UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Subsidiary Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

PHYSICAL SCIENCE **8780/03**

Paper 3 Structured Questions **October/November 2011**

1 hour 30 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
You may lose marks if you do not show your working or if you do not use appropriate units.

A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
Total	

This document consists of **20** printed pages.

Answer **all** the questions in the spaces provided.

Relevant Data, Formulae and the Periodic Table are provided in the Data Booklet.

For Examiner's Use

1 A student is using a thermistor as a thermometer. He sets up the circuit shown in Fig. 1.1.

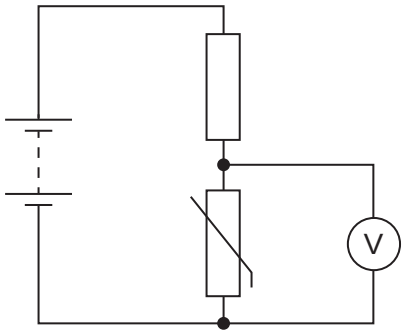

Fig. 1.1

He plots the calibration graph shown in Fig. 1.2.

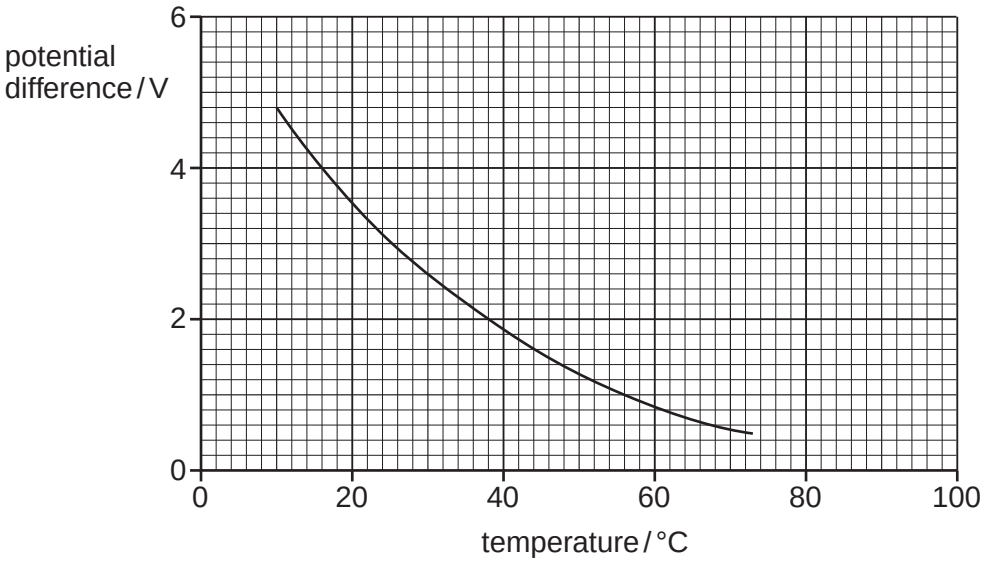

Fig. 1.2

The voltmeter used gives full scale deflection when there is a potential difference of 5.0V across it.

For Examiner's Use

(a) Estimate the temperature when the voltmeter reads full scale.

temperature = ...°C [1]

(b) Fig. 1.3 shows the voltmeter face calibrated in volts on the lower scale.
Calibrate the scale in °C, choosing suitable intervals.

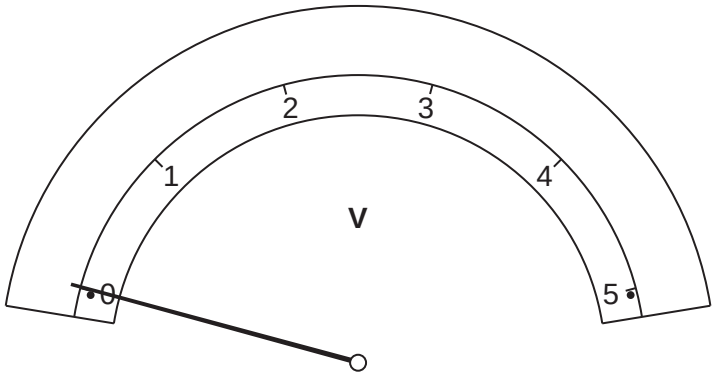

Fig. 1.3

[2]

[Total: 3]

2 Antimony, Sb, has been known for many thousands of years and is often used to strengthen lead alloys.

For Examiner's Use

Antimony is produced in a two-stage process from stibnite, Sb_2S_3. Stibnite is first roasted in oxygen to form the oxide.

$$2Sb_2S_3 + 9O_2 \longrightarrow 2Sb_2O_3 + 6SO_2$$

The oxide is then reduced with carbon.

$$2Sb_2O_3 + 3C \longrightarrow 4Sb + 3CO_2$$

(a) What is the oxidation number of antimony in Sb_2O_3?

.....[1]

(b) Using the ideal gas equation, calculate the volume of carbon dioxide, measured at 298 K and 100 kPa, which would be produced by the processing of 10.0 mol of Sb_2S_3.

volume = ... m^3 [3]

[Total: 4]

3 Fig. 3.1 shows a rectangular block of ice of mass 1760 kg floating in sea water of density 1080 kg m^{-3}. The block of ice is 0.80 m high, 2.4 m long, and 1.0 m wide.

For Examiner's Use

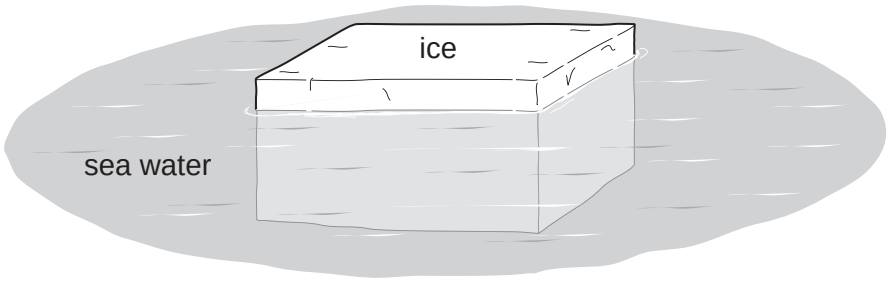

Fig. 3.1

(a) Calculate the weight of the block. Hence write down the upward force the water pressure must exert on the bottom of the block.

weight = ... N

upward force = ... N [1]

(b) (i) Calculate the pressure on the bottom of the block. Give the appropriate unit.

pressure = ... unit ..... [2]

(ii) Hence calculate the depth of ice below the water surface.

depth = ... m [2]

(c) Use your answer to **(b)(ii)** to calculate the mass of water displaced by the ice. Show your working.

mass = ... kg [1]

[Total: 6]

4 The equation below shows the reaction between boron trifluoride and a fluoride ion to form a boron tetrafluoride ion.

For Examiner's Use

$$BF_3 + F^- \rightarrow BF_4^-$$

(a) (i) Draw diagrams to show the shape of the BF_3 molecule and the shape of the BF_4^- ion.

Name the shape of the BF_3 molecule and state the bond angle found in the BF_4^- ion.

BF_3 BF_4^-

shape ..... bond angle .....

(ii) Explain the shape of the BF_3 molecule.

.....

.....

[5]

(b) (i) Name the type of bond formed in this reaction.

.....

(ii) Explain how the bond between a BF_3 molecule and an F^- ion is formed.

.....

.....

.....

[2]

[Total: 7]

5 **(a)** Microwaves are a form of electromagnetic radiation. They are used in modern communications.

(i) State the approximate wavelength of microwaves.

wavelength = ... m [1]

(ii) Fig. 5.1 shows a mast from which both radio waves and microwaves are transmitted.

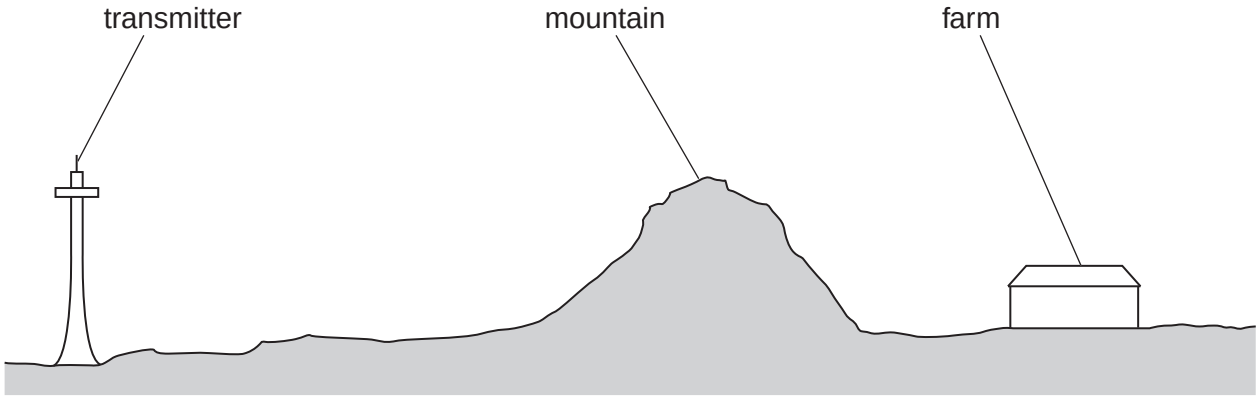

Fig. 5.1

Explain why a suitable receiver at the farm is able to receive radio waves but not microwaves.

.....

.....

.....

.....[2]

(b) Fig. 5.2 shows the apparatus used to demonstrate the interference of microwaves. A pair of slits is formed by using three metal plates. The detector is moved from **A** to **B** parallel to the metal plates.

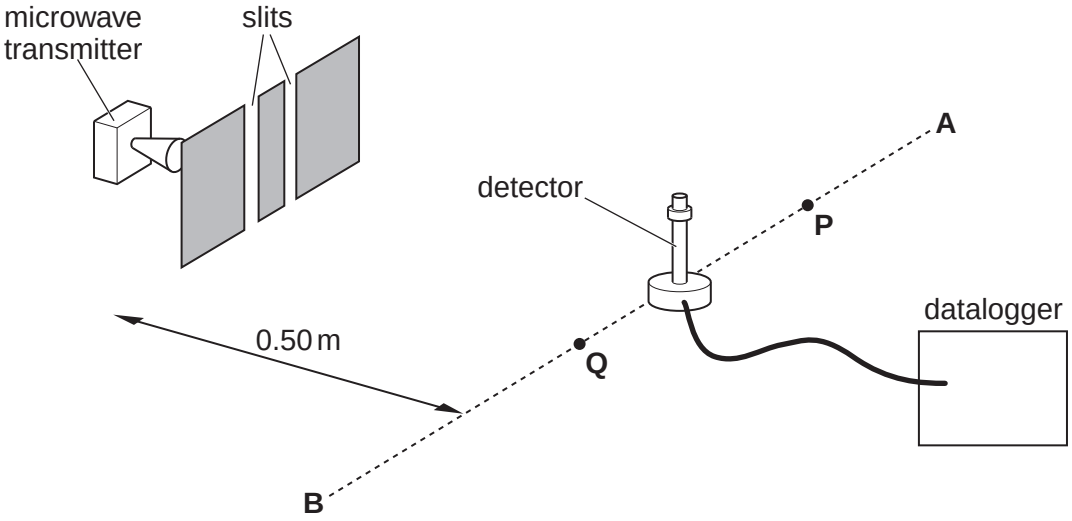

Fig. 5.2

Fig. 5.3 shows the trace recorded by the datalogger.

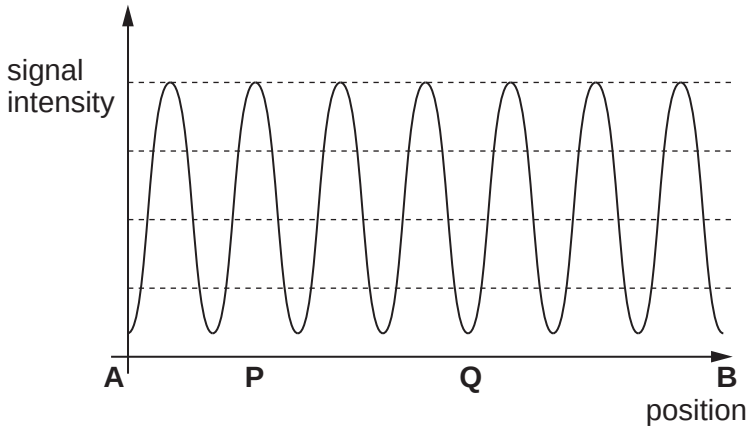

Fig. 5.3

(i) Explain why the signal is a maximum at **P**.

.....

.....

.....

(ii) Explain why the signal is a minimum at **Q**.

.....

.....

.....

[4]

For Examiner's Use

(iii) When the detector is at the position shown in Fig. 5.2 the intensity of the signal is exactly one half the intensity of the maximum signal detected.

Deduce how the amplitude at this position compares with the maximum amplitude.

.....

..... [1]

(iv) State how the trace would change if

1. the slits are closer together,

.....

.....

2. shorter wavelength microwaves are used.

.....

.....
[2]

[Total: 10]

6 Ammonia is manufactured by passing a mixture of hydrogen and nitrogen over an iron catalyst.

Nitrogen is obtained from the air. Hydrogen is obtained by reacting methane with steam, which produces hydrogen and carbon monoxide.

(a) Write an equation for the reaction between methane and steam.

.....[1]

(b) Table 6.1 shows the percentage yield of ammonia obtained by reacting hydrogen with nitrogen in the laboratory, under different conditions of temperature and pressure.

Table 6.1

temperature / °C	pressure / MPa							
	1	3	5	10	30	60	100	
200	51	68	74	82	90	95	98	percentage yield
300	15	30	39	52	71	84	93	
400	3.9	10	15	25	47	65	80	
500	1.2	3.5	5.6	11	26	42	57	
600	0.49	1.4	2.3	4.5	14	23	31	
700	0.23	0.68	1.1	2.2	7.3	13	13	

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 \qquad \Delta H = -92.4\,kJ\,mol^{-1}$$

(i) The enthalpy change for this reaction shows that the reaction is exothermic.

Explain how the data in Table 6.1 is consistent with an exothermic reaction.

.....

.....

.....

.....

(ii) Explain why the yield of this reaction increases as pressure increases.

.....

.....

(iii) Typically, a pressure of 20 MPa is used commercially.
Explain why this pressure might be described as a *compromise* condition.

.....

.....
[4]

(c) The boiling point temperatures, at 100 kPa, of hydrogen, nitrogen and ammonia are 20 K, 77 K and 240 K respectively.

(i) In terms of the intermolecular forces present, explain why the boiling point of ammonia is so much higher than the other boiling points.

.....

.....

.....

(ii) These differences in boiling point are important in the recovery of ammonia from the reaction mixture. Explain why.

.....

.....

[3]

(d) Urea, $CO(NH_2)_2$, is a naturally occurring substance which can be hydrolysed with water to form ammonia according to the following equation.

$$H_2O(l) + CO(NH_2)_2(aq) \rightarrow CO_2(aq) + 2NH_3(aq)$$

Enthalpy changes of formation of water, urea, carbon dioxide and ammonia (in aqueous solution) are given in Table 6.2.

Table 6.2

compound	ΔH_f / kJ mol^{-1}
$H_2O(l)$	–287.0
$CO(NH_2)_2(aq)$	–320.5
$CO_2(aq)$	–414.5
$NH_3(aq)$	–81.0

Use these data to calculate an enthalpy change for the hydrolysis of urea.

enthalpy change = ... kJ mol^{-1} [2]

[Total: 10]

7 When a radioactive particle passes through a cloud chamber it ionises the air. Vapour condenses on the ions leaving a visible track.

Fig. 7.1 shows a cloud chamber in which alpha particles are incident on a very thin polythene film.

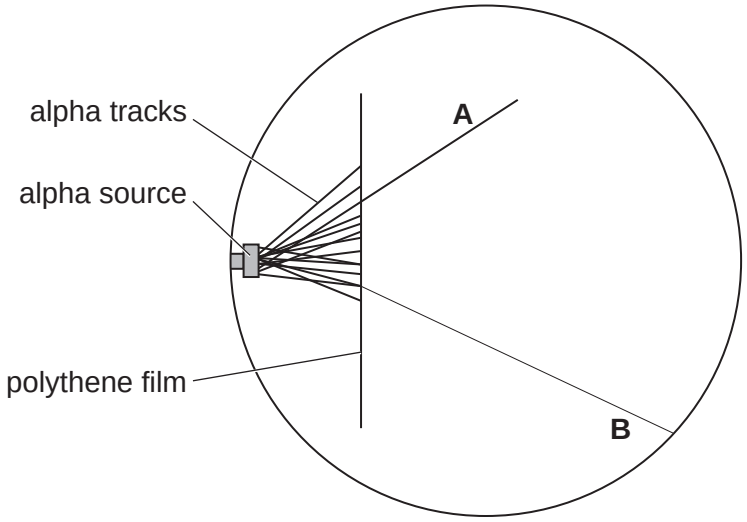

Fig. 7.1

The majority of alpha particles are absorbed by the polythene.
A few pass through it leaving tracks similar to track **A**.

Occasionally an alpha particle collides with a hydrogen nucleus and knocks it out of the polythene. The hydrogen nucleus leaves track **B**, a much thinner track. This shows that it causes less ionisation per cm of track than an alpha particle.

(a) Suggest why the hydrogen nucleus causes less ionisation per cm than the alpha particle.

.....

.....

..... [1]

(b) A teacher models the collision between an alpha particle and a hydrogen nucleus. She fires a steel ball of mass 0.40 kg at a speed of 5.0 m s^{-1}. The moving ball collides with a second stationary ball. After the collision the original ball continues in the same direction with a speed of 3.0 m s^{-1}. The second ball has a speed of 8.0 m s^{-1} in the same direction.

For Examiner's Use

(i) Use the principle of conservation of momentum to show that the mass of the second ball is 0.10 kg.

[2]

(ii) Show that this collision is perfectly elastic.

[3]

[Total: 6]

8 **(a)** The ethene molecule, C_2H_4, has both σ and π bonding.

(i) Describe the difference in the way in which σ bonds and π bonds are formed.

.....

.....

.....

(ii) Complete Fig. 8.1 to show the shape and position of the π bond.

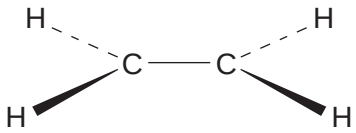

Fig. 8.1

[3]

(b) Bromine reacts with ethene by a mechanism known as electrophilic addition.

(i) Use drawings to show the mechanism for the reaction between ethene and bromine.
In your mechanism, use curly arrows to show the movement of electrons.
Give the name of the product formed.

mechanism

name of product .....

(ii) Bromine is a non-polar molecule. Despite this it is able to act as an electrophile in this mechanism. Explain why.

.....

.....

.....

[4]

(c) The reaction of propene with hydrogen bromide gives two isomeric products, **A** and **B**, with formula C_3H_7Br.

For Examiner's Use

One of these isomers, compound **A**, reacts with aqueous sodium hydroxide to give compound **C**, C_3H_8O.

Oxidation of **C** gives compound **D**, C_3H_6O.

When tested, **D** gave a positive test with 2,4-dinitrophenylhydrazine but gave a negative test with Fehling's solution.

(i) Draw the displayed structure of compound **A**.

(ii) State the functional group present in **C**.

.....

(iii) Suggest suitable reagents and conditions for converting **C** into **D**.

.....

.....

(iv) Give the name of product **D**.

.....

[4]

[Total: 11]

For Examiner's Use

9 **(a)** After the discovery of the electron in 1897, J. J. Thomson proposed the 'plum-pudding' model of the atom.

Briefly describe this model of the atom.

.....

.....

.....

.....[2]

(b) In 1911 Rutherford proposed a nuclear model for the atom.

(i) Briefly outline the experiment which led Rutherford to propose this new model.

.....

.....

.....

.....

(ii) Explain how the results of this experiment led to this new model.

.....

.....

.....

.....

.....

[4]

(c) In 1913 Neils Bohr put forward a quantum-based model.

For Examiner's Use

(i) State two differences between the Bohr model and the Rutherford model.

1. .....

.....

2. .....

.....[2]

(ii) Describe how the Bohr model of the atom supports the arrangement of elements in the Periodic Table.

.....

.....

.....

.....[2]

[Total: 10]

10 Fig. 10.1 shows a network of resistors connected to a battery of negligible internal resistance.

For Examiner's Use

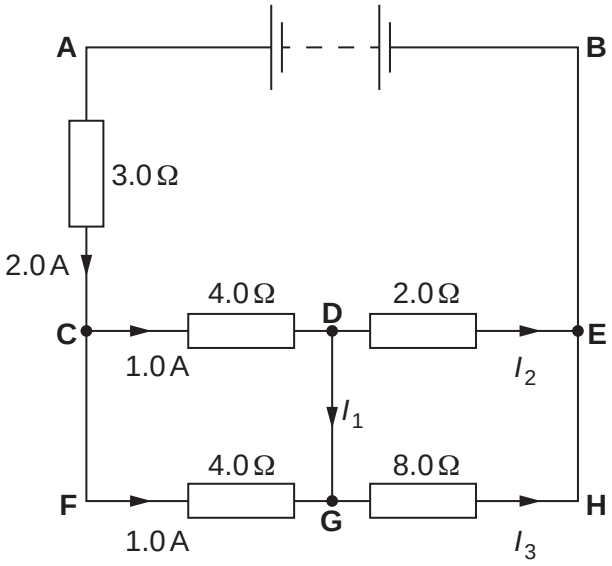

Fig. 10.1

(a) (i) Use Kirchhoff's second law for loop **DEHG** to show that $I_2 = 4\ I_3$.

(ii) Hence calculate the values of I_2 and I_3.

I_2 = ...A I_3 = ...A
[2]

(b) Use Kirchhoff's first law to find I_1.

I_1 = ...A [1]

(c) To find the e.m.f. of the battery you need to choose a suitable loop around which to apply Kirchhoff's second law.

For Examiner's Use

(i) State which loop you have chosen.

.....

(ii) Calculate the e.m.f. of the battery.

e.m.f. = ...V [2]

[Total: 5]

Question 11 is on the next page.

For Examiner's Use

11 **(a)** A sodium salt contains 21.6% of sodium, 33.3% of chlorine and 45.1% of oxygen, by mass.

(i) State what is meant by the term *empirical formula*.

.....

.....

(ii) Use the above data to deduce the empirical formula of this sodium salt.

empirical formula = ... [3]

(b) The carbonate of a Group 1 metal, **Q**, has the formula Q_2CO_3.
The equation for the reaction of this carbonate with hydrochloric acid is given below.

$$Q_2CO_3 + 2HCl \rightarrow 2QCl + CO_2 + H_2O$$

A sample of Q_2CO_3, of mass 0.394 g, required the addition of 21.7 cm^3 of a 0.263 mol dm^{-3} solution of hydrochloric acid for complete reaction.

(i) Use this information to calculate how many moles of Q_2CO_3 were in the sample. Hence find the relative molecular mass, M_r, of this carbonate.

M_r = ...[3]

(ii) Use your answer to part **(b)(i)** to deduce the identity of metal **Q**.

identity of **Q** = ...[2]

[Total: 8]