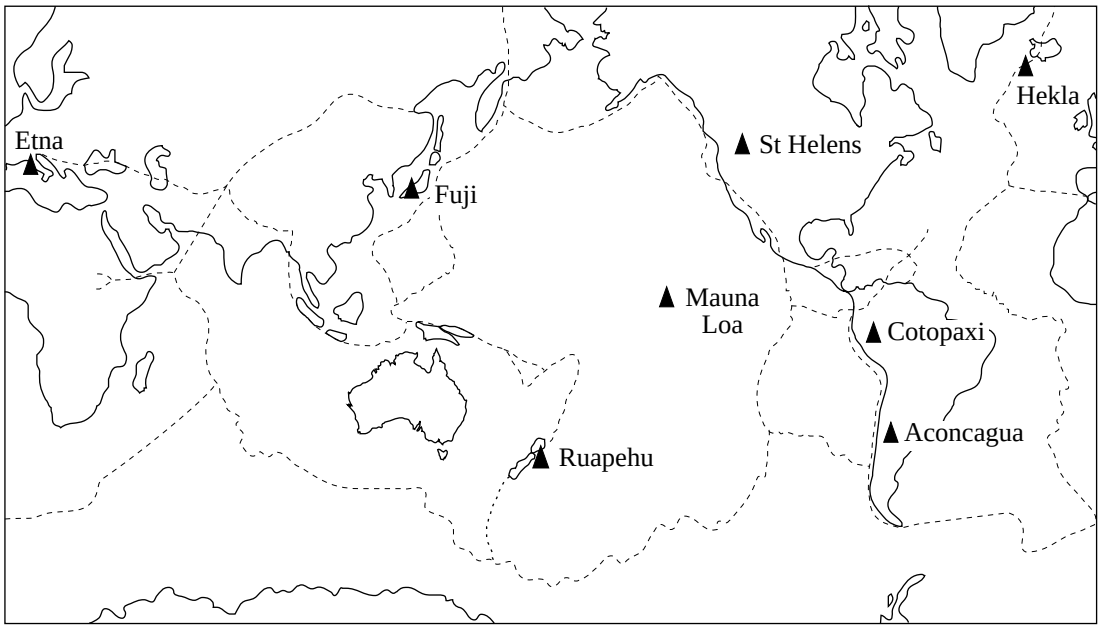
(ii) Describe the geological process by which the resource was formed.

(iii) When was the resource formed?

(iv) What is the end use of the material extracted?

QUESTION 9. Mountains

(a) The map shows a number of active volcanoes. **10**



KEY

▲ Volcano

---------- Plate boundaries

Select TWO volcanoes, indicated on the map, that have formed in different ways.

(i) Name the TWO volcanoes.

(ii) Compare and contrast the two volcanoes, mentioning:

1. position on the plate;

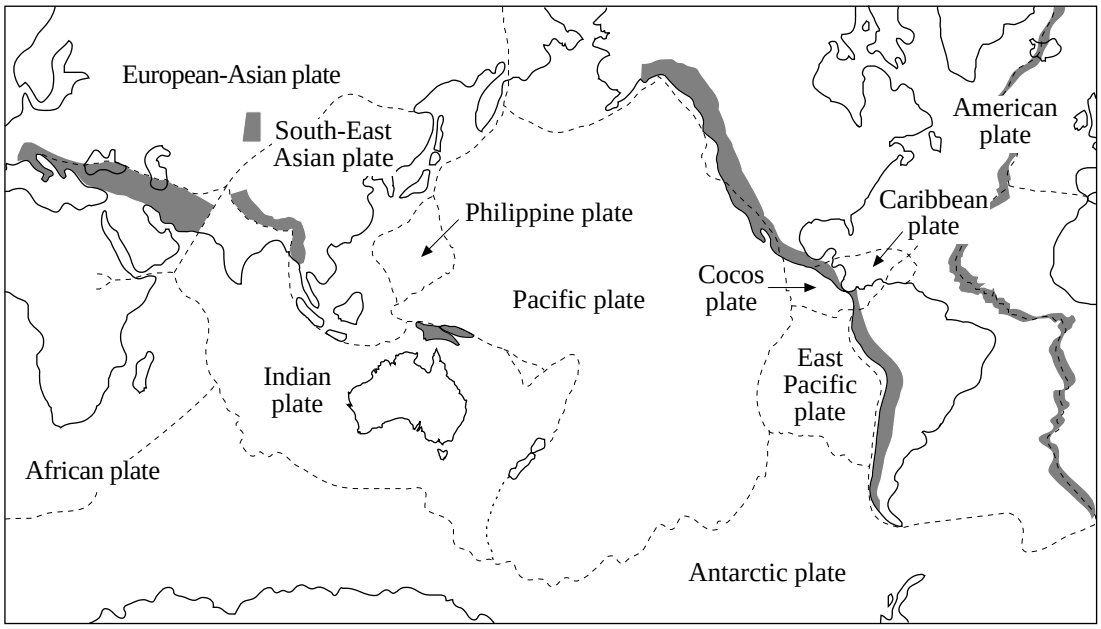
2. mode of formation;

3. composition and structure.

Use diagrams to explain your answers.

QUESTION 9. (Continued)

(b) The map shows the position of some major mountain ranges. **10**



Select TWO mountain ranges that were formed by different types of plate interactions.

(i) Name the TWO mountain ranges.

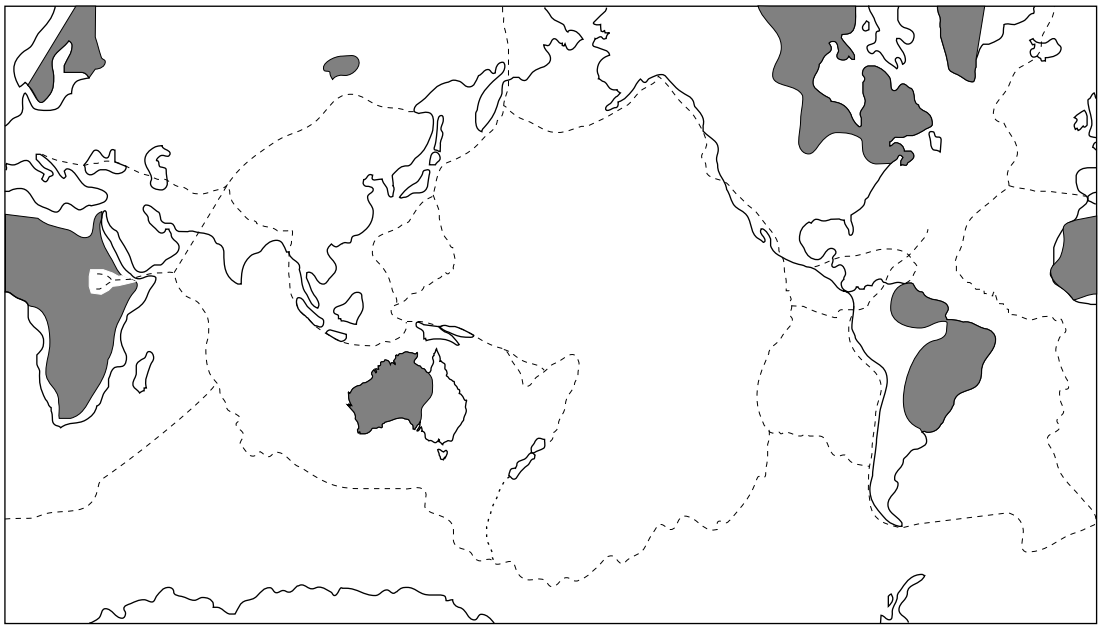
(ii) Compare and contrast the two ranges, mentioning:

1. the type of plate interaction;
2. the mode of formation;
3. common structural features;
4. rock types.

Question 9 continues on page 22

QUESTION 9. (Continued)

(c) The map shows ancient shield areas found on many continents. **5**



KEY

Shield area

Plate boundaries

(i) Explain the formation of a shield area.

(ii) What rock types are typically found in a shield area?

GROUP 4—PHYSICS ELECTIVES

QUESTION 10. Electromagnetism

(a) (i) Draw a diagram showing a long solenoid carrying a current. Draw at least six magnetic field lines produced by this current. Indicate the direction of the magnetic field. **4**

(ii) Write down an equation for the flux density at the centre of the solenoid. State the units for each quantity in the equation.

(b) A proton travels in a vacuum through a magnetic field of flux density 1·5 T. The velocity of the proton is 2×10^6 m s^{-1} at an angle of 30° to the direction of the field. What force does it experience? **2**

(c) A rectangular coil, 5·0 cm by 10·0 cm, consisting of fifty turns, is placed at right angles to a magnetic field. Calculate the e.m.f. induced in the coil if the flux density varies from 0·8 T to zero in 0·02 s. **2**

(d) A current of 6 A flows in a straight wire which is then placed in a field of uniform flux density of 2×10^{-3} T. Calculate the force per unit length on the wire if it is placed: **2**

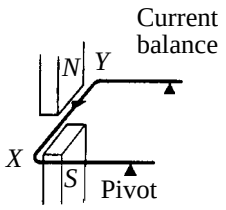
(i) perpendicular to the field;

(ii) inclined at an angle of 30° to the direction of the field.

(e) A current balance consists of a current-carrying conductor *XY* resting on pivots. The diagrams show this current-carrying conductor *XY* in four different situations. **3**

The current flows from *Y* to *X* in each case.

In diagrams *Q* and *S*, the conductor is situated inside the coil.



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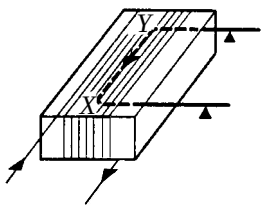

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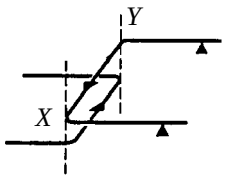

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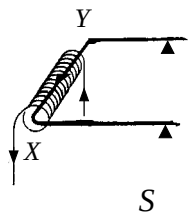


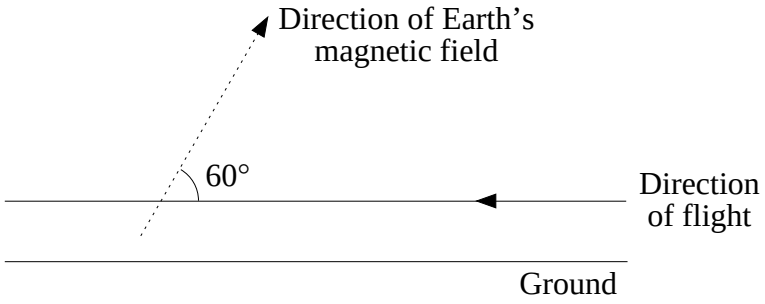
S

In which of the four cases shown will *XY* experience a force? Give the direction of the force in each case, if applicable.

Question 10 continues on page 24

QUESTION 10. (Continued)

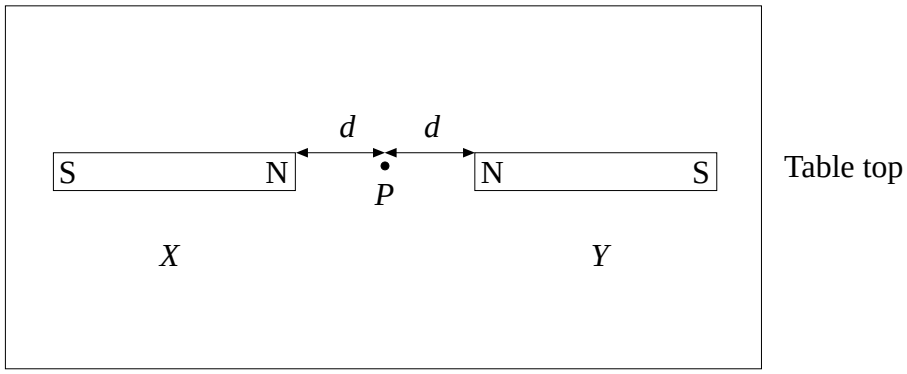
(f) An all-metal aircraft is flying horizontally at 360 km h^{-1} at an angle of 60° to the Earth's magnetic field. The Earth's magnetic flux density is $2{\cdot}0 \times 10^{-5}$ T. The wing tips are 30 m apart. **3**



(i) Calculate the e.m.f. induced along the wings from tip to tip during the flight.

(ii) The plane then descends parallel to the Earth's magnetic field without changing its speed. Calculate the e.m.f. induced along the wings from tip to tip during the descent.

(g) Magnet *X* initially produces a magnetic field of *B* tesla at point *P* on a table top. A similar magnet *Y* is then placed at an identical distance from *P*, as shown in the diagram. **2**



Determine the value of the magnetic flux density at *P*. Give a reason for your answer.

(h) The plane of a rectangular coil of cross-sectional area $3{\cdot}00 \times 10^{-2}$ m^2 sits vertically in a horizontal magnetic field of flux density 1·50 T. If the coil rotates once every 4·00 s, calculate the flux through the coil after: **2**

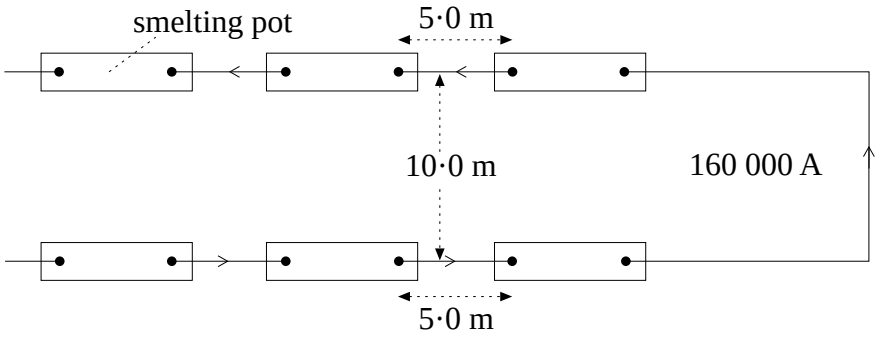
(i) 0·50 s;

(ii) 1·00 s.

QUESTION 10. (Continued)

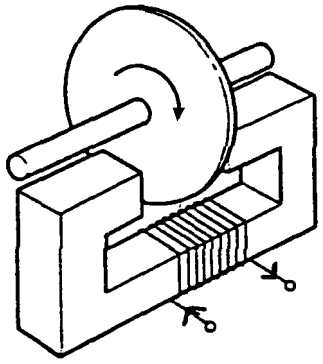
(i) In an aluminium smelter, pots are connected in series by electrical conductors. Each conductor is 5·0 m in length. During the smelting process, a direct current (d.c.) of 160 000 A flows in the direction shown in the diagram. **2**

The pots form two long lines, 1000 m long, separated by 10·0 m.



Calculate the force acting on a 5·0 m length of the conductor.

(j) A copper disk, spinning freely, is lowered between the poles of an electromagnet as shown in the diagram. **3**



(i) Describe what you would observe.

(ii) Give an explanation for your observations.

QUESTION 11. Oscillations and Waves

(a) (i) The Moon has a mass of $7{\cdot}4 \times 10^{22}$ kg, a diameter of 3476 km, and orbits the Earth at a mean distance of 384 400 km in 27·32 days. **5**

For the Moon, calculate:

1. the angular displacement in its orbit after twenty days (in radians);

2. its angular velocity about the Earth (in rad s^{-1});

3. the linear speed in its orbit;

4. the centripetal force keeping it in orbit.

(ii) If the Moon has captured rotation (that is, it keeps the same face to the Earth as it revolves round the Earth), what is the frequency of rotation about its own axis (in day^{-1})?

(b) Waves may be grouped into various types: transverse, longitudinal, and torsional. Each type can be further classified as progressive or stationary. **3**

Write down the *type* of wave and its *classification* for the following examples (more than one type may apply).

(i) Light from the Sun.

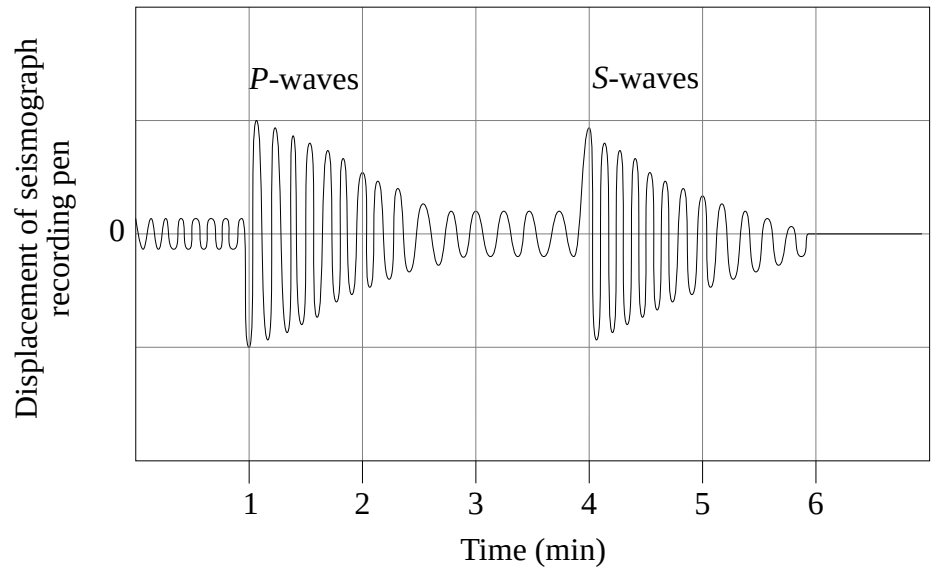
(ii) Sound in an organ pipe.

(iii) The vibrating metal in a ringing bell.

QUESTION 11. (Continued)

(c) Earthquakes generate *S*-waves and *P*-waves in the Earth. Typically, the speed of *S*-waves is about $4{\cdot}5\ \text{km s}^{-1}$ and that of *P*-waves $8{\cdot}0\ \text{km s}^{-1}$. A seismograph records *P*-waves and *S*-waves from an earthquake. The first *P*-waves arrive 3·0 minutes before the first *S*-waves, as shown in the diagram below. **4**

'Fundamentals of Physics', Halliday et al, Wiley & Sons 1993, 4th ed, Fig 18-24, p.526.



(i) From the information on the diagram, calculate:

1. the mean period of the *P*-waves in the first minute after their arrival;

2. the frequency of these *P*-waves;

3. the wavelength of these *P*-waves.

(ii) What is ONE difference, other than speed, between the *P*-waves and *S*-waves?

(d) (i) Describe, with the aid of a diagram, the motion of a conical pendulum. **3**

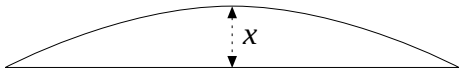
(ii) How does the motion differ from that of a simple pendulum?

(iii) What property of the conical pendulum makes it suitable as a time keeper?

Question 11 continues on page 28

QUESTION 11. (Continued)

(e) The diagram shows a violin string that was plucked and released. **3**



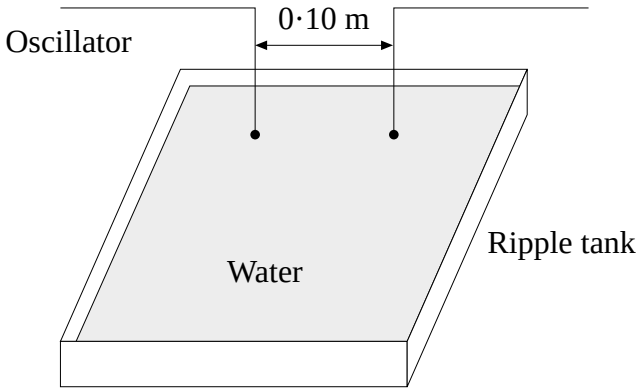
A net force of the form $F = -kx$ acts on the string to restore it to its equilibrium position.

(i) What type of motion does this violin string execute? Give your reasons.

(ii) Where will the string have its maximum kinetic energy?

(iii) From where does this kinetic energy come?

(f) A ripple tank is set up, fitted with an oscillator which has two prongs that are 0·10 m apart. **5**



The frequency of the oscillator is 5·6 Hz. Ripples spread out in concentric circles from each prong at a speed of 0·28 m s^{-1}.

(i) Calculate the wavelength of the ripples.

(ii) Draw a diagram showing the correct proportion between the wavelengths and the distance between the prongs.

(iii) Label on your diagram a feature of the water surface that undergoes maximum displacement.

(iv) Draw a diagram showing the standing wave pattern formed along the line joining the two prongs.

(g) When waves travel from one medium into another, part of each wavefront is reflected, and part is transmitted into the second medium. **2**

Which characteristic of waves remains unchanged across the boundary? Explain your answer.

QUESTION 12. Light

(a) Light travelling through a pool of water in a parallel beam is incident on the water surface. Its speed in water is $2{\cdot}2 \times 10^8$ m s^{-1}. Calculate the maximum angle that the beam can make with the vertical if light is to escape into the air, where its speed is $3{\cdot}0 \times 10^8$ m s^{-1}. **1**

(b) State, giving reasons, what you would expect to happen to the interference fringes formed in a Young's double-slit experiment, if: **3**

(i) the distance between the slits is decreased;

(ii) one of the slits is covered;

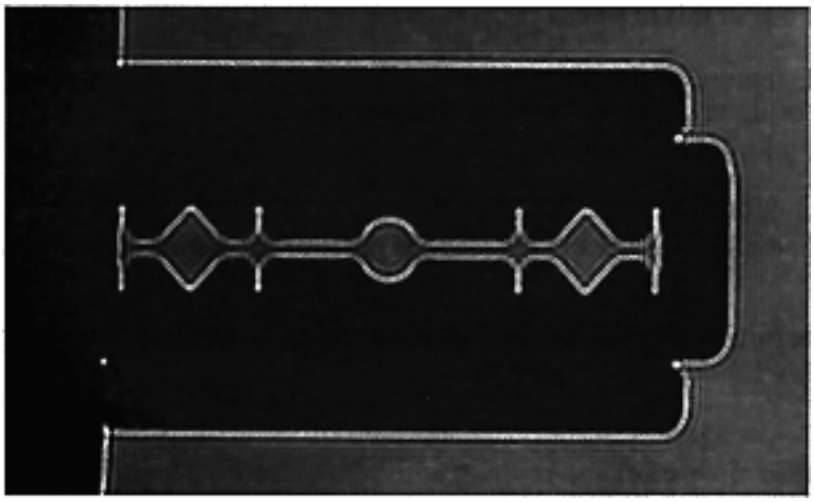
(iii) instead of monochromatic light, white light is used.

(c) (i) A beam of light may be described as 'plane polarised'. Explain what is meant by this. **2**

(ii) The human eye is not able to distinguish polarised light from unpolarised light. If a beam of light is polarised, how can this be made observable?

(d) A razor-blade was placed midway between an illuminated pinhole and a photographic film. The pattern shown below was formed. **2**

'Advanced physics', 4th edn, t Duncan, John murray, 1994, fig. 20.21, p376.



(i) What property of light waves is shown in the diagram?

(ii) Explain how such a pattern is formed.

Question 12 continues on page 30

QUESTION 12. (Continued)

(e) A luminous object (light) 5 cm in height is placed on the principal axis of a spherical concave mirror of focal length 25 cm. **8**

(i) Use rays of construction to draw TWO diagrams to scale (1 cm = 5 cm) showing the image formed when the light is placed at the following distances from the centre of the mirror:

- 50 cm;
- 10 cm.

(ii) A magnified image of the light is to be projected onto a wall 75 cm from the mirror.

Draw an arrangement (using rays of construction) showing the position of the light, the wall, and the concave mirror that would produce this image. Describe the image produced.

(f) Use a ray diagram to show how a lens could be used to obtain a magnified image of a small object. **2**

(g) Three forms of electromagnetic radiation are ultraviolet, X-rays, and γ-rays. Which has the longest wavelength? **1**

(h) State the relationship between E, n, and h as postulated by Einstein. Define any symbols you use in this answer. **1**

(i) Choose ONE feature of the photoelectric effect that is not consistent with the wave theory of light. Explain why it is not consistent. **2**

(j) What was a major difference between Newton's corpuscular (particle) theory and Huygens' wave theory regarding refraction? **1**

(k) On what observations of the behaviour of light did Young base his theory of light? **2**

GROUP 5—INTERDISCIPLINARY ELECTIVES

QUESTION 13. Biochemistry

(a) A science student was given an avocado. He carried out tests to determine whether it contained carbohydrates, lipids, amino acids and/or proteins. **4**

(i) Describe the tests he would use for each of these substances.

(ii) Describe a positive result for each of these tests.

(b) Use a labelled diagram to explain the roles of mRNA and tRNA in the synthesis of proteins. **5**

(c) Enzymes act under particular conditions. **5**

(i) Name an enzyme.

(ii) Design an experiment that would allow you to determine the optimum conditions for the action of this enzyme.

(d) (i) Name a carbohydrate that exhibits stereoisomerism. **2**

(ii) What test would you use to distinguish between the stereoisomers of this substance?

(e) When exercising vigorously, muscles may accumulate lactic acid. **4**

(i) Outline the biochemical processes leading to lactic acid production from glucose.

(ii) Why is the efficiency of muscle reduced when lactic acid accumulates?

(f) Amino acids behave as zwitterions. **2**

(i) What is meant by the term ‘zwitterion’?

(ii) What important property of amino acids arises from their behaviour as zwitterions?

(g) (i) What is meant by ‘carbon fixation’? **3**

(ii) Discuss the biological significance of the carbon fixation stage of photosynthesis.

QUESTION 14. Photography

(a) (i) Draw a labelled conventional diagram of a simple camera with a lens of focal length 50 mm, focused at infinity. **7**

(ii) Describe the image formed on the focal plane of the camera.

(iii) How would a lens of this focal length be described if it were fitted to a camera that uses 35 mm film?

(b) **7**

The photograph shows the control panel of a photomicrographic system which is attached to a microscope. The left-hand knob controls settings for film speed, and the right-hand knob controls exposure time. The shutter is electrically controlled by the switch on the lower right-hand side.

Settings on the right-hand knob range from 30 m (30 minutes) to 1/100 s ($\frac{1}{100}$ of a second). Note that many of the settings are longer than one second.

(i) Why are such long exposure times necessary in photomicrography?

(ii) What is one disadvantage of long exposure times in photomicrography?

(iii) Why is it an advantage to use an electric shutter control, rather than a mechanical control directly attached to the shutter?

(iv) The photograph of the control panel was taken using a 35 mm SLR camera fitted with a macro lens. A high *f*-number and a long exposure were used.

What characteristic of an image is controlled by the *f*-number, and why is this of great importance in close-up photography and photomicrography?

(v) The photograph of the control panel was computer enhanced to make the numbers around the control knobs clearer.

Describe two techniques that can be used in the dark-room to improve the contrast of photographic images during the printing process.

QUESTION 14. (Continued)

(c) Most cameras today are fitted with a built-in exposure meter, but professional photographers regularly use hand-held meters that are separate from the camera. **3**

(i) Describe two ways in which an exposure meter can be used to measure light intensity.

(ii) What is an advantage of TTL (through-the-lens) systems over other types of camera-mounted exposure meters?

(d) Toning is a chemical technique for altering photographic images after printing. **5**

(i) Name ONE type of toning or toner.

(ii) Give TWO reasons why toning might be used on a print.

(iii) Describe the main steps in the process of toning.

(e) Fixing is a step in the processing of black-and-white film. **3**

(i) Why is fixing necessary?

(ii) Describe the chemical reaction that takes place when film is immersed in fixer.

QUESTION 15. Physics in Medicine

(a) The photographs show images of the neck of a patient. These images were produced by normal X-ray, a CAT scan, and NMR. **4**

(i) What information, which is not available from the X-ray, is provided by:

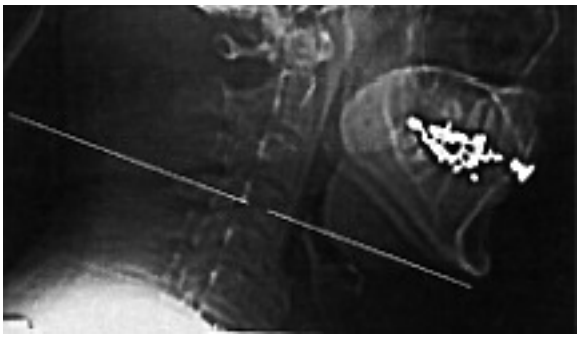
1. the CAT scan?

2. the NMR image?

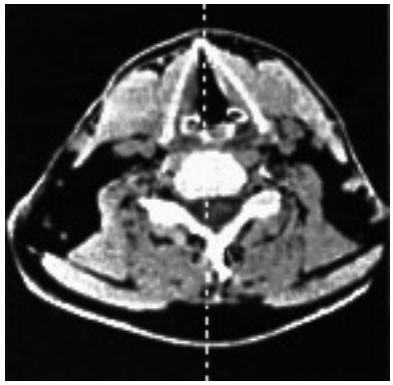
(ii) How does the production of the NMR image differ from that of the X-ray and CAT scan procedures?

X-RAY

NMR IMAGE



CAT SCAN



CAT SCAN

QUESTION 15. (Continued)

(b) (i) What is the Doppler frequency shift? **2**

(ii) How can it be used to measure blood flow in a living organism?

(c) There are a number of techniques available to measure the temperature of patients. **8**

(i) Mercury thermometers normally respond quickly to changes in temperature. Explain, using a labelled diagram, how a clinical thermometer retains a record of a patient's temperature after sampling.

(ii) Name and briefly describe TWO techniques used to obtain a continuous record of a patient's temperature.

(iii) Temperature measurements are to be made of various parts of a patient without body contact.

1. What technique could be used?

2. How does this technique provide a measure of temperature?

(d) Radiologists wear film badges as a safety precaution. **3**

(i) What forms of radiation can a film badge measure?

(ii) How does the badge record information?

(iii) Why is it important for film badges to be worn in environments where radiation is used?

Question 15 continues on page 36

QUESTION 15. (Continued)

(e) The table lists radioactive nuclei used in medicine and some of their properties. **5**

Radioactive nucleus	*Half-life*	*g-ray energy* (MeV)
^{99}Tc	6·02 hours	0·142
^{198}Au	2·698 days	0·412–1·088
^{222}Rn	3·823 days	0·047–2·44
^{131}I	8·0 days	0·364
^{125}I	60·25 days	0·0355
^{192}Ir	74·2 days	0·136–1·062
^{182}Ta	115·0 days	0·043–1·453
^{60}Co	5·26 years	1·173
^{137}Cs	30·0 years	0·662
^{226}Ra	1604 years	0·047–2·44

(i) Define the term ‘half-life’.

(ii) Select ONE radioactive nucleus that could be suitable for use in diagnosis. Give reasons for your choice.

(iii) Select ONE radioactive nucleus that could be suitable for the treatment of cancer. Give reasons for your choice.

(f) (i) What is meant by the term ‘ultrasound’? **3**

(ii) How can ultrasound be used to distinguish between bone and muscle in medical diagnosis?

QUESTION 16. Space Science

(a) The development of the space shuttle in the 1980s provided a reusable space carrier. **6**

(i) Identify THREE specific problems that were unique to the development of the shuttle.

(ii) Explain the solutions for each of these problems.

(b) Rockets are used to carry payloads, probes, and satellites into space. **3**

(i) Briefly describe the physical principles upon which a rocket operates.

(ii) Explain, using examples, the role of chemical propellants in providing the energy for lift-off.

(c) Satellites are put into space using rockets. **6**

(i) Given that:

$$v_{\text{escape}}^2 = 2G\,\frac{M_{\text{earth}}}{R_{\text{earth}}}$$

calculate the theoretical escape velocity from Earth.

(ii) The theoretical escape velocity and the actual velocity are not the same. Explain.

(iii) A satellite is to be put into geostationary orbit $3{\cdot}59 \times 10^4$ km above the surface of the Earth at the equator. Given that:

$$v_{\text{orbital}}^2 = G\,\frac{M_{\text{earth}}}{R_{\text{orbit}}}$$

calculate the orbital velocity of the satellite.

(iv) Describe TWO geophysical uses of satellites.

(d) The Apollo Program to the Moon greatly expanded our knowledge of Earth's satellite. **3**

Briefly explain a theory for the origin of the Moon, based on knowledge gained from this program.

Question 16 continues on page 38

QUESTION 16. (Continued)

(e) You are designing a small space station to be located between Earth and Mars to accommodate ten people. There will be no visiting manned probes for many years, so the station needs to be self-sufficient. **7**

Explain how you would provide:

(i) a food supply;

(ii) temperature control;

(iii) power sources;

(iv) communications;

(v) refuse removal;

(vi) atmosphere control.

DATA SHEET

Values of several numerical constants

Avogadro's constant, N_A	$6{\cdot}022 \times 10^{23}$ mol^{-1}
Elementary charge, e	$1{\cdot}602 \times 10^{-19}$ C
Faraday constant, F	96 490 C mol^{-1}
Gas constant, R	8·314 J K^{-1} mol^{-1} 0·0821 L-atm K^{-1} mol^{-1}
Mass of electron, m_e	$9{\cdot}109 \times 10^{-31}$ kg
Mass of neutron, m_n	$1{\cdot}675 \times 10^{-27}$ kg
Mass of proton, m_p	$1{\cdot}673 \times 10^{-27}$ kg
Volume of 1 mole ideal gas	
at 101·3 kPa (1 atm) and	
at 273 K (0°C)	22·41 L
at 298 K (25°C)	24·47 L
Earth's gravitational acceleration, g	9·8 m s^{-2}
Speed of light, c	$3{\cdot}00 \times 10^8$ m s^{-1}
Coulomb's constant, k	$9{\cdot}0 \times 10^9$ N m^2 C^2
Permeability constant, μ_0	$4\pi \times 10^{-7}$ N A^{-2}
Universal gravitation constant, G	$6{\cdot}7 \times 10^{-11}$ N m^2 kg^{-2}
Mass of Earth	$6{\cdot}0 \times 10^{24}$ kg
Radius of Earth	6378 km
Planck's constant, h	$6{\cdot}626 \times 10^{-34}$ J s
Density of water	$1{\cdot}00 \times 10^3$ kg m^{-3}
Specific heat capacity of water	$4{\cdot}18 \times 10^3$ J kg^{-1} K^{-1}
Speed of sound in air	340 m s^{-1}

Some Standard Potentials

$K^+ + e^-$	$\rightleftharpoons$	$K(s)$	–2·94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba(s)$	–2·91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2·87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na(s)$	–2·71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg(s)$	–2·36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al(s)$	–1·68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn(s)$	–1·18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2} H_2(g) + OH^-$	–0·83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	–0·76 V
$S(s) + 2e^-$	$\rightleftharpoons$	S^{2-}	–0·57 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0·44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0·24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–0·14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	–0·13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2} H_2(g)$	0·00 V
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(aq) + 2H_2O$	0·16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0·34 V
$\frac{1}{2} O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0·40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0·52 V
$\frac{1}{2} I_2(s) + e^-$	$\rightleftharpoons$	I^-	0·54 V
$\frac{1}{2} I_2(aq) + e^-$	$\rightleftharpoons$	I^-	0·62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0·77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag(s)$	0·80 V
$NO_3^- + 4H^+ + 3e^-$	$\rightleftharpoons$	$NO(g) + 2H_2O$	0·96 V
$\frac{1}{2} Br_2(l) + e^-$	$\rightleftharpoons$	Br^-	1·08 V
$\frac{1}{2} Br_2(aq) + e^-$	$\rightleftharpoons$	Br^-	1·10 V
$\frac{1}{2} O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1·23 V
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	$\rightleftharpoons$	$2Cr^{3+} + 7H_2O$	1·36 V
$\frac{1}{2} Cl_2(g) + e^-$	$\rightleftharpoons$	Cl^-	1·36 V
$\frac{1}{2} Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	1·40 V
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1·51 V
$\frac{1}{2} F_2(g) + e^-$	$\rightleftharpoons$	F^-	2·89 V

Alyward and Findlay, *SI Chemical Data* (3rd Edition) is the principal source of chemical data for this examination paper. Some data may have been modified for examination purposes.

PERIODIC TABLE

				1 H 1·008 Hydrogen													2 He 4·003 Helium
3 Li 6·941 Lithium	4 Be 9·012 Beryllium											5 B 10·81 Boron	6 C 12·01 Carbon	7 N 14·01 Nitrogen	8 O 16·00 Oxygen	9 F 19·00 Fluorine	10 Ne 20·18 Neon
11 Na 22·99 Sodium	12 Mg 24·31 Magnesium											13 Al 26·98 Aluminium	14 Si 28·09 Silicon	15 P 30·97 Phosphorus	16 S 32·07 Sulfur	17 Cl 35·45 Chlorine	18 Ar 39·95 Argon
19 K 39·10 Potassium	20 Ca 40·08 Calcium	21 Sc 44·96 Scandium	22 Ti 47·88 Titanium	23 V 50·94 Vanadium	24 Cr 52·00 Chromium	25 Mn 54·94 Manganese	26 Fe 55·85 Iron	27 Co 58·93 Cobalt	28 Ni 58·69 Nickel	29 Cu 63·55 Copper	30 Zn 65·39 Zinc	31 Ga 69·72 Gallium	32 Ge 72·59 Germanium	33 As 74·92 Arsenic	34 Se 78·96 Selenium	35 Br 79·90 Bromine	36 Kr 83·80 Krypton
37 Rb 85·47 Rubidium	38 Sr 87·62 Strontium	39 Y 88·91 Yttrium	40 Zr 91·22 Zirconium	41 Nb 92·91 Niobium	42 Mo 95·94 Molybdenum	43 Tc 98·91 Technetium	44 Ru 101·1 Ruthenium	45 Rh 102·9 Rhodium	46 Pd 106·4 Palladium	47 Ag 107·9 Silver	48 Cd 112·4 Cadmium	49 In 114·8 Indium	50 Sn 118·7 Tin	51 Sb 121·8 Antimony	52 Te 127·6 Tellurium	53 I 126·9 Iodine	54 Xe 131·3 Xenon
55 Cs 132·9 Cesium	56 Ba 137·3 Barium	57 La 138·9 Lanthanum	72 Hf 178·5 Hafnium	73 Ta 180·9 Tantalum	74 W 183·9 Tungsten	75 Re 186·2 Rhenium	76 Os 190·2 Osmium	77 Ir 192·2 Iridium	78 Pt 195·1 Platinum	79 Au 197·0 Gold	80 Hg 200·6 Mercury	81 Tl 204·4 Thallium	82 Pb 207·2 Lead	83 Bi 209·0 Bismuth	84 Po — Polonium	85 At — Astatine	86 Rn — Radon
87 Fr — Francium	88 Ra 226·0 Radium	89 Ac — Actinium	104	105	106												

KEY

Atomic Number — 79 — Symbol of element

Atomic Mass — 197·0 — Name of element

Gold

58 Ce 140·1 Cerium	59 Pr 140·9 Praseodymium	60 Nd 144·2 Neodymium	61 Pm — Promethium	62 Sm 150·4 Samarium	63 Eu 152·0 Europium	64 Gd 157·3 Gadolinium	65 Tb 158·9 Terbium	66 Dy 162·5 Dysprosium	67 Ho 164·9 Holmium	68 Er 167·3 Erbium	69 Tm 168·9 Thulium	70 Yb 173·0 Ytterbium	71 Lu 175·0 Lutetium
90 Th 232·0 Thorium	91 Pa 231·0 Protactinium	92 U 238·0 Uranium	93 Np 237·0 Neptunium	94 Pu — Plutonium	95 Am — Americium	96 Cm — Curium	97 Bk — Berkelium	98 Cf — Californium	99 Es — Einsteinium	100 Fm — Fermium	101 Md — Mendelevium	102 No — Nobelium	103 Lr — Lawrencium

This sheet should be REMOVED for your convenience.