Paper 1-style questions

Section A — Multiple Choice

1 The upper frequency limit of human hearing is about 20 kHz.

Which value gives the minimum rate needed to accurately sample sound of this frequency?

A > 10 kHz **B** > 20 kHz

C > 40 kHz **D** > 80 kHz

2 'Conductive putty' is a malleable material which conducts electricity. A piece of this putty is rolled into the cylinder shown in Figure 1. The conductance between the ends of the cylinder is measured as 0.18 S.

▲ Figure 1

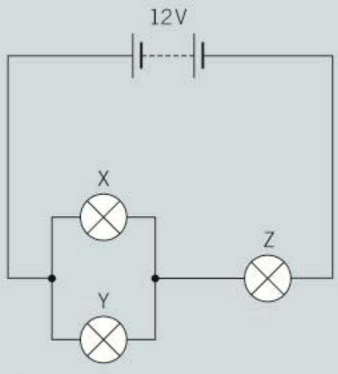
This piece of putty is then rolled out further to make a uniform cylinder 12 cm long. What will be the conductance between the ends of this new cylinder?

A 0.08 S **B** 0.12 S

C 0.27 S **D** 0.41 S

3 The circuit in Figure 2 contains three identical lamps, each marked *6.0 V, 0.2 A*.

'Normal brightness' is the brightness of one bulb with a current of 0.2 A.



▲ Figure 2

Which of the following statements about the bulbs in Figure 2 are correct?

1 Bulbs X and Y have the same brightness

2 The p.d. across bulb Y is more than 6 V

3 Bulb Z is dimmer than normal

A 1, 2, and 3 are correct

B Only 1 and 2 are correct

C Only 2 and 3 are correct

D Only 1 is correct

4 Light passing through a narrow gap diffracts. Which of the following changes would decrease the amount by which the light diffracts?

A Decreasing the intensity of the light

B Decreasing the width of the gap

C Decreasing the wavelength of the light

D Decreasing the amplitude of the light

5 A converging lens of power +7.0 D focuses an image at a distance of 15 cm from the lens. Which of the values below is the object distance?

A −0.14 m **B** −3.0 m

C −0.33 m **D** −0.08 m

6 Which of the following units are the correct units for stress?

A $\mathrm{N\,m^{-3}}$ **B** $\mathrm{J\,m^{-3}}$

C $\mathrm{J\,m^{-1}}$ **D** $\mathrm{N\,m^{-1}}$

7 The work function of potassium is 3.5×10^{-19} J. What is the maximum speed of the emitted photoelectrons when the potassium is illuminated by light of wavelength 3.9×10^{-7} m?

Electron mass = 9.1×10^{-31} kg

Planck constant = 6.63×10^{-34} J s

A $3.5 \times 10^{11}\ \mathrm{m\,s^{-1}}$ **B** $5.9 \times 10^{5}\ \mathrm{m\,s^{-1}}$

C $4.2 \times 10^{5}\ \mathrm{m\,s^{-1}}$ **D** $2.9 \times 10^{5}\ \mathrm{m\,s^{-1}}$

8 Which of the following values is the best estimate of the de Broglie wavelength of an electron travelling at ten percent of the speed of light?

Electron mass = 9.1×10^{-31} kg

Planck constant = 6.63×10^{-34} J s

A 2.4×10^{-12} m **B** 4.8×10^{-12} m

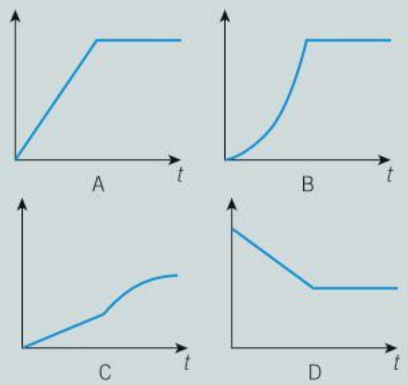
C 2.4×10^{-11} m **D** 4.8×10^{-11} m

9 A metal spring extends elastically by 0.17 m. The energy stored by the spring at this extension is 0.87 J. What is the force constant k of the spring?

A $60\,\mathrm{N\,m^{-1}}$ **B** $30\,\mathrm{N\,m^{-1}}$

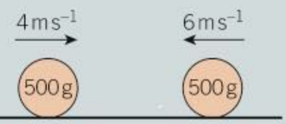
C $10\,\mathrm{N\,m^{-1}}$ **D** $5\,\mathrm{N\,m^{-1}}$

10 Graphs **A** to **D** describe four different straight-line trips, each in two parts. In each graph, the x-axis variable is time.



Assuming the y-axis variable is displacement, which graph shows deceleration over one part of the trip?

11 Figure 3 shows two soft balls of equal mass rolling towards each other on a horizontal, frictionless surface.



▲ **Figure 3**

What is the magnitude of the total momentum of the two balls after the collision?

A 1 N s **B** 5 N s

C 1000 N s **D** 5000 N s

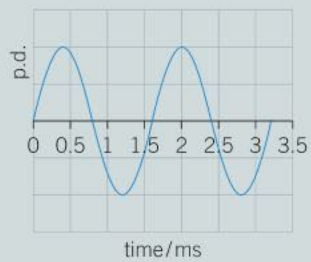
12 What is the maximum possible total kinetic energy of the two balls in Figure 3 after the collision, assuming they stick together?

A 0.5 J **B** 1 J

C 9 J **D** 25 J

Section B

1 Figure 5 shows an oscilloscope waveform of a pure sound wave.



▲ **Figure 4**

Calculate the frequency of the note. Give the units. *(3 marks)*

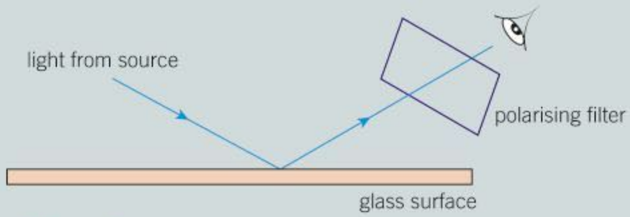
2 A data projector has an illuminated display that is 48 mm wide. A lens projects an image of the display on to a screen. The width of the image is 1.7 m.

a Calculate the magnification of the image. *(1 mark)*

b The distance between the illuminated display and the lens in 8 cm. Calculate the distance from the lens to the screen. *(1 mark)*

c Calculate the power of the lens. *(2 marks)*

3 Light is partially polarised when it reflects from a sheet of glass. A student investigates this phenomenon using a polarising filter, as shown in Figure 5.



▲ **Figure 5**

a Describe how the student could use the filter to observe the polarisation of light. *(2 marks)*

b State the observation that would make the student conclude that the light was only partially polarised. *(1 mark)*

4 Figure 5 represents light waves incident on a lens. The lens focuses the waves at point *F*.

▲ Figure 6

a Copy Figure 4 and draw the three waves between the lens and the point of focus. *(2 marks)*

b What does Figure 6 indicate about the distance between the light source and the lens? Explain your answer. *(2 marks)*

5 A lens has power +15 D.

The curvature of light waves incident on the lens is −3 D.

a Calculate the curvature of the waves as they pass out of the lens. *(1 mark)*

b Calculate the distance from the lens at which the light is focused. *(1 mark)*

6 Figure 7 shows the result of plane wavefronts passing through a converging lens.

The lens is replaced with one of the same shape and dimensions, made from a material with a higher refractive index.

▲ Figure 7

a Copy Figure 7, then draw another diagram to show the effect of using a lens with *higher* refractive index on the wavefronts to the right of the lens. *(2 marks)*

b State with a reason whether the power of the new lens in part **(a)** is larger, smaller, or the same as that of the original lens. *(1 mark)*

OCR Physics B Paper 2860 January 2009

7 A memory cell has an area of 1×10^{-14} m^2. It stores 1 bit of information.

The total area of memory cells on a microchip is 6×10^{-5} m^2.

Calculate the number of bytes of information the chip can store. *(2 marks)*

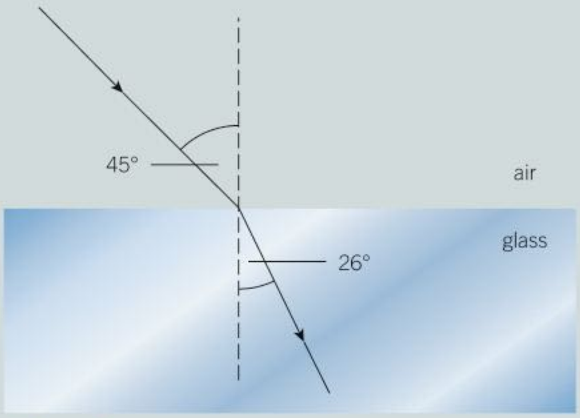
8 An analogue signal has a voltage variation of 6.7 V. It is sampled with 1024 voltage levels.

a Calculate the resolution of each sample. *(1 mark)*

b Calculate the number of bits required for 1024 levels. *(1 mark)*

c The noise in the signal gives a random voltage variation of ± 0.1 V. Calculate the number of bits worth using to sample the signal. *(3 marks)*

9 Figure 8 shows light entering glass from air. The angles of incidence and refraction are given.



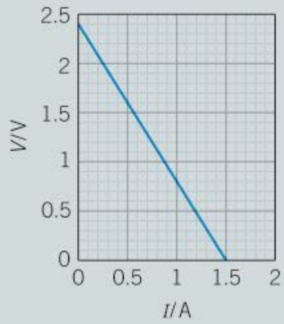
▲ Figure 8

a Use Figure 8 to calculate the refractive index of the glass. *(2 marks)*

b The velocity of light in air $= 3.00 \times 10^8$ m s^{-1}. Calculate the velocity in the glass. *(2 marks)*

c Light passes from the glass into air. The angle of incidence in the glass is 35°. Calculate the angle of refraction in the air. *(2 marks)*

10 A variable resistor is connected to a battery of e.m.f. ε and and internal resistance r via an ammeter. The p.d. V across the terminals of the battery is measured for different values of current I to give the graph in Figure 9.



▲ Figure 9

a Explain why the graph shows that the e.m.f. of the battery is 2.4 V. *(1 mark)*

b Use the graph to calculate the internal resistance r of the battery. *(2 marks)*

11 Table 1 displays the electrical conductivity of four different materials at room temperature.

▼ Table 1

material	gold	lithium	pure silicon	doped silicon
conductivity / S m^{-1}	4.9×10^7	1.2×10^7	4.7×10^{-4}	22

a Gold and silicon are both metals. In metals, each atom provides one free electron to the cloud responsible for conduction. Suggest and explain two reasons for the difference in resistivity between gold and silicon. *(2 marks)*

b The doped silicon has one atom in every ten million replaced by a boron atom. Suggest why this tiny proportion of foreign atoms increases the conductivity so significantly. *(2 marks)*

12 A student makes the following measurements to find the tensile stress in a wire:

tension in wire = 147 ± 1 N

cross-sectional area = $(0.86 \pm 0.10) \times 10^{-6}\,\text{m}^2$

a Calculate the value of the tensile stress in the wire. *(1 mark)*

b Calculate the largest possible value of the stress, given the uncertainties in the data. *(2 marks)*

c The student wishes to reduce the uncertainty in the value of the stress.

State which measurement you would choose to improve to achieve this.

Explain your choice. *(1 mark)*

OCR Physics B Paper G491 June 2010

13 Metals can show plastic behaviour under stress.

a Explain what is meant by the terms plastic behaviour and stress. *(2 marks)*

b Use what you know about the microscopic structure of metals to describe how they can show plastic behaviour. *(2 marks)*

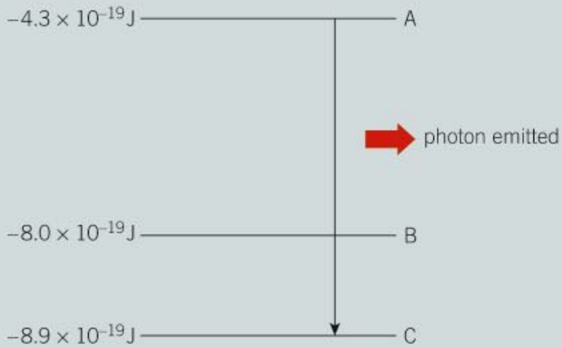
14 A light-emitting diode emits photons of energy 3.7×10^{-19} J.

a Calculate the wavelength of the radiation emitted. *(2 marks)*

b The output power of the diode is 40 mW. Calculate the number of photons emitted each second. *(2 marks)*

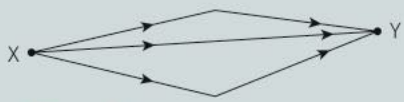
15 Figure 10 shows some energy levels in an atom.

Calculate the frequency of the photon emitted when an electron falls from level A to level C. *(2 marks)*



▲ Figure 10

16 A photon travels from X to Y. Three possible paths for the photon are shown in Figure 11.



▲ Figure 11

The phasors at Y for the three paths are shown in Figure 12. Each has the same amplitude A.

▲ Figure 12

a Draw a diagram of the phasor arrows adding tip-to-tail and show the resultant phasor. *(2 marks)*

b Show by calculation that the amplitude of the resultant phasor is between $2A$ and $2.5A$. *(2 marks)*

17 A standing wave is formed on a stretched wire, as shown in Figure 13.

▲ Figure 13

a State the wavelength of the standing wave on the wire. *(1 mark)*

b The frequency of vibration of the wire is 360 Hz. Calculate the speed of transverse waves on the wire. *(2 marks)*

c On a copy of the diagram, label the positions of a displacement node and a displacement antinode with the letters N and A. *(1 mark)*

18 A stone is dropped down a well. The time for it to reach the water is measured to be 1.6 s.

a Calculate the depth of the well, assuming that $g = 9.8\,\text{m}\,\text{s}^{-2}$. *(2 marks)*

b The timing has an uncertainty of ±0.1 s. Calculate the uncertainty in your calculated depth in part **(a)**. *(2 marks)*

c The speed of sound in air is $340\,\text{m}\,\text{s}^{-1}$. Use your answer to **(a)** to calculate the time taken for the sound of the splash to reach the person timing the fall, and comment on how the systematic error will affect the estimate of the depth obtained in **(a)**. *(2 marks)*

19 A car travels a distance s in a time t with constant acceleration a. In this time, the velocity of the car increases from an initial velocity u to a final velocity v.

The equations below model the motion.

$$s = \frac{(u+v)t}{2} \qquad \text{equation 1}$$

$$v = u + at \qquad \text{equation 2}$$

a Rearrange each of these equations to make t the subject of the equation. *(2 marks)*

b Equate the two expressions for t and hence show that $v^2 = u^2 + 2as$. *(1 mark)*

20 On a test drive on a straight, horizontal track, a high-performance car accelerates from 0 to 60 mph ($27\,\text{m}\,\text{s}^{-1}$) in 6.2 s. The mass of the car and driver is 1400 kg.

a Calculate the mean resultant accelerating force over the 6.2 s. *(2 marks)*

b Draw a labelled sectional diagram showing all forces acting on the car during this acceleration. Label the forces with appropriate descriptions, but without values. *(3 marks)*

c The car continues to accelerate to its top speed of 162 mph ($72\,\text{m}\,\text{s}^{-1}$). Assuming that the accelerating force between the wheels and the road is the same as in part **(a)**, calculate the power dissipated when travelling at this speed. *(3 marks)*

21 This question is about stretching polythene.

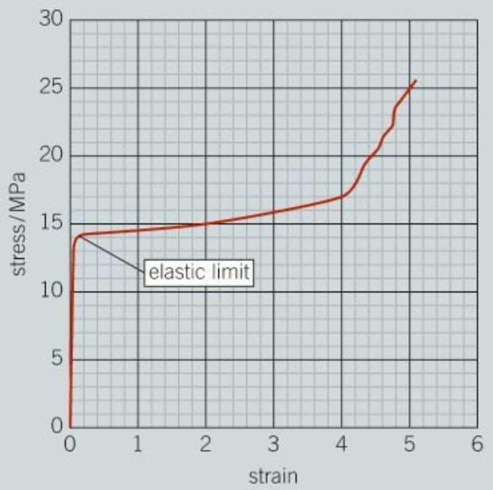
a A long narrow sample strip of polythene is cut from a shopping bag. It stretches elastically up to a strain of 0.082 at a stress of 14 MPa. This is the elastic limit of the material.

(i) Calculate the Young modulus of the polythene and state the unit. *(3 marks)*

(ii) The cross-sectional area of the sample is $1.9 \times 10^{-7}\,\text{m}^2$.

Calculate the force applied to the sample to produce a stress of 14 MPa. *(2 marks)*

b Figure 14 shows the stress against strain graph for the sample to its breaking point.



▲ **Figure 14**

(i) Describe the behaviour of the sample as it is stretched from the elastic limit to its breaking point. *(2 marks)*

(ii) Use Figure 14 to calculate the extension of the sample at the breaking point. The original length of the sample is 15 cm. *(3 marks)*

c Suggest and explain what is happening to the **long chain molecules** in the sample between the elastic limit and the break point as stress is increased slowly.

You may wish to use labelled diagrams. *(4 marks)*

OCR Physics B Paper G491 June 2012

22 This question is about electron diffraction.

The equation for single slit diffraction is $\lambda = b \sin\theta$, where b is the width of the slit and θ is the angle to the first minimum.

a (i) Show that an electron accelerated through a potential difference of 900 V will gain kinetic energy of about 1.4×10^{-16} J. *(1 mark)*

(ii) The kinetic energy of an electron is related to its momentum in the equation

$$\text{kinetic energy} = \frac{\text{momentum}^2}{2m}$$

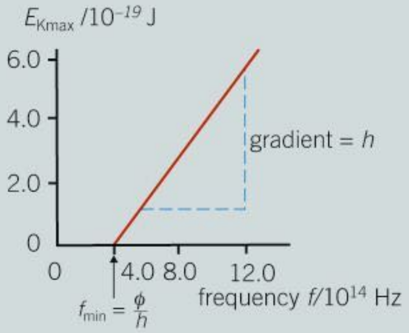
where m is the mass of an electron $= 9.11 \times 10^{-31}$ kg.

Calculate the momentum mv of the electron. *(2 marks)*

(iii) Use your answer from (a)(ii) to calculate the angle to the first minimum when electrons of energy 1.4×10^{-16} J pass through a gap of width 4×10^{-9} m *(3 marks)*

b State how the position of the first minimum will change when the electrons are accelerated through a greater potential difference. Explain your answer. *(3 marks)*

23 A photocell generates electric current by the photoelectric effect.



▲ **Figure 15**

Light of a wavelength 4.6×10^{-7} m is incident on a metal plate called the photocathode.

a Show that the energy of a photon of this light is about 4×10^{-19} J. *(2 marks)*

About 3×10^{17} photons strike the photocathode every second. A current of 1.3 mA is detected.

b (i) Calculate the number of electrons released from the photocathode each second. *(2 marks)*

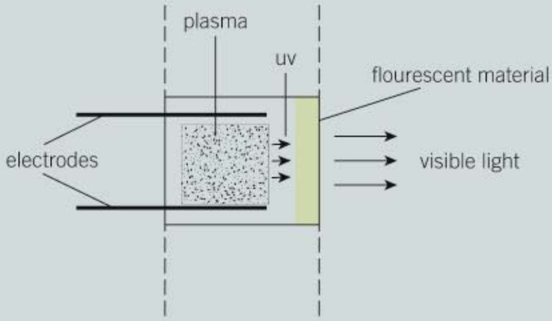
(ii) Suggest and explain why the number of electrons released each second is smaller than the number of photons incident on the photocathode each second. *(2 marks)*

c When red light of wavelength 6×10^{-7} m is incident on the photocathode there is no current detected, even though the number of photons striking the photocathode each second is greater than 3×10^{17}. Explain this observation. *(2 marks)*

Paper 2-style questions

Section A

1 This question is about the operation of a gas-filled pixel in a plasma TV screen. A plasma is a conducting ionised gas. It is formed by a high voltage pulse across a pair of electrodes in the pixel as shown in Figure 1.



▲ **Figure 1** *Schematic diagram of a pixel in plasma display*

a Describe what is meant by an ionised gas. *(2 marks)*

b Plasma emits UV radiation at a frequency of 2.9×10^{15} Hz.

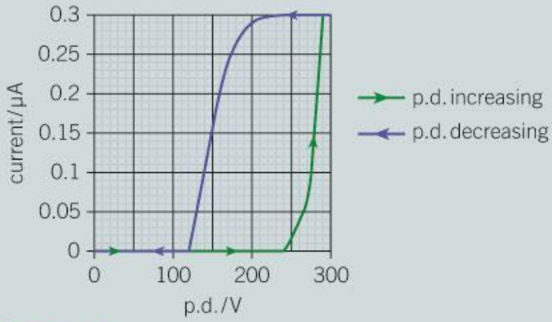
Calculate the wavelength of this radiation.

Speed of light = $3.0 \times 10^{8}\,\text{m}\,\text{s}^{-1}$ *(1 mark)*

c Gas atoms can be ionised by collision with fast-moving electrons. The p.d. between the electrodes provides energy for these electrons.

Calculate the energy gained by an electron of charge 1.6×10^{-19} C when it passes through a p.d. of 240 V. *(2 marks)*

d Once started by a high voltage pulse the plasma in a pixel can be maintained at a lower voltage. The plasma can be ended by switching off the voltage. Figure 2 shows how the current in the gas in a pixel changes as the p.d. is raised to 290 V and lowered back to 0 V.



▲ **Figure 2**

(i) **1** State the voltage at which ionisation starts.

2 State the voltage at which ionisation stops. *(2 marks)*

(ii) There are 6.2×10^{6} pixels in the display. When emitting visible light pixels operate at 180 V.

Use data from Figure 2 to calculate the total operating power of the display with all the pixels on.

(3 marks)

OCR Physics B Paper G491 Jan 2011

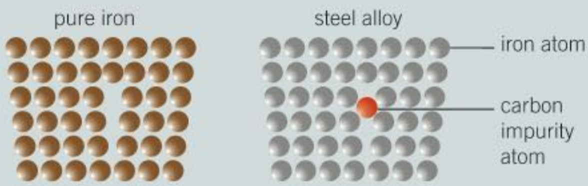
2 This question is about the materials from which cutting tools such as drill bits are made.

a (i) Metals have a polycrystalline structure.

Explain the term *polycrystalline* as applied to the structure of a metal.

You may wish to use labelled diagrams in your answer. *(2 marks)*

(ii) Drill bits can be made from steel alloy. Figure 3 shows the microstructures of pure iron metal and a steel alloy.



▲ **Figure 3**

Steel alloy containing carbon is less ductile than pure iron.

State the meaning of the term *ductile* and describe how Figure 3 can be used to help explain why steel is less ductile than iron. *(3 marks)*

b (i) Diamond is much harder than steel. This gives a diamond-coated steel drill bit an advantage over a steel one.

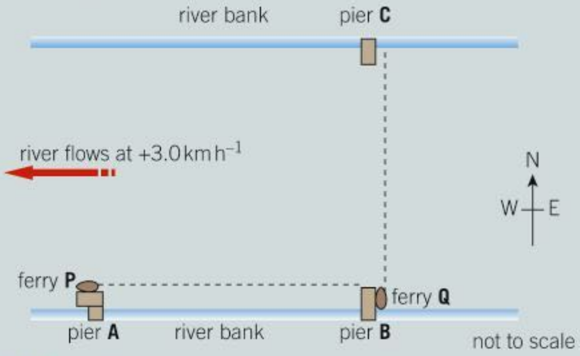
1 State what is meant by *hardness*.

2 Explain the advantage. *(2 marks)*

(ii) The atoms in steel have metallic bonding and in diamond the atoms have covalent bonding. Describe these types of bonding. Use your description to explain the difference in hardness between steel and diamond.
You may wish to use labelled diagrams in your answer. *(4 marks)*

OCR Physics B Paper G491 Jan 2013

3 This question is about *relative* and *resultant* velocities.



▲ **Figure 4**

Figure 4 shows part of a wide river on which there are three piers. The river flows from east to west at a constant velocity of $+3.0\,\text{km}\,\text{h}^{-1}$ as shown.

a Ferry **P** travels from pier **A** to pier **B**, and then back again. The ferry travels at a speed of $5.0\,\text{km}\,\text{h}^{-1}$ through still water.

(i) Calculate the velocity of the ferry relative to the river bank as it sails.

1 From **A** to **B**

2 From **B** to **A** *(2 marks)*

(ii) Piers **A** and **B** are 2.0 km apart.

Show that the total sailing time for a return journey for ferry **P**, sailing from pier **A** to **B** and back again to **A**, is 1.25 hours.
Ignore the time taken for the boat to turn around at pier **B**. *(2 marks)*

b There is another pier **C** directly across the river from pier **B**, as shown in Figure 4.

A second ferry **Q** travels between piers **B** and **C** which are 2.0 km apart. This ferry also travels at a speed of $5.0\,\text{km}\,\text{h}^{-1}$ through still water.

(i) By scale drawing, or some other method of your choosing, show that the ferry **Q** must sail in a direction 37 degrees east of north in order to travel due north across the river, from pier **B** to pier **C**. *(2 marks)*

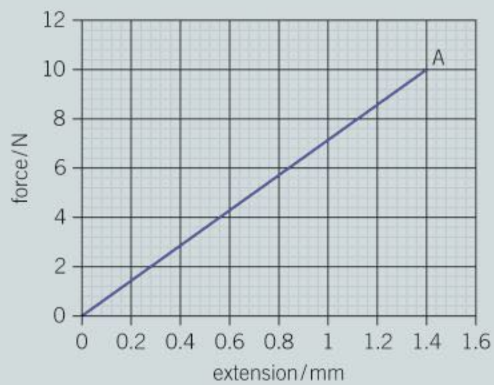
(ii) Show that the resultant velocity of this ferry relative to the river bank is $4.0\,\text{km}\,\text{h}^{-1}$ due north. *(2 marks)*

c Ferry **Q** sets off from pier **B** on an outward bound journey to **C** at the same time as ferry **P** sets off from pier **A** towards pier **B**.

Show that the bearing of ferry **Q** from ferry **P** is about 27 degrees east of north, when **Q** just reaches pier **C**. *(2 marks)*

OCR Physics B Paper 2861 June 2004

4 Figure 7 shows the graph of force against extension for a metal wire **A**.



▲ **Figure 7**

a (i) Draw on a copy of Figure 5 the graph you would expect for a wire of the same material and diameter as **A**, but of **twice** the original length. Label this graph **B**. *(1 mark)*

(ii) Draw on a copy of Figure 5 the graph you would expect for a wire of the same material and length as **A**, but of **double** the original diameter. Label this graph **C**. *(1 mark)*

b (i) State **one** piece of evidence from the graph which suggests that the stretching of the wire (by a force of 10 N) is elastic. *(1 mark)*

(ii) Wire **A** has a cross-sectional area of $7.8 \times 10^{-8}\,m^2$ and an original length of 2.00 m.

Calculate the Young modulus of the material of the wire. *(3 marks)*

c Describe metallic bonding on the atomic scale. Include in your description an explanation of how metals such as wire **A** can show elastic behaviour.

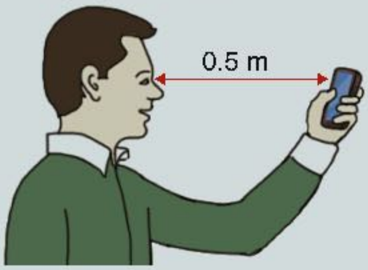
In your explanation, you should make clear how the bonding between atoms can account for the large-scale elastic behaviour of the material. *(4 marks)*

OCR Physics B Paper G491 Jan 2011

Section B

1 This question is about taking a self-portrait with a mobile phone camera.

A camera on a mobile phone has a lens of focal length 4.5 mm. It is held 0.5 m from the photographer's face.



▲ Figure 6

a (i) Show that the power of the lens is about 220 D. *(1 mark)*

(ii) Calculate the distance behind the lens that the image of the photographer will be focused. *(2 marks)*

(iii) Calculate the magnification of the image. *(2 marks)*

The photographer's face has approximate dimensions of 270 × 225 mm. This fills the picture area of the light-sensitive chip.

b Use your answer to **(a)**(iii) to calculate the dimensions of the light-sensitive chip. *(2 marks)*

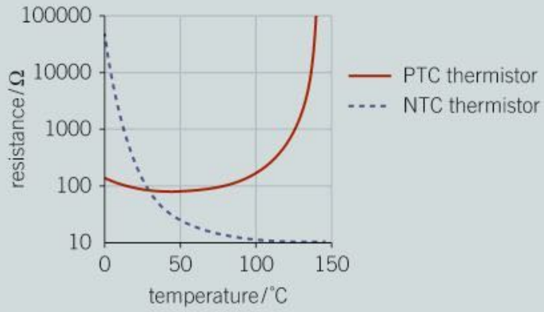
c The light-sensitive chip has 1200 × 1000 pixels. Calculate the resolution of the image of the face and comment on whether the image could resolve an individual eyelash of diameter 0.1 mm. *(3 marks)*

The camera stores three colours for each pixel, each with 256 levels of intensity. The camera memory has 0.9 GB available to store image files.

d (i) Calculate how many images can be stored in the memory. *(3 marks)*

(ii) Suggest how this number could be increased without increasing the size of the memory. Describe the advantages and disadvantages of your suggestion. *(3 marks)*

2 One type of component, called a PTC thermistor, has a resistance which varies with temperature, as shown by the solid line in Figure 7. An 'ordinary' NTC thermistor, as used in sensing circuits, has a resistance which varies as shown by the dashed line.

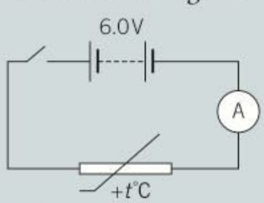


▲ Figure 7

a Compare the behaviour of these two components at different temperatures and suggest, in each case, reasons for the variation of resistance shown by the graph. This question tests your ability to construct and develop a sustained and coherent line of reasoning. *(6 marks)*

b In one sensor application, a chemical reaction vessel which needs to be kept at 50 ± 2 °C needs to be monitored. Explain why the PTC thermistor is a poorer temperature sensor than the NTC thermistor for this application. *(2 marks)*

c The PTC thermistor is connected to a 6 V battery of negligible internal resistance, as shown in Figure 8



▲ Figure 8

The temperature is 15 °C when the circuit is set up.

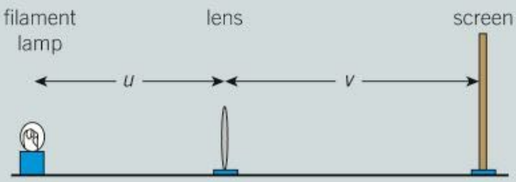
(i) Calculate the power dissipated in the PTC thermistor when the switch is closed. *(3 marks)*

(ii) After closing the switch, it is noted that there is an initial change in the current, but that it eventually settles on a fixed value. Explain this observation. *(4 marks)*

Section C

1 This question is about an experiment to determine the focal length of a converging lens.

A student uses a converging lens, a 12 V filament lamp and a ground glass screen. Distances are measured using a pair of metre rules. The basic set up is shown in Figure 9.



▲ Figure 9

The object distance is varied between −0.3 m and −1.4 m.

a (i) Suggest a possible cause of systematic error in measuring the object distance u. *(1 mark)*

(ii) Suggest a possible cause of uncertainty in the measurement of image distance v. *(1 mark)*

b Here are two comments students made about the uncertainty in measuring the image distance v.

- The actual value of the uncertainty increases as v increases.
- The percentage uncertainty in the measurement of v remains approximately constant over the range of measurements.

(i) Suggest and explain why the value of the uncertainty in the reading may increase with v. *(2 marks)*

(ii) Explain why the percentage uncertainty can remain the same even though the actual value changes. *(2 marks)*

c The student recorded this pair of values $u = 1.000$ m and $v = 0.260$ m

Show that this pair of values leads to a value to a value of the focal length of the lens of about 0.21 m. *(2 marks)*

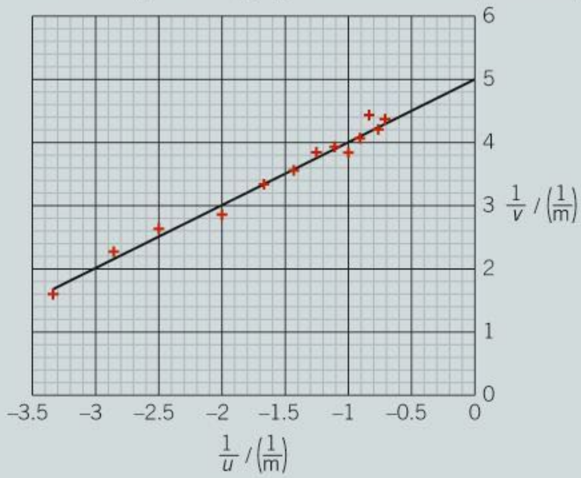
The uncertainty in the v value was estimated at ±10 mm. The uncertainty in the u value was estimated at ±1 mm. It was thought that the uncertainty in u could be ignored in considering the uncertainty in the final result.

d Using the uncertainty in v, calculate the highest and lowest values for the focal length using the data pair in **(c)** to show that the uncertainty in the focal length result is more than ±5 mm. *(4 marks)*

e The student took a range of u and v readings.

She recalled the equation $\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$ and decided to calculate $\frac{1}{u}$ and $\frac{1}{v}$ values and plot the graph in Figure 10.

Explain why she assumed this would give a straight-line graph. *(2 marks)*



▲ Figure 10

f Use the graph to find the focal length of the lens. *(2 marks)*

g Suggest why the result obtained from the best-fit line in Figure 10 is better than the mean of individual calculations of focal length from v and u data pairs. *(1 mark)*

Question	Answer	Marks
Section A		
1	C	
2	A	
3	A	
4	C	
5	C	
6	B	
7	B	
8	C	
9	A	
10	C	
11	A	
12	A	
Section B		
1	Time period = 1.6 ms $f = \dfrac{1}{1.6 \times 10^{-3}}$ = 630 Hz (2 s.f.)	1 1 1
2 a	35(.4)	1
2 b	2.8 m	1
2 c	power = $\dfrac{1}{2.8} + \dfrac{1}{0.08}$ = 13 D	1 1
3 a	Rotate filter (in plane perpendicular to direction of light). If the intensity varies from maximum to minimum and back to maximum through 180°, the light has been polarised.	1 1
3 b	Minimum intensity is greater than zero.	1
4 a	See Figure 4, Section 1.1.	2
4 b	Distance between source and lens is very great/infinite. Distant sources produce plane wave-fronts.	1 1
5 a	+12 D	1
5 b	0.083 m	1
6 a	In the second diagram the focal point is nearer the lens. Distance between wavefronts the same before and after the lens.	1 1
6 b	New lens power is larger as power = $\dfrac{1}{f}$ and f is smaller (or the second lens adds more curvature)	1
7	$\dfrac{6 \times 10^{-5}}{8 \times 10^{-14}}$ = 750 Mbyte (= 7.5 × 10^8 Byte)	1 1
8 a	0.065 V	1

8 b	10	1
8 c	6 bits (gives a resolution of 0.106 V) (7 bits gives a resolution of 0.053 V so there is some redundant information).	1 1
9 a	$\frac{\sin 45°}{\sin 26°}$ = 1.6	1 1
9 b	$\frac{3.0 \times 10^8}{1.6}$ $=1.9 \times 10^8$ m s^{-s}	1 1
9 c	angle = $\sin^{-1}$ (1.6 × sin 35°) = 68°	1 1
10 a	EMF = $V - Ir$ When I = zero, V = EMF	 1
10 b	Gradient giving 1.6 Ω	1 1
11 a	Any sensible suggestions, e.g.: • In gold, the structure allows electrons to travel more freely between atoms. • Gold is more dense (has more atoms per given volume), and so it has more free electrons.	2
11 b	Any sensible suggestions, e.g.: • It alters the structure to allow electrons to travel more freely. • It increases the number of free electrons.	2
12 a	1.7(1) × 10^8 Pa	1
12 b	Using largest F and smallest A e.g. $\frac{148}{0.76 \times 10^{-6}}$ evaluation = 1.9 × 10^8 Pa	1 1
12 c	Area because this measurement has the greatest relative or % uncertainty.	1
13 a	Plastic behaviour: suffers permanent deformation from applied force. Stress: force per unit area acting at right angles to the surface.	1 1
13 b	Plastic behaviour from slipping of planes of ions/atoms. Presence of dislocations allows slippage at lower stress.	1 1
14 a	$\lambda = \frac{hc}{E}$ = 5.3 × 10^{-7} m	1 1
14 b	$\frac{40 \times 10^{-3}}{3.7 \times 10^{-19}}$ = 1 × 10^{17} photons s^{-1}	1 1
15	$\frac{4.6 \times 10^{-19}}{6.63 \times 10^{-34}}$ = 6.9 × 10^{14} Hz	1 1
16 a	Diagram: correct tip to tail and resultant.	1 1
16 b	Resultant = $(1^2 + 2^2)^{0.5}$ = 2.24	1 1
17 a	0.60 m	1
17 b	v = 360 Hz × 0.60 m = 216 m s^{-1}	1 1
17 c	See Figure 8, Section 6.1	1

18 a	$s = ut + \frac{1}{2}at^2 = 0 \times 1.6 + \frac{1}{2} \times 9.8 \times 1.6^2$ = 12.544 m = 13 m (2 s.f.)	1 1
18 b	Uncertainty = 0.1 + 0.1 = (±)0.2	1 1
18 c	(using depth from part **a**) $t = \frac{s}{v} = \frac{12.544}{340}$ = 0.037 s (2 s.f.) This will increase the estimate of the depth.	1 1
19 a	$t = \frac{2s}{u+v}$ $t = \frac{v-u}{a}$	1 1
19 b	$\frac{2s}{u+v} = \frac{v-u}{a}$ $2as = (v-u)(v+u) = v^2 - u^2$ $v^2 = u^2 + 2as$	1
20 a	$F = ma = \frac{m\Delta v}{\Delta t} = \frac{1400 \times 27}{6.2}$ = 6096.7… N = 6100 N (2 s.f.)	1 1
20 b	Diagram drawn to show: • Forwards arrow labelled driving force or similar. • Backwards arrow labelled resistive force or similar OR two backwards arrows labelled air resistance and friction or similar. • Forwards arrow is visibly larger than backwards arrow or backwards arrows combined (award zero marks if backwards arrows are visibly larger). Arrows showing normal and reaction forces to the road are not needed but should not be penalised.	1 1 1
20 c	Power = Force × velocity = 6096.7… × 72 = 4.4×10^5 J s^{-1} (2 s.f.)	1 1 1
21 a i	$\frac{14}{0.082}$ = 170 MPa or MNm^{-2} (or 1.7×10^8 Pa etc)	1 2
21 a ii	$F = 14 \times 10^6 \times 1.9 \times 10^{-7}$ = 2.7 N (2.66 N)	1 1
21 b i	Any 2 points about the sample: • Plastic behaviour. • Very large increase in strain for small increase in stress. • Gets stiffer OR larger $\Delta\sigma$ $\Delta\varepsilon$ OR larger ΔF for small Δx. • Up to ×6 original length for breaking OR ×5 at strain 4.	2
21 b ii	breaking strain ε = 5.1 $x = \varepsilon L$ = 5.1 × 15 cm = 76.5 cm	1 1 1
21 c	• Originally long chains are amorphous (crumpled, folded etc). • Monomers (or bonds) rotate or chains slip past each other/unfold. • Bonds break OR once molecules aligned bonds themselves are being stretched. Fourth mark for correct use of any one of these technical terms: Amorphous, random, monomers rotate, bonds rotate, crystalline, cross links	1 1 1 1
22 a i	$900 \times 1.6 \times 10^{-19} = 1.44 \times 10^{-16}$ J	1

22 a ii	momentum = $\sqrt{2mE} = \sqrt{2 \times 9.11 \times 10^{-31} \times 1.44 \times 10^{-16}}$ = 1.6×10^{-23} kg m s^{-1}	1 1
22 a iii	$b \sin\theta = \frac{h}{mv}$ $\sin\theta = \frac{6.6 \times 10^{-34}}{1.6 \times 10^{-23} \times 4 \times 10^{-9}}$ = 0.01… $\theta = 0.6°$	1 1 1
22 b	The first minimum will be at a smaller angle because the electrons have greater energy and therefore greater momentum so their wavelength is decreased.	1 1 1
23 a	Energy of photon = $\frac{hc}{\lambda}$ = 4.3×10^{-19} J	1 1
23 b i	$\frac{1.3 \times 10^{-3}}{1.6 \times 10^{-19}}$ = 8.125×10^{15} s^{-1}	1 1
23 b ii	Although the energy of the photons incident on the surface is greater than the work function. Some photons will interact with electrons deeper in the metal and have insufficient energy to eject a photoelectron.	1 1
23 c	Energy of red light photon = 3.3×10^{-19} J is lower than the work function of the surface	1 1

Question	Answer	Marks
Section A		
1 a	(A gas) in which some atoms/molecules/particles have lost electrons to become positive ions/charged ions.	1 1
1 b	$\lambda = \frac{c}{f} = 1.0(3) \times 10^{-7}$ m	1
1 c	$E = VQ = 240 \times 1.6 \times 10^{-19}$ $= 3.8(4) \times 10^{-17}$ J	1 1
1 d i 1	240 V	1
1 d i 2	120 V	1
1 d ii	From the graph, 0.26(4) μA Power = $2.64 \times 10^{-7} \times 180 \times 6.2 \times 10^{6}$ = 295 W	1 1 1
2 a i	There are many small crystals with close-packed planes of different alignments/with grain boundaries.	1 1
2 a ii	Ductile means it can be drawn into a wire. Two marks for any two further points, e.g.: • In the pure metal, there is a dislocation in the regular crystal where atoms are free to move. • Slips occur easily where planes move over each other.	1 2
2 b i 1	Hard materials are difficult to dent or scratch (they resist wear).	1
2 b i 2	Hard materials last longer / don't blunt so easily / give a cleaner or more accurate cut.	1
2 b ii	Any two points from e.g.: • Metals have free/delocalised electrons. • Metals have non-directional bonds • which hold positive ions in lattice / allow positive ions to slip or dislocate. Any two points from e.g.: • In diamond, there are bound/localised electrons • which form strong directional bonds. • Diamond forms a giant lattice that is hard to displace.	2 2
3 a i 1	2.0 km h^{-1}	1
3 a i 2	8.0 km h^{-1}	1
3 a ii	Time = $\frac{\text{distance}}{\text{velocity}}$ Time from **A** to **B** = $\frac{2\text{ km}}{(5-3)\text{ km h}^{-1}}$ = 1 h Time from **B** to **A** = $\frac{2\text{ km}}{(5+3)\text{ km h}^{-1}}$ = 0.25 h Total time = 1 + 0.25 = 1.25 h (1.3 h to 2 s.f.)	1 (for method) 1
3 b i	Either correct scale drawing OR $\sin^{-1}\left(\frac{3.0}{5.0}\right)$ = 36.8… = 37° (2 s.f.)	2 1 1
3 b ii	resultant velocity = $\sqrt{3.0^3 + 5.0^2}$ = 4.0 km h^{-1} (alternatively using sin or cos 37° and a known velocity)	1 1

3 c	Time taken for **Q** to reach **C** = $\frac{\text{distance}}{\text{velocity}} = \frac{2.0}{4.0}$ = 0.50 h Therefore distance travelled by **P** = 0.5 × 2.0 = 1.0 km $\theta = \tan^{-1}\frac{1.0}{2.0}$ = 26.5… = 27° (2 s.f.)	1 1
4 a i	Straight line passing through the origin of half the gradient of A.	1
4 a ii	Straight line passing through of 4 times the gradient of A.	1
4 b i	(Direct) proportionality/straight line through origin.	1
4 b ii	$\sigma = \frac{1.2(8)\times10^{8}}{1.3\times10^{8}}$ ε = 0.00070 $E = 1.8(3) \times 10^{-11}$ Pa	1 1 1
4 c	Any 4 sensible points, e.g.: • Metal atoms lose electrons/form positive ions. • Free/delocalised (negative) electrons are present. • Attractive forces/non-directional bonding between positive and negative ions cause bonds. • Positive metal ions are closely-packed/regularly stacked in planes or lattices. • When positive ions are given small displacement, atomic planes move relative to neighbours. • Ions return to their positions when the displacing force is removed.	4
Section B		
1 a i	power = $\frac{1}{4.5\times10^{-3}}$ = 222 D	1
1 a ii	$\frac{1}{v}$ = –2 + 222 = 220 D $v = 4.5(4) \times 10^{-3}$ m	1 1
1 a iii	$\frac{v}{u} = \frac{4.54\times10^{-8}}{0.5}$ $= 9.1\times10^{-3}$	1 1
1 b	Multiply both dimensions by 9.1×10^{-3} gives dimensions 2.4 × 2.0 mm	
1 c	Resolution = $\frac{270}{1200}$ = 0.23 mm This is bigger than the width of an eyelash so if eyelashes are not separated by at least a gap of about one eyelash thick, they will not be resolved.	1 1 1
1 d i	256 levels are coded by 8 bits, which gives 3 × 8 = 24 bits per pixel bits in one image = 24 × 1200 × 1000 = 2.88×10^{7} number of images = $\frac{0.9\times10^{9}}{2.88\times10^{7}}$ = 31 images	1 1 1
1 d ii	decrease bits per image by e.g. fewer intensity levels but this will decrease image quality/accuracy of the match with object.	1 1 1

2 a	Marks are awarded for a well-structured answer. Relevant points can include e.g.: • At low temperatures, NTC thermistors have a very large resistance whilst PTC thermistors have a reasonably low resistance. • At high temperatures, NTC thermistors have low (next to no) resistance whilst PTC thermistors have a very large resistance. • NTC thermistors display a steady exponential decline in resistance with increasing temperature. • PTC thermistors have a relatively steady resistance, with large and sudden increase at a given temperature. • Reasons: e.g. The molecules/atoms in an NTC thermistor require energy to allow electrons to pass through the material. • Reasons: e.g. The molecules/atoms in a PTC resistor change structure at a given temperature/energy so that no electrons can pass freely through to material.	6
2 b	The PTC thermistor shows a large range of resistance over a small temperature range (over 100 °C), but little change around 50 °C, so it would not be suitable for keeping something at 50 °C. The NTC thermistor shows a steady decreases in resistance over this temperature range, so it would be suited to the task	1 1
2 c i	$P = IV = \frac{V^2}{R}$ $= \frac{6.0^2}{100}$ = 0.36 W	1 1 1
2 c ii	When the current is switched on, the temperature rises. This rise causes a slight decrease in resistance. At around 50 °C the resistance remains steady. So the current will remain steady.	1 1 1 1
Section C		
1 a i	Measuring from the glass casing of the lamp rather than filament/refraction due to the glass casing	1
1 a ii	Difficulty when the image of the lamp is most clear.	1
1 b i	When the image is larger and dimmer the point of greatest sharpness/clarity is harder to judge.	1 1
1 b ii	If the absolute uncertainty increases in proportion to distance the ratio absolute uncertainty/distance will remain constant.	1 1
1 c	$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{0.260} - \left(-\frac{1}{1.000}\right) = \frac{63}{13}\ \text{m}^{-1}$ $f = \frac{13}{63} = 0.206\ \text{m}$	1 1
1 d	Calculating lowest value of *f* as 0.200 highest value as 0.212 range = +/- 0.006 m which is greater than 5 mm	1 1 1 1
1 e	Equation is of the form $y = mx + c$ *y* identified with $\frac{1}{v}$, *x* identified with $\frac{1}{u}$, and *c* (*y*-intercept) with $\frac{1}{f}$.	1 1
1 f	$\frac{1}{f} = 5.0\ \text{m}^{-1}$ so $f = 0.20$ D	1
1 g	Best-fit line highlights the presence of outliers. A simple mean could be incorrectly weighted by such data points.	1