# Tuesday 20 May 2014 – Morning

## AS GCE PHYSICS B (ADVANCING PHYSICS)

**G491/01** Physics in Action

Candidates answer on the Question Paper.

**OCR supplied materials:**
- Data, Formulae and Relationships Booklet (sent with general stationery)

**Other materials required:**
- Electronic calculator
- Ruler (cm/mm)

**Duration:** 1 hour

| Candidate forename | | Candidate surname | |
|---|---|---|---|

| Centre number | | | | | | Candidate number | | | | |
|---|---|---|---|---|---|---|---|---|---|---|

**INSTRUCTIONS TO CANDIDATES**

- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Show clearly the working in all calculations, and give answers to only a justifiable number of significant figures.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined page at the end of this booklet. The question number(s) must be clearly shown.
- 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 **60**.
- You are advised to spend about 20 minutes on Section A and 40 minutes on Section B.
- 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.
- Where you see this icon you will be awarded marks for the quality of written communication in your answer.

  This means, for example, you should:
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- This document consists of **16** pages. Any blank pages are indicated.

Answer **all** the questions.

## SECTION A

**1** Here is a list of units.

**$m^{-1}$** **$m^{-2}$** **$m^{-3}$** **$kg\,m^{-3}$** **$s^{-1}$**

Choose the correct unit for the following quantities:

frequency ............................................

lens power ............................................

charge carrier density ............................................

**[3]**

**2** A single musical note is played on an oboe.

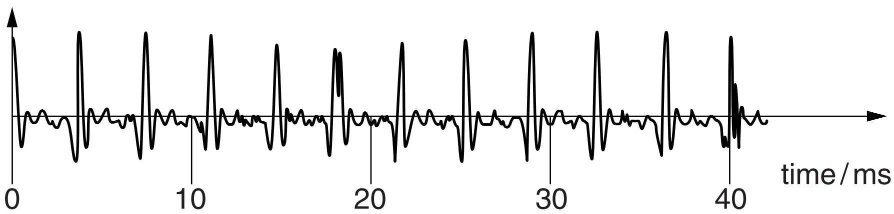


**Fig. 2.1**

Fig. 2.1 shows the waveform of the note over a time interval of about 40 ms.

**(a)** State how the waveform shows that the note has a definite pitch (fundamental frequency) but that it also contains more than one frequency component.

**[2]**

**(b)** Calculate the frequency of the largest amplitude component of the note.

frequency = .................................................. Hz **[1]**

**3** A sound engineer wants to digitise a sound waveform in which the range of frequencies is 0 to 6000 Hz.

**(a)** State the minimum sampling frequency she should employ.

...................................................... Hz **[1]**

**(b)** The noise level in her system is such that

$$\frac{\text{total noisy signal range}}{\text{noise range}} = \frac{V_{total}}{V_{noise}} \approx 400$$

Calculate how many bits should be used for each sample.

bits per sample = .................................................. bits **[1]**

**(c)** Describe how you would estimate the bandwidth needed for transmitting the digitised information.

**[2]**

**4** Here is a list of orders of magnitude.

**$10^6$** **$10^3$** **1** **$10^{-3}$** **$10^{-6}$**

State the best estimate for

**(a)** the density in $kg\,m^{-3}$ of wood .............................

**(b)** the mass in kg of a 1 mm diameter raindrop .............................

**(c)** the wavelength in m of infra red radiation just beyond the visible spectrum .............................

**[3]**

**5** An electron beam carries a current of 8.0 pA.

Calculate how many electrons pass a point in the beam per second.

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

electrons per second = .................................................. $s^{-1}$ **[2]**

**6** A resistor has a resistance of 4.7 Ω and a maximum operating voltage of 12 V.

**(a)** Calculate the maximum power that the resistor can dissipate.

power = .................................................. W **[2]**

**(b)** The resistor is made of a wire of resistivity $4.5 \times 10^{-7}$ Ω m.

The cross-sectional area of the wire is $1.8 \times 10^{-8}$ $m^2$.

Calculate the length of wire needed to make the 4.7 Ω resistor.

length = .................................................. m **[2]**

**7** Fig. 7.1 shows the effect of a converging lens on plane wavefronts which have passed through it.

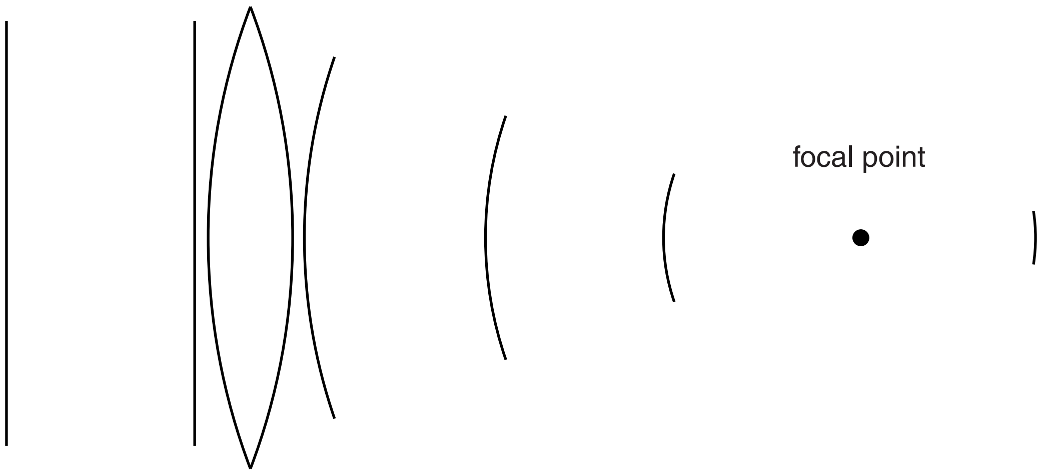


**Fig. 7.1**

The lens is replaced with one of the same shape and dimensions, made from a material with a **lower** refractive index (shown in Fig. 7.2).

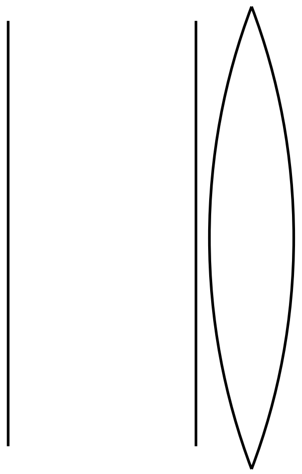

**Fig. 7.2**

**(a)** Complete Fig. 7.2 carefully to show the wavefronts to the right of the lens with the **lower** refractive index. Make the new position of the focal point clear. **[2]**

**(b)** State with a reason whether the power of this lens is larger, smaller or the same as that of the original lens.

**[1]**

**[Section A Total: 22]**

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## SECTION B

**8** This question is about a light dependent resistor (LDR) in a light sensing circuit.

**(a) (i)** An LDR and a fixed resistor R are connected as a potential divider to the 6.0V battery shown in Fig. 8.1 to make a sensing circuit.

Draw the potential divider on Fig. 8.1 to complete the circuit.
Label the components R and LDR on the diagram. **[1]**

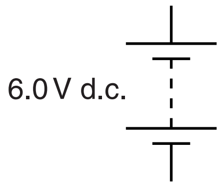


**Fig. 8.1**

**(ii)** A voltmeter is to be connected to the circuit to indicate an **increasing** output p.d. when the sensor detects an **increasing** light intensity.

The resistance of the LDR **decreases** when the light intensity incident upon it increases.

Explain clearly why the voltmeter should be connected across the fixed resistor.

*Make the steps in your reasoning clear.*

**[3]**

**(b)** Fig. 8.2 shows how the output p.d. of this sensing circuit varies with the light intensity measured in lux incident upon the LDR.

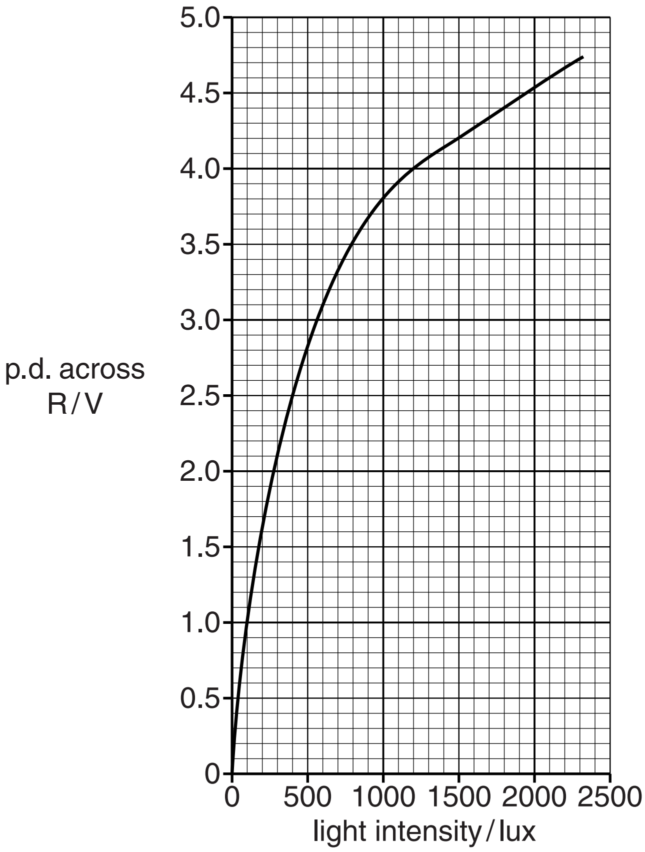


**Fig. 8.2**

**(i)** State what you understand by the sensitivity of the sensing circuit.

**[1]**

**(ii)** Calculate the sensitivity for the sensor at an intensity of 1000 lux.

You may find it helpful to draw a construction line on Fig. 8.2.

sensitivity = ................................................ V lux$^{-1}$ **[3]**

**(iii)** The resistance of the fixed resistor R is 800 Ω.

The light intensity on the LDR is 1000 lux. Use Fig. 8.2 to find the p.d. across the fixed resistor at this light intensity.

Use this to calculate the resistance of the LDR.

resistance = ...................................................... Ω **[4]**

**[Total: 12]**

**9** This question is about a new nano-material called graphene. It is a **single layer of carbon atoms** arranged in an open hexagonal lattice. Fig. 9.1 shows a scaled TEM (Transmission Electron Microscope) image of graphene.

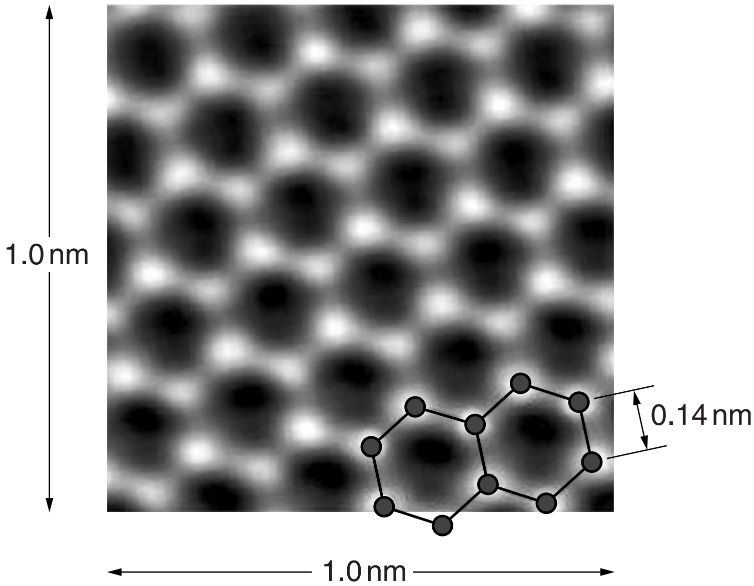


**Fig. 9.1**

**(a)** The image shows a square piece of graphene of side length 1.0 nm containing about 60 carbon atoms.

**(i)** Show that the mass of a single layer of graphene of area 1.0 $m^2$ is about $10^{-6}$ kg.

mass of carbon atom = $2.0 \times 10^{-26}$ kg

**[3]**

**(ii)** The thickness of a layer of graphene is 0.34 nm.

Show that the density of graphene is comparable with that of graphite (2300 kg m$^{-3}$).

**[1]**

**(iii)** Measurements with an atomic force microscope on the tiny perfect sample of graphene shown in Fig. 9.1 suggest a breaking stress of about $4 \times 10^{10}$ Pa.

Imagine it is possible to scale this up to a single sheet of graphene 0.10 m wide, as is illustrated in Fig. 9.2.

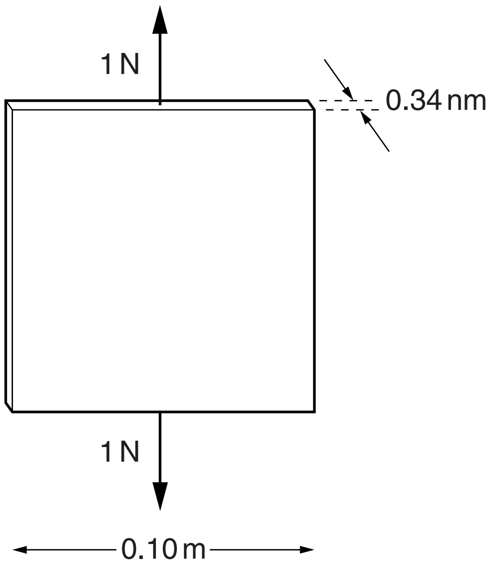


**Fig. 9.2** (single atomic layer not to scale)

Show that just a single atomic layer could hypothetically support a weight of about 1 N.

Make your method clear.

thickness of graphene layer = 0.34 nm

**[2]**

**(b)** The electrical properties of graphene are unusual. Within the layer it conducts like a metal, but perpendicular to the layer it conducts like a semiconductor.

Fig. 9.3 illustrates a conductivity measurement of a square layer of graphene of side 200 nm.

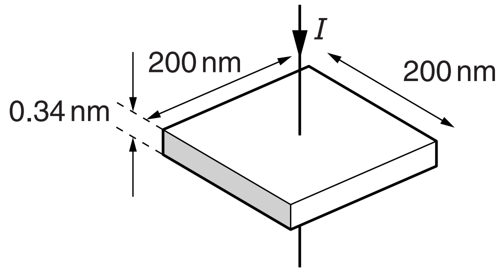


**Fig. 9.3**

It carries a current of $6.7 \times 10^{-15}$ A when a p.d. of 0.15 mV is applied across its thickness of 0.34 nm.

Calculate the conductivity of graphene perpendicular to the layer.

conductivity = ............................................. $S\,m^{-1}$ **[3]**

**(c)** Suggest **two** possible applications for graphene, one linked to mechanical properties and one to electrical properties.

*Clearly link each application you describe to a property of graphene.*

**1**

**2**

**[4]**

**[Total: 13]**

**10** Fig. 10.1a shows a traditional bar code and Fig. 10.1b a more modern QR (Quick Response) code.

**Fig. 10.1a** **Fig. 10.1b**

Bar codes consist of a scannable strip of black bars and white spaces and QR codes consist of black and white squares (modules) arranged in a square pattern.

**(a)** Suggest an advantage of QR codes over bar codes of a similar physical size. Explain how the QR code achieves this advantage.

**[2]**

**(b)** The QR code in Fig. 10.1b consists of a square array of $33 \times 33$ modules each representing a 0 or a 1.

**(i)** Calculate the maximum information in bytes that such a QR code can store.

information = ................................................ bytes **[1]**

**(ii)** State how many alternative characters can be coded by one byte of information.

number of alternative characters = ........................................................ **[1]**

**(iii)** The three $8 \times 8$ modules in the corners of the QR code are actually not used to transmit user information. Suggest a reason for their inclusion.

**[1]**

**(c)** QR codes can be read by the camera in a mobile phone. Fig. 10.2 shows such a camera having a CCD (Charge Coupled Device) of physical size 2.0 mm × 2.0 mm, placed behind a lens of focal length 5.0 mm.

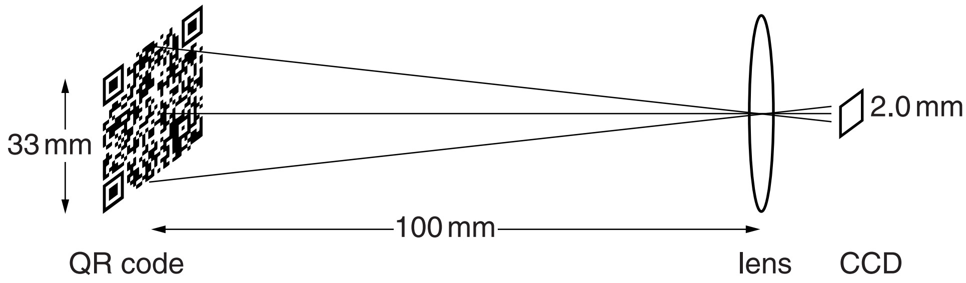


**Fig. 10.2** (not to scale)

A 33 mm × 33 mm QR code (with 33 × 33 modules) is photographed 100 mm in front of the lens.

**(i)** Show that the image of the code fits inside the dimensions of the CCD.
You may assume the image is approximately at the focal point of the lens.

**[2]**

**(ii)** Justify this approximation, showing that the image distance is only about 5% larger than assumed.

**[3]**

**(iii)** The CCD has a million pixels in a 1000 × 1000 square array.

Show that with this number of pixels there will be a further problem in reading the code if the camera is more than about 2.5 m from the QR code.

**[3]**

**[Total: 13]**

**[Section B Total: 38]**

**END OF QUESTION PAPER**

## ADDITIONAL ANSWER SPACE

If additional answer space is required, you should use the following lined page. The question number(s) must be clearly shown in the margins.