



ADVANCED GCE
PHYSICS B (ADVANCING PHYSICS)
 Advances in Physics

2865/01

Candidates answer on the Question Paper

OCR Supplied Materials:

- Insert (Advance Notice Article for this question paper) (inserted)
- Data, Formulae and Relationships Booklet

Other Materials Required:

- Electronic calculator
- Ruler (cm/mm)

Thursday 28 January 2010
Afternoon

Duration: 1 hour 30 minutes



Candidate Forename		Candidate Surname	
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Centre Number						Candidate Number			
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INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.
- Show clearly the working in all calculations, and give answers to only a justifiable number of significant figures.
- Do **not** write in the bar codes.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [] at the end of each question or part question.
- The total number of marks for this paper is **90**.
- Section A (questions 1–7) is based on the Advance Notice article, a copy of which is included as an insert. You are advised to spend about 60 minutes on Section A.
- There are four marks available for the quality of written communication on this paper.
- The values of standard physical constants are given in the Data, Formulae and Relationships booklet. Any additional data required are given in the appropriate question.
- This document consists of **20** pages. Any blank pages are indicated.

For Examiner's Use		
Qu.	Max	Mark
1	4	
2	7	
3	8	
4	14	
5	8	
6	9	
7	7	
8	16	
9	13	
QWC	4	
Total	90	

Answer **all** the questions.

Section A

- 1 This question is about the properties of silicon (lines 8–12 in the article).
Fig. 1.1 represents, in two dimensions, the covalent bonding of pure silicon atoms in a single crystal.
The curved lines between the atoms represent the shared electrons in the covalent bonds.

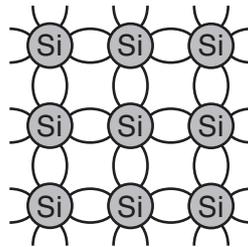


Fig. 1.1

- (a) Describe what is meant by the term *polycrystalline* (line 11 in the article).

[1]

- (b) Explain why a sample of pure silicon is likely to be a poor electrical conductor.

[1]

- (c) Fig. 1.2 is a diagram representing a crystal of silicon containing a doping atom of phosphorus which has one more bonding electron than silicon (lines 34–39 in the article).

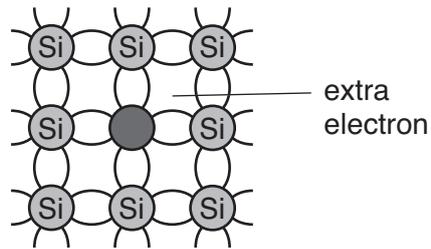


Fig. 1.2

Explain how the presence of the phosphorus atom in the crystal structure changes the conductivity of the material.

[2]

[Total: 4]

- 2 This question is about the method of heating the silicon (lines 14–22 and Fig. 2 in the article).

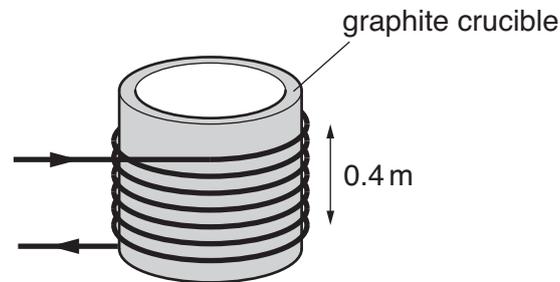


Fig. 2.1

- (a) Draw on Fig. 2.1 two flux loops showing the shape of the magnetic field produced by the current shown. [2]
- (b) The peak magnetic flux density created by the high-frequency current in the coils is about 0.02 T. The 7 turn coil has a cross-sectional area of 0.2 m^2 . Show that the peak flux linked with the **coil** is about $3 \times 10^{-2} \text{ Wb turns}$.

[2]

- (c) Fig. 2.2 shows how the flux linked with the coil changes with time.
Add a second line to Fig. 2.2 showing how the induced emf in the coil changes with time.

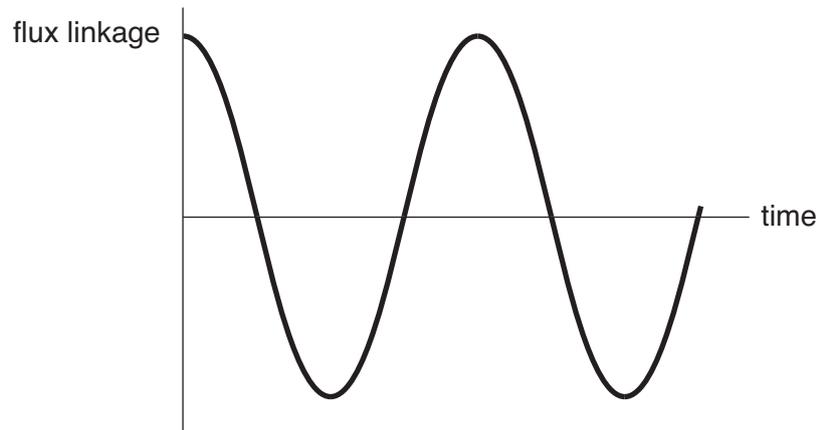


Fig. 2.2

[2]

- (d) Give a reason why the induced emf across the coil is **not** in phase with the current in the coil.

[1]

[Total: 7]

- 3** This question is about the energy needed to melt the silicon.
The article states that the final single crystal is about 1 m long and 20 cm in diameter (lines 25–26 in the article).

(a) Show that the volume of the ingot is about $3 \times 10^{-2} \text{ m}^3$.

[2]

(b) Show that the mass of silicon in the ingot is about 70 kg.

$$\text{density of silicon} = 2300 \text{ kg m}^{-3}$$

[2]

(c) Estimate the minimum energy required to raise the ingot material from room temperature to its melting point of 1700 K.

$$\text{specific thermal capacity of silicon} = 690 \text{ J kg}^{-1} \text{ K}^{-1}$$

minimum energy required = J [3]

7

(d) Suggest why there may be appreciable heat losses in heating the silicon to 1700K.

[1]

[Total: 8]

4 This question is about Moore's Law and the reduction in transistor size (lines 75–89 and Fig. 7 in the article).

- (a) Show that a reduction in size of about 11% per year would be consistent with the linear dimensions of transistors dropping from $20\mu\text{m}$ to $0.2\mu\text{m}$ in the period between 1960 and 2000 (lines 81–89 in the article).

[2]

- (b) Use information from Fig. 7 in the article to estimate the number of transistors per chip in 2010. Show your working clearly.

[2]

- (c) Figs. 4.1 and 4.2 show a section of mask being used to imprint an interconnecting track onto the surface of a chip (lines 40–53 and Fig. 5 in the article).

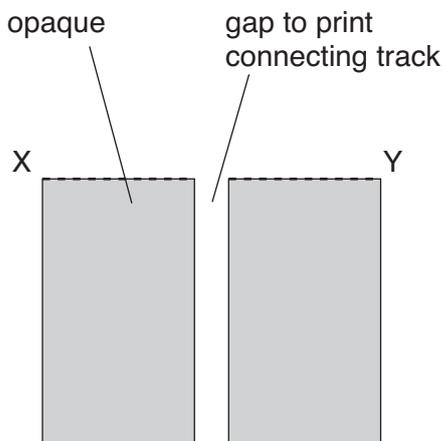


Fig. 4.1

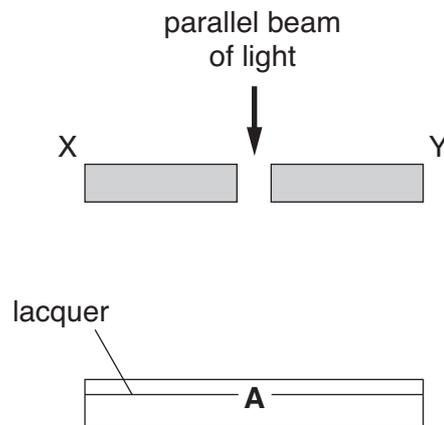


Fig. 4.2

- (i) The gap in the mask is $0.8\mu\text{m}$ in width. Explain why visible light of wavelength $5 \times 10^{-7}\text{m}$ would not expose a strip $0.8\mu\text{m}$ wide on the lacquer at point A.

[2]

- (ii) By considering the kinetic energy gained by electrons of charge e and mass m , accelerated through a potential difference V , show that the gain in momentum p is given by

$$p = \sqrt{2meV}.$$

[3]

- (iii) Show that the de Broglie wavelength associated with electrons accelerated through a potential difference of 5000V would be less than 2×10^{-11} m.

$$\begin{aligned} h &= 6.6 \times 10^{-34} \text{ Js} \\ e &= 1.6 \times 10^{-19} \text{ C} \\ \text{electron mass, } m &= 9.1 \times 10^{-31} \text{ kg} \end{aligned}$$

[3]

- (iv) Explain why electrons of wavelength less than 2×10^{-11} m can be used successfully to produce very much smaller scale features on the surface of the silicon than is possible with visible light.

[2]

[Total: 14]

- 5 This question is about the problems of waste heat generated in integrated circuits (lines 102–123 in the article).

Fig. 5.1 shows two blocks **P** and **Q** of conducting material of resistivity ρ .

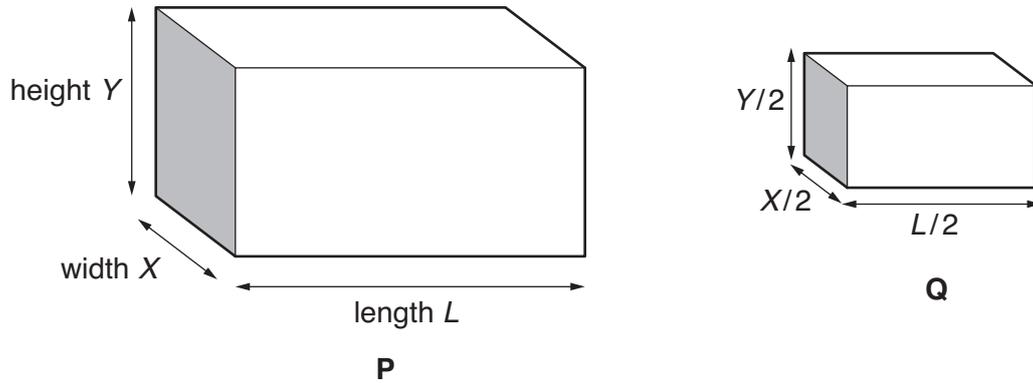


Fig. 5.1

- (a) The linear dimensions of **Q** are half those of **P** (Fig. 5.1).

(i) Show that the resistance of **Q** is double that of **P** (lines 103–104 in the article).

[3]

(ii) Show that the mass of **Q** is one-eighth that of **P**.

[2]

(iii) Write down the value of

$$\frac{\text{total surface area of Q}}{\text{total surface area of P}}$$

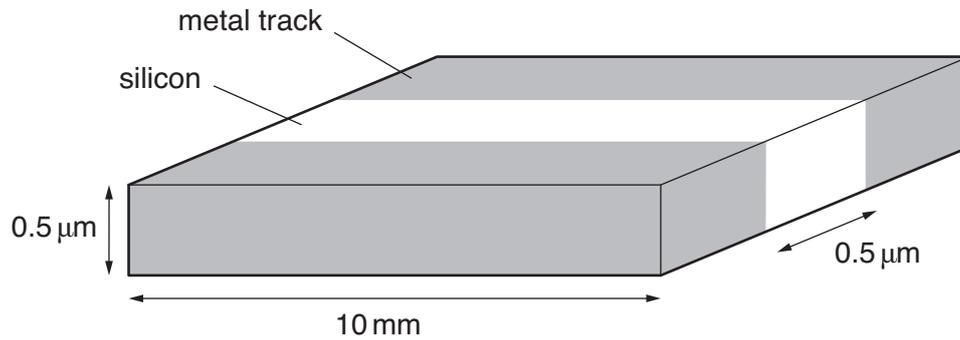
[1]

(b) The voltage required across such components is fixed by the nature of silicon. Show that if the voltage across each block is the same, the power dissipated in **Q** is less than that in **P**, but that its temperature will be higher.

[2]

[Total: 8]

- 6 This question is about the resistance along a metal track and the capacitance between adjacent metal tracks (lines 106–113 and Fig. 8 in the article).



not to scale

Fig. 6.1

The electrical behaviour of the pair of tracks can be modelled using the circuit of Fig. 6.2.

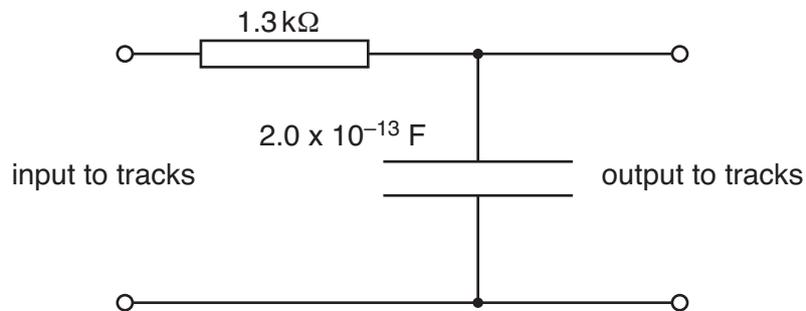


Fig. 6.2

When the input voltage is high, the capacitor charges up.
When the input voltage drops, the capacitor discharges through the resistor.

- (a) (i) Show that the time constant of the circuit of Fig. 6.2 is about 0.3 ns.

[1]

- (ii) Explain what is meant by the time constant of such a circuit.

[1]

(b) Fig. 6.3 shows the first voltage pulse (dotted line) applied to the input of the circuit Fig. 6.2 at time $t = 0$.

The output voltage (solid line) for the first 0.5 ns is shown.

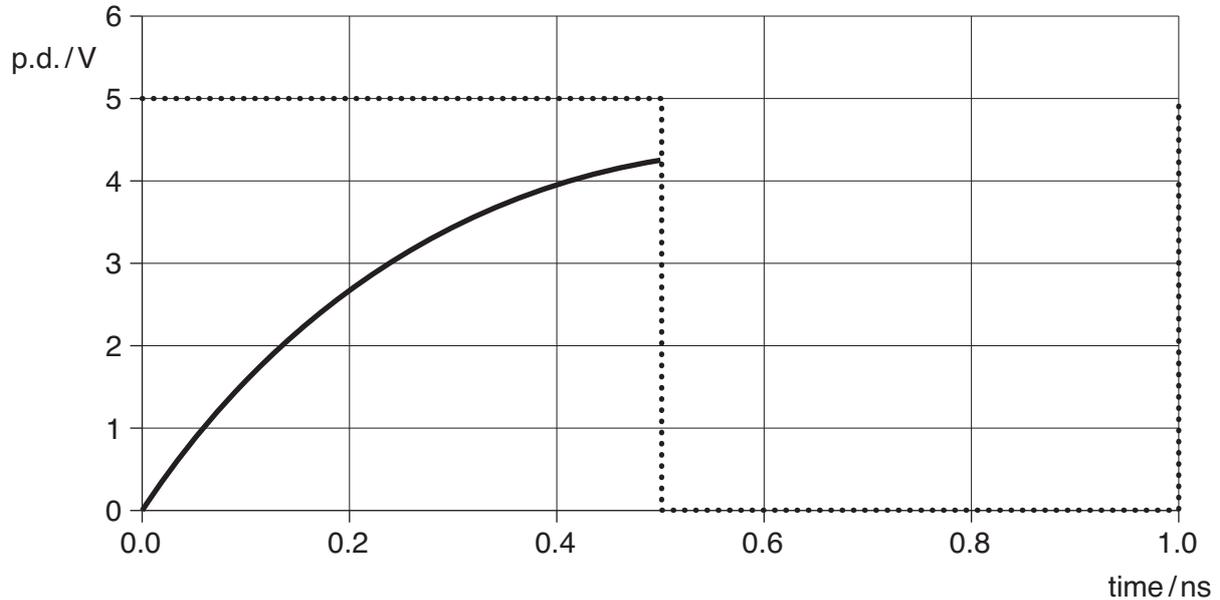


Fig. 6.3

(i) Draw, on Fig. 6.3, a line to complete the output voltage to 1.0 ns. [3]

(ii) The frequency of the pulses in Fig. 6.3 is 1.0 GHz. Explain what would happen to the amplitude of the output voltage if the frequency of the input pulses was increased to 10 GHz.

[2]

(c) If the linear dimensions of the device in Fig. 6.1 are reduced by a factor of 10, the resistance increases by a factor of 10 from 1.3 k Ω to 13 k Ω .

Use the equation $C = \epsilon_0 \frac{A}{d}$ to explain what would happen to the capacitance when the linear dimensions are reduced by a factor of 10. State the effect this would have on the time constant.

[2]

[Total: 9]

7 This question is about the rate at which data has to be processed in a CPU, and the need to compress video signals (lines 114–120 in the article).

(a) A standard resolution wide TV screen contains about 2×10^6 pixels, with 16 bits used to describe each pixel. Show that the video data for one frame would have to be compressed by a factor of more than 100 to reach the value of 30 kbyte per frame (lines 116–118 in the article).

[2]

(b) Use the information in the article to show that the rate at which information has to be processed to handle the video file described in lines 116–120 is less than 10^6 bytes per second.

[2]

(c) The bandwidth required to transmit a signal is of the same order as the rate of transmission of information in bits per second.

Show that a broadband telephone line with a bandwidth 8 Mbit s^{-1} could just transmit the signal from such a video file.

[1]

(d) In many homes, the available bandwidth on the telephone line varies. It could drop to 2 Mbit s^{-1} . Suggest and explain what effect this would have when viewing a TV program on a computer.

[2]

[Total: 7]

15
Section B

8 This question is about remote sensing.

(a) The table below gives information about the electromagnetic spectrum.

frequency /Hz	wavelength in vacuum/m	type of radiation
10^{24}	3×10^{-16}	Gamma
10^{21}	3×10^{-13}	
10^{18}	3×10^{-10}	
10^{15}	3×10^{-7}	
10^{12}	3×10^{-4}	Microwave
10^9	3×10^{-1}	
10^6	3×10^2	
10^3	3×10^5	

(i) Write down the formula relating the frequency of the radiation to its wavelength.

[1]

(ii) Add the words **ultra-violet** and **radio** in the column for the type of radiation in the table above, at the frequencies at which you would expect to find them.

[2]

(b) Remote sensing of the Earth is done from artificial satellites in orbit around it at different altitudes.

(i) Complete the table below by suggesting two **different** types of electromagnetic radiation that could be gathered by a satellite in orbit around the Earth and the information that each could give about the Earth.

type of radiation	information obtained

[2]

(ii) Low altitude and high altitude orbits have different advantages for imaging the surface of the Earth. Complete the table below to compare the advantages of low and high altitude orbits for **one** application you have chosen.

information to be gathered	
advantage of low altitude orbit	
advantage of high altitude orbit	

[2]

(c) Artificial satellites around the Earth can also be used to observe the Universe.

(i) State **one** advantage of using a telescope in space rather than on Earth.

[1]

- (ii) Explain how the fact that the Universe is expanding can be deduced from observations of the light from distant galaxies.

[3]

- (iii) The intensity of light from galaxy A is observed to be about 50 times greater than that from a similar galaxy B.
Show that this is consistent with galaxy B being about 7 times more distant from the Earth.
State a condition required for this to be correct.

[4]

- (d) The cosmic background radiation is thought to be radiation 'left over' from an earlier, hotter state of the Universe.
State the part of the electromagnetic spectrum in which the peak of this radiation now lies.

[1]

[Total: 16]

9 This question is about Radioactive Thermal Generators (RTGs) used to provide electricity on space missions to the outer planets of the solar system.

(a) Suggest why alternatives to solar power have to be used when sending probes to explore the outer planets.

[1]

RTGs use the heat provided by the natural decay of radioactive plutonium-238 to generate electricity by warming one side of an array of thermocouples.

(b) Plutonium-238 decays by alpha emission releasing 5.6 MeV per decay. Show that this is equivalent to about 9×10^{-13} J.

$$e = 1.6 \times 10^{-19} \text{ C}$$

[2]

(c) The probe for the Cassini mission to Saturn used three RTGs, each of which needed to have a power of 630W at the end of the 11 year mission.

(i) Show that about 7×10^{14} decays per second are needed at the **end** of the mission to provide 630W.

[1]

(ii) The half life of plutonium-238 is 88 years.

Estimate the number of decays per second at the beginning of the 11-year mission.

number of decays per second = s^{-1} [3]

- (d) The Cassini mission was unmanned. If 3 similar RTGs, each producing 630W, were used on a manned mission, calculate the absorbed dose received by a 70 kg astronaut in a year. Assume that the energy of the radiation absorbed by the astronaut is 1 part in 10^{11} of the power output of the RTGs.

$$1 \text{ year} = 3.2 \times 10^7 \text{ s}$$

absorbed dose = Gy [3]

- (e) In the RTGs, temperature differences of about 700 K are produced between different parts of a semiconductor.
Show why the electrical conductivity of a part of the semiconductor at 800 K is much greater than its electrical conductivity at 100 K.

[3]

[Total: 13]

[Quality of Written Communication: 4]

END OF QUESTION PAPER

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