Answer **all** the questions.

SECTION A

1 Here is a list of electrical units.

As Cs^{-1} Js^{-1} JC^{-1} AV^{-1}

Choose the correct unit from this list for

(a) electric charge ...As... $Q = It$

(b) potential difference ...JC^{-1}... $V = E/Q$

(c) conductance. ...AV^{-1}... $G = I/V$

[3]

2 Fig. 2.1 shows three wavefronts of the light from a very distant object incident on a lens.

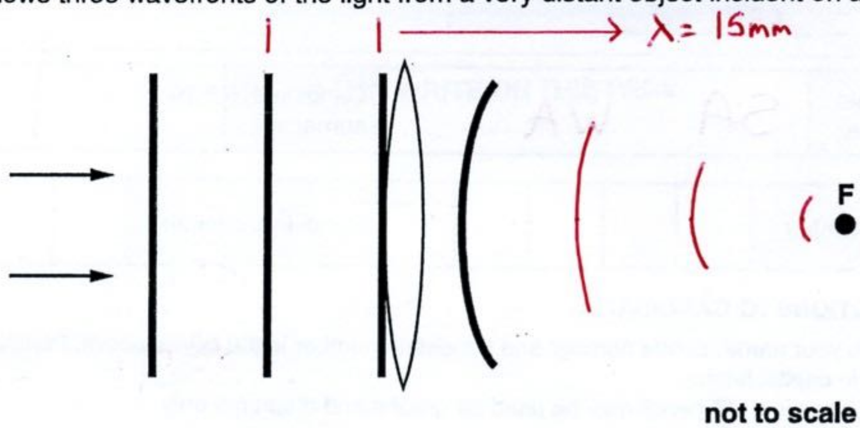


Fig. 2.1

(a) State how the diagram shows that the object is very distant from the lens.

curvature of wavefronts is zero ($1/\infty = 0$)

[1]

(b) On Fig. 2.1 one wavefront of the light between the lens, and **F**, the principal focus of the lens, has been drawn.

Add **three more** wavefronts to the diagram between the lens and **F**. **[2]**

3 Fig. 3.1 shows part of the stress against strain graph for mild steel.

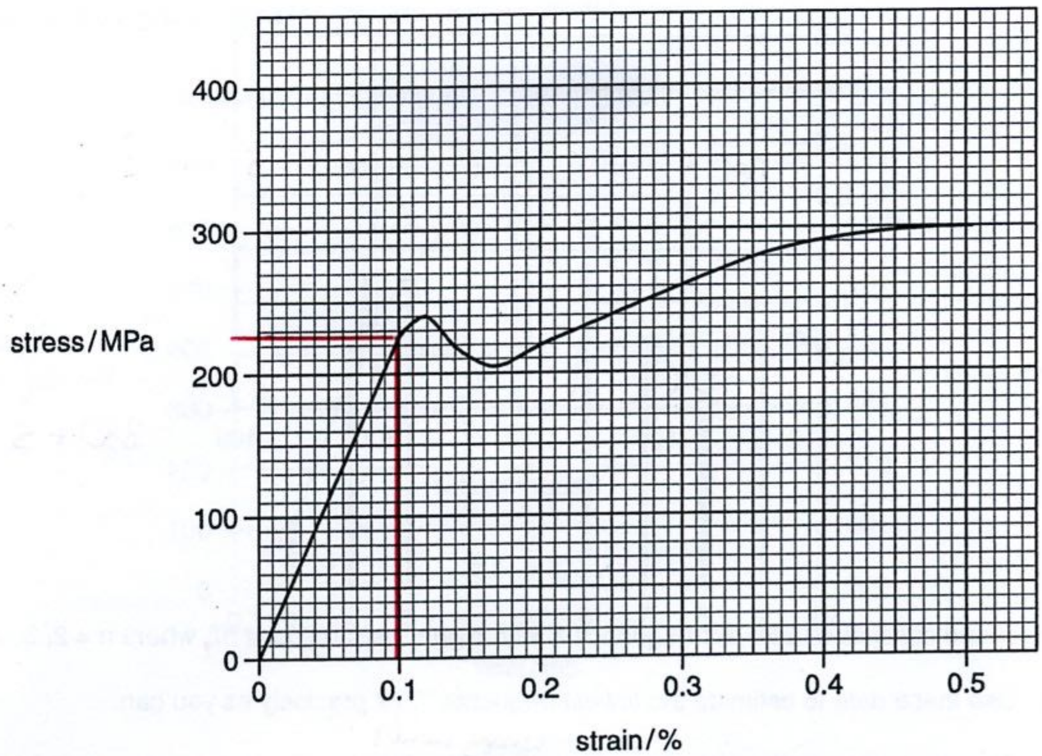


Fig. 3.1

(a) Write down the stress when the strain is 0.1%.

stress = 225 MPa **[1]**

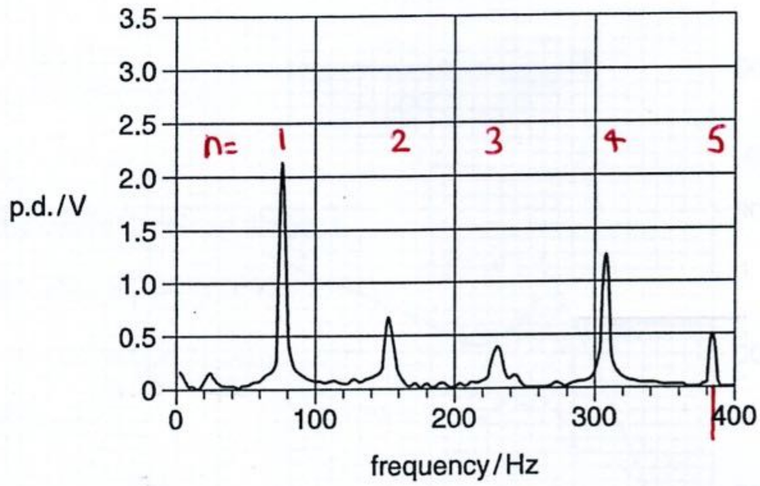
(b) Calculate the Young modulus for mild steel.

Make your method clear.

$E = \frac{\text{stress}}{\text{strain}} = \frac{225 \times 10^6 \text{ Pa}}{0.1/100} =$

Young modulus = 2.25×10^{11} Pa **[2]**

4 Fig. 4.1 shows the frequency spectrum of a sound.



1/4 division ↓ 380 + 5 = 385 Hz

Fig. 4.1

The sound consists of a lowest frequency f_1 with higher harmonics at nf_1 where n = 2, 3, 4 or 5.

(a) Use these data to estimate the lowest frequency f_1 as precisely as you can.

Show how your method improves precision (wrong word!) and quote your final answer to a sensible number of significant figures.

Use n=5 peak to reduce % uncertainty in f

$5f_1 = 385$ Hz ∴ $f_1 = 385\text{ Hz}/5 =$

lowest frequency f_1 = ...77.... Hz **[2]**

(b) Describe the spectrum of the sound when the sound is quieter.

Peaks are of lower p.d. (amplitude) but are at same frequencies

[2]

2 points

5 Fig. 5.1 shows an analogue voltage signal varying in time.

It is sampled every 1.0 ms for conversion into a digital signal.

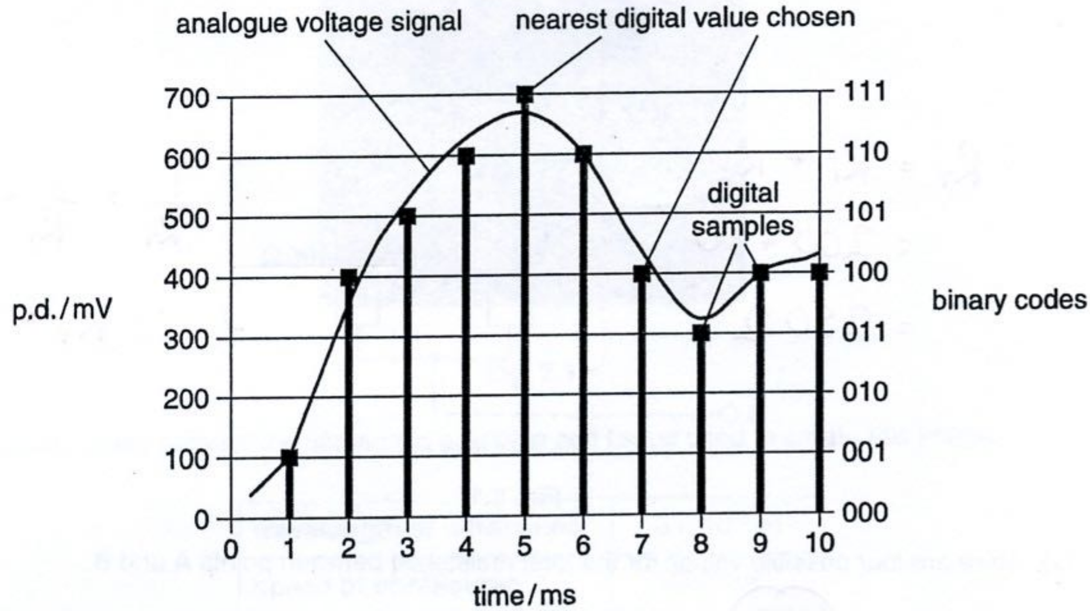


Fig. 5.1

(a) Use information from Fig. 5.1 to calculate the number of bits per second used for the binary coding.

bit rate = sample rate × bits per sample

$= \frac{1}{1 \times 10^{-3}} \times 3 =$

number of bits per second = 3000 **[2]**

(b) Fig. 5.1 shows that the digital samples can differ from the original analogue signal.

State and explain how this error can be reduced.

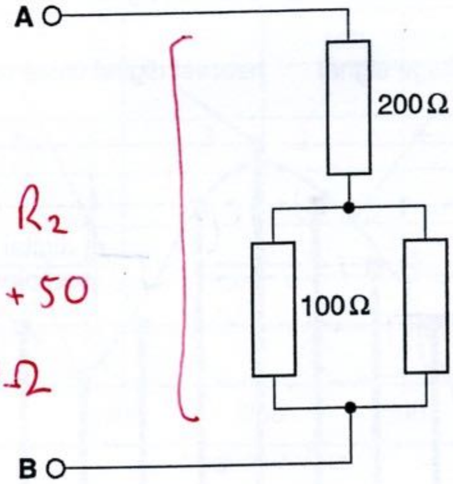
Use more bits per sample to give more levels/alternatives

alternatives = 2^{bits}

[2]

2 points

6 Three resistors are connected as shown in Fig. 6.1.



$R_T = R_1 + R_2 = 200 + 50 = 250\,\Omega$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{2}{100}$ $\therefore R_T = 50\,\Omega$

Fig. 6.1

(a) Here are four possible values for the total resistance between points **A** and **B**.

250 Ω   300 Ω   350 Ω   400 Ω

Put a ring around the correct answer. **[1]**

(b) A 12 V battery of negligible internal resistance is connected between **A** and **B**.

Calculate the current drawn from the battery.

$I = V/R = 12V/250\,\Omega =$

current = 0.048 A **[2]**

7 Fig. 7.1 shows part of an ultrasound image of a 20 week old foetus.

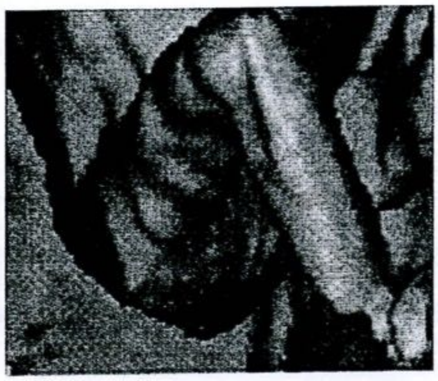


Fig. 7.1

Here are some data for the ultrasound pulses in soft tissue used to create this image.

wavelength of ultrasound	3×10^{-4} m
speed of ultrasound	$1500\,\mathrm{m\,s^{-1}}$
pulse duration	$0.8\,\mu\mathrm{s}$

(a) Calculate the frequency of the ultrasound used.

$v = f\lambda$ $\quad 1500/3\times10^{-4}$

$\therefore f = v/\lambda =$

frequency = 5×10^6 Hz **[2]**

(b) Calculate the number of oscillations in a pulse.

Make your method clear.

$T = 1/f = 1/5\times10^6 = 2\times10^{-7}\,\mathrm{s}$

$0.8\times10^{-6}\,\mathrm{s} / 2\times10^{-7}\,\mathrm{s} =$

number of oscillations per pulse = 4 **[2]**

SECTION B

8 A laptop computer is connected to the internet by sending and receiving radio signals through a wireless hub.

The following specifications are given for the hub.

power rating	8W
bit rate	300 Mbit s^{-1}
wave speed *c*	$3 \times 10^8\, m\, s^{-1}$

mains voltage	230V
carrier wave frequency	5GHz
maximum range of hub	60m

(a) Calculate the current drawn by the hub from the mains supply.

$P = IV \quad \therefore \quad I = P/V = 8W/230V =$

current = 0.035 A **[2]**

(b) Calculate the wavelength of the radio carrier waves used to communicate between the hub and laptop.

$\lambda = c/f = \frac{3 \times 10^8}{5 \times 10^9}$

wavelength = 0.06 m **[2]**

(c) (i) A 2 Gbyte file is downloaded from the internet through the hub.

Calculate the minimum time to complete the download.

$8 \times 2 \times 10^9 / 300 \times 10^6$

time = 53 s **[2]**

(ii) Suggest and explain a reason why the time could be significantly longer than the value you have calculated.

There could be interference / radio noise so the hub uses a lower bit rate

[2]

(d) Explain why the laptop will fail to communicate reliably with the hub beyond a certain distance. You should consider ideas about **signal strength** and **noise**.

Organise your explanation clearly and coherently using ideas about signal strength and noise.

You may wish to use labelled diagrams to illustrate your answer.

As the distance increases the signal strength will fall. Eventually the signal to noise ratio will become too small. The receiver will not be able to pick out the signals information from the background noise.

[3]

[Total: 11]

9 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.

many small crystals packed together with different orientations

[2]

(ii) Drill bits can be made from steel alloy. Fig. 9.1 shows the microstructures of pure iron metal and a steel alloy.

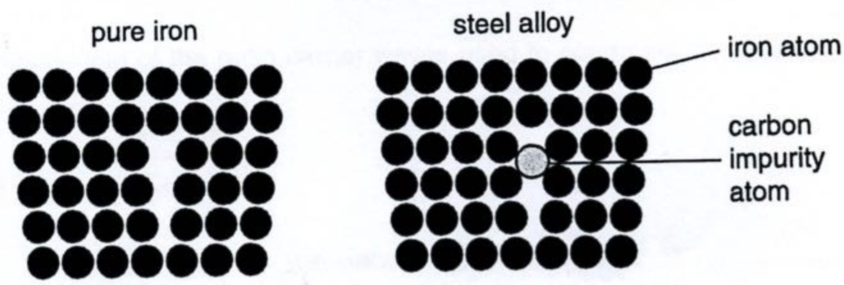


Fig. 9.1

Steel alloy containing carbon is less ductile than pure iron.

State the meaning of the term *ductile* and describe how Fig. 9.1 can be used to help explain why steel is less ductile than iron.

ductile = can be drawn into a wire

In iron the dislocations are free to move through structure allowing planes of atoms to slip resulting in ductile behaviour. In steel the carbon atoms pin the dislocations in place preventing slip and so reducing ductility.

[3]

(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*.

difficult to scratch OR dent OR wear away

2 Explain the advantage.

Lasts longer

[2]

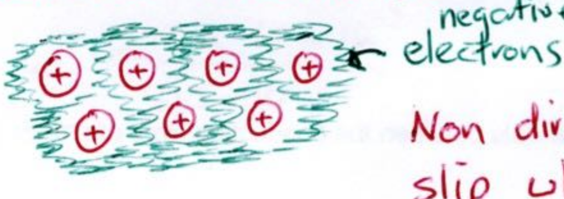
(ii) The atoms in steel have metallic bonding and in diamond the atoms have covalent bonding.

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.

Use appropriate technical terms in your answer.

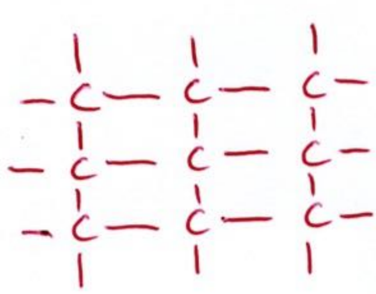
In metallic bonding a lattice of metal ions is held together by a sea of delocalised electrons.



Non directional bonds allow slip which reduces hardness

In diamond the carbon atoms are held by directional bonds (shared pairs of electrons)

[4]



Directional bonds prevents slip giving a hard material

[Total: 11]

10 This question is about the touch-sensitive screen of a mobile phone such as the one shown below.

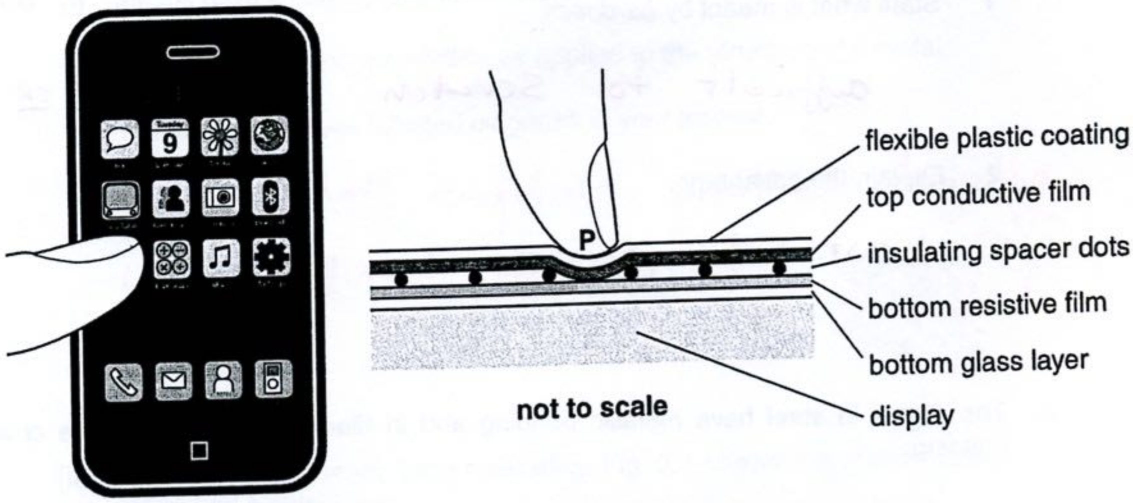


Fig. 10.1

The screen consists of several layers as shown in Fig. 10.1. A finger pressed on the screen at point **P** causes two separate conducting films (the top conductive film and the bottom resistive film) to touch and make an electrical contact.

(a) **(i)** State why the plastic coating and the top conductive film need to be flexible.

Layers need to bend so they can touch

[1]

(ii) State why the spacer dots between the conducting films are made from an insulator.

To prevent electrical contact

[1]

* low number density

(b) The two conducting films are made from a semiconducting material.

(i) State what you understand by the term *semiconductor*.

Material with a few mobile charge carriers*

OR

Has conductivity between metal & insulator **[1]**

(ii) The top conductive film has a much higher conductivity than the lower resistive film.

State and explain how the conductivity of a semiconducting material can be varied in the manufacturing process.

In text book extension section pg 55

By adding impurity element with more or fewer outer electrons

[2]

(iii) Here are some data for the lower resistive film.

length *L*	60 mm
cross-sectional area *A*	$2.5 \times 10^{-6}\,m^2$
resistivity *ρ*	0.17 Ω m

Calculate the resistance of this length of film.

$$R = \frac{\rho L}{A} = \frac{0.17 \times 60 \times 10^{-3}}{2.5 \times 10^{-6}}$$

resistance = 4.1×10^{3} Ω **[2]**

(c) Fig. 10.2a shows the circuit connections to measure the x-position on the touch-sensitive screen. Fig. 10.2b shows the equivalent potential divider circuit using conventional circuit symbols. Point **P** represents the point of contact between the films.

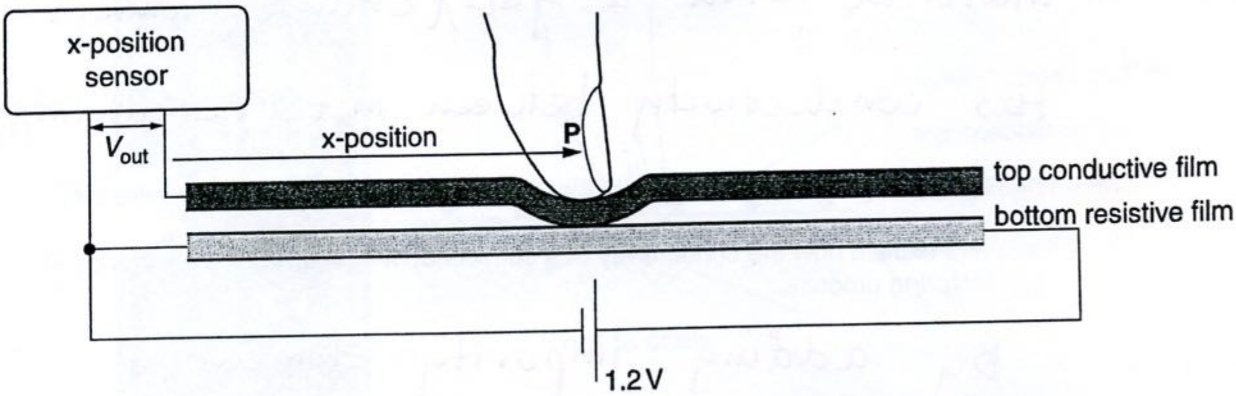


Fig. 10.2a

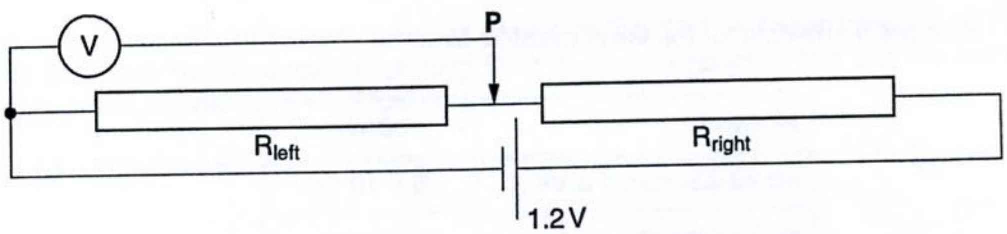


Fig. 10.2b

not why

(i) Explain how the voltage output V_{out} across the sensor varies with the x-position of the contact point **P** on the screen.

Since $R_{left} \propto x$

$$V_{OUT} = 1.2V \frac{R_{left}}{R_{left} + R_{right}}$$

[2]

(ii) The length of the resistive film is 60 mm and the p.d. across it is 1.2 V.

1 Show that the sensitivity of the touch-screen film is 20 mV mm^{-1}.

$\frac{\Delta \text{ OUTPUT}}{\Delta \text{ INPUT}}$ = Sensitivity = $\frac{\Delta V}{\Delta x} = \frac{1.2\text{V}}{60\text{mm}} = 0.02\text{Vmm}^{-1}$

$= 20\text{mVmm}^{-1}$

2 The voltage resolution of the x-position sensor is 5.0 mV.

Calculate the position resolution of this system.

$\Delta x = \Delta V/\text{sensitivity} = 5\text{mV}/20\text{mVmm}^{-1} =$

position resolution = ...0.25...... mm **[2]**

(iii) Calculate the number of bits needed to code for the x-position voltage.

Make your method clear.

Number of levels = $60\text{mm}/0.25\text{mm} = 240$

$\log_2 240 = 7.91$

number of bits = ...8...... **[3]**

[Total: 14]

END OF QUESTION PAPER