

Sample Examination Questions

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NB. Material covered by the AS papers may also appear in A2 papers.

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- 1 A photographic enlarger consists of a mains lamp, and two converging lenses as shown in Fig. 1.1.
A transparent negative is illuminated by light from a diffusing screen.
The transparent negative then acts as an optical object and its image is focused by the projecting lens onto the photographic paper below.

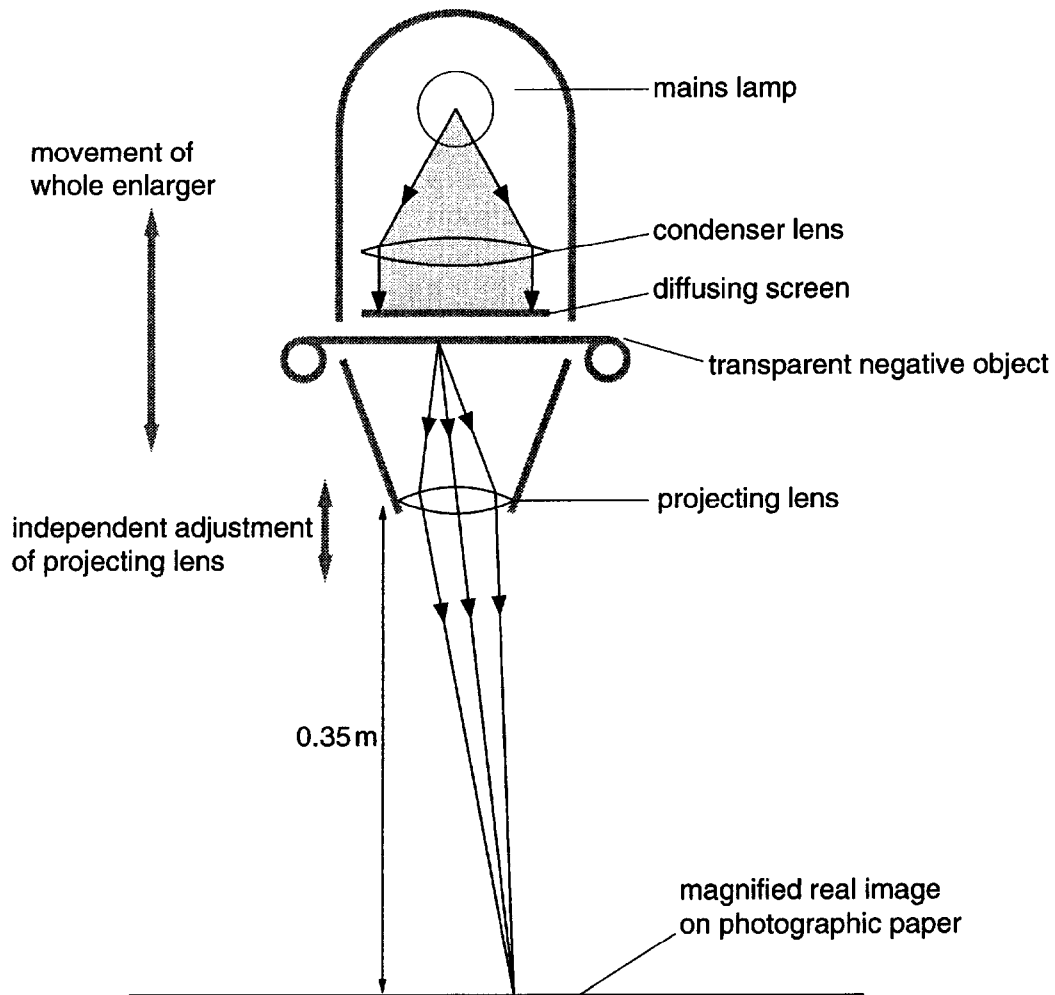


Fig. 1.1

Light from the mains lamp passes through the condenser lens to illuminate the diffusing screen with a **parallel beam** of light.

- (a) (i) Describe and explain how the **curvature** of the wavefront changes as light passes from the mains lamp to the diffusing screen.

[2]

- (ii) The power of the condenser lens is +4.0 D.

Calculate the distance between the centres of condenser lens and lamp, so that **parallel** rays are produced. Explain your reasoning.

[3]

- (b) The transparent negative acts as an object for the projecting lens. The linear magnification required is $\times 6$ onto the photographic paper. This is achieved when the projecting lens is 0.35 m above the photographic paper.

- (i) Use the magnification to show that the distance between the transparent negative and the centre of the projecting lens is about 0.06 m.

distance = m [2]

- (ii) Using the information above, calculate the focal length f of the projecting lens.

focal length = m [3]

[Total: 10]

- 2 In high quality audio, the audio signal samples are recorded with 16-bit precision. Show that this is better than measuring the height of an elephant (5 m) to an uncertainty of the thickness of a sheet of paper (0.1 mm).

[2]

- 3 What voltage amplitude of noise can be tolerated in an audio system with a 100 mV signal sampled at 16 bits?

[2]

- 4 (a) A noisy audio signal is encoded with 8 bit samples. If the total voltage variation in the signal is 200 mV, what is the greatest amplitude of noise that the signal can contain without the samples picking up noise rather than signal information?

[2]

- (b) An analogue signal is expected to contain noise amounting to up to 0.5% of the total voltage variation in that signal.

- (i) What is the maximum number of bits that can be used to encode the signal?

[2]

- (ii) What differences would you expect to hear between an 8-bit signal and a 16-bit signal?

[1]

5 This question is about some aspects of mobile phone technology.

A SIM card provides the memory for a mobile phone, and contains a small memory chip. This can be programmed to remember the user's personal telephone directory, with up to 100 names and numbers.

An example of a stored entry might be: **LAURENT 01396 813976**
Memory is reserved for names of up to ten letters and numbers of 12 digits.

(a) There are ten alternative decimal digits (0 to 9).

By working out the number of alternatives that can be coded by a 4-bit binary number, show that 4 bits is sufficient to code for each decimal digit in the number.

[2]

(b) Calculate the number of bits of information needed to store one hundred 12-digit numbers in memory.
Convert this to bytes.

bits required = bytes required = [2]

(c) Explain why more memory is needed to code for a letter from the English alphabet, than for a decimal digit.

[2]

(d) (i) A mobile phone samples sound 10 000 times per second.

Write down the highest sound frequency the mobile phone can transmit.

highest frequency = kHz [1]

(ii) The mobile phone reproduces speech satisfactorily, but the quality of music reproduction is poor.

Suggest **two** reasons for this.

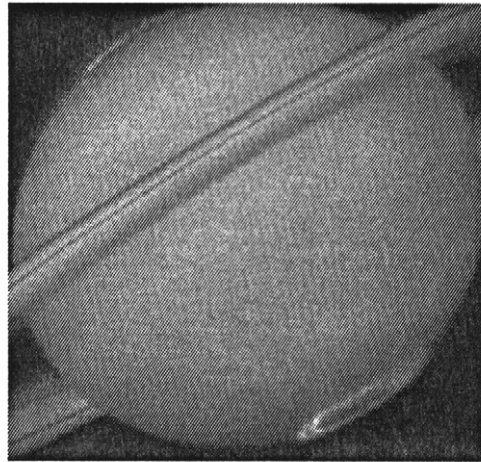
- 1.
- 2.

[2]

[Total: 9]

- 6 This is an ultraviolet image of Saturn taken from the Hubble space telescope.

512 pixels



512 pixels

- (a) Suggest why ultraviolet images cannot be obtained by ground based telescopes.

[1]

Saturn has a diameter of 1.2×10^8 m, and the picture contains 512×512 pixels.

- (b) Estimate the resolution of the image, making your method clear.

[2]

- 7 For much of the history of radio, analogue radio transmissions were mainly on Long Wave (LW) and Medium Wave (MW) wavebands. Long Wave ranged from frequencies of 30 kHz to 300 kHz. Medium Wave contained higher frequencies, from 300 kHz to 3 MHz.

(a) Explain why the LW waveband is referred to as **Long Wave**.

[1]

(b) The bandwidth allocated for each radio station on Long Wave and Medium Wave bands is 9 kHz. Explain why there were only a few radio stations broadcasting on LW.

[2]

(c) Most analogue radio transmissions are now on the VHF (Very High Frequency) band, from 30 MHz to 300 MHz. The bandwidth allocated to each station is 200 kHz. Explain why the VHF waveband has many more radio stations, with much better quality of sound, than that on Long and Medium Wave.

[3]

(d) Digital radio transmissions have now become common. Most UK transmissions are at bit rates of 128 kilobits s^{-1} .

(i) Show that encoding high quality audio at up to 15 kHz with 16 bit digital samples requires a considerably larger rate of transmission of information than this, unless the signal is compressed.

You can assume that the rate of sampling must be twice the maximum frequency.

[2]

(ii) Suggest a reason why the rate of transmission of digital information in DAB radio is kept as small as possible.

[1]

[Total: 9]

- 8 The voltage signal:noise ratio of a signal is 5000:1, and the signal is sampled at 44.1 kHz in each of two stereo channels;
- (a) Show that the maximum number of bits which could be used to encode the signal, without any redundant bits, is 12.

[2]

- (b) Show that the bit rate for the encoded signal is about 10^6 bit s^{-1} , and express the rate of information transfer in bytes s^{-1}

[3]

- (c) Assuming that the bandwidth is of the order of magnitude of the bit rate, show that this signal could be listened to 'live' on a computer through a broadband connection operating at 2.0 Mbit s^{-1} , and suggest why watching a 'live' film on the computer would require a much greater bandwidth.

[2]

[Total: 7]

- 9 This question is about aspects of a portable, flexible electrical extension cable, shown in cross-section in Fig. 9.1.

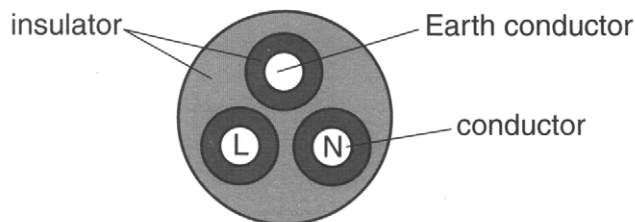


Fig. 9.1

- (a) Complete the table for the required properties of suitable materials for making the cable.

	conductor	insulator
electrical conductivity		very low
suitable material	copper	

[2]

- (b) The live **L** and neutral **N** conductors are connected in series with the load and the supply as shown in Fig. 9.2.

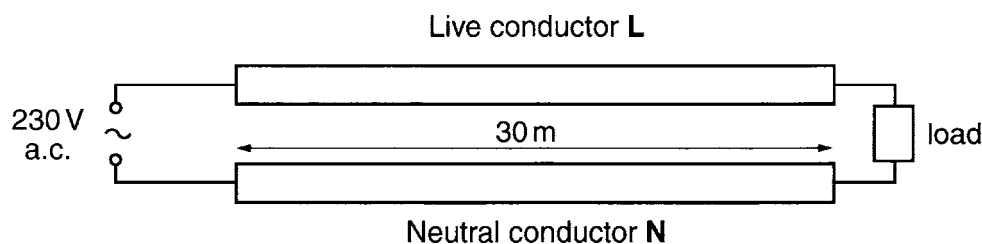


Fig. 9.2

- (i) The cable is 30 m long, so that in total 60 m of conductor in the cable are in series with the load.
 Each conductor has a cross-sectional area of $1.8 \times 10^{-6} \text{ m}^2$.
 Copper has a conductivity of $5.9 \times 10^7 \text{ S m}^{-1}$.

Show that the conductance of the cable is about 1.8 S.

[2]

- (ii) The cable has a maximum current rating of 13 A.

Calculate the voltage dropped across the total resistance of the 60 m of conductor when there is a current of 13 A.

voltage dropped = V [2]

- (iii) Show that the power dissipated in the cable under these conditions is of the order of 100 W.

[1]

- (iv) The cable is stored by being tightly wound on a reel. The makers recommend that if the cable is used coiled on its reel, the current in it should be significantly less than 13 A.

Use the data from (b) (iii) to suggest and explain a reason for this recommendation.

[2]

[Total: 9]

- 10 This question is about monitoring stress with the voltage output from a stressed crystal (as in a microphone). The crystal stress gauge is glued to the surface of a beam under slowly changing stress. A voltage appears across the crystal when it is stressed. The output voltage varies up to 200 mV, and the internal resistance r of the crystal is $5.0 \text{ M}\Omega$

- (a) (i) Calculate the maximum current the crystal stress gauge can produce.

maximum current = A [2]

The crystal stress gauge is connected in a circuit as shown in Fig. 10.1, with a measuring device of load resistance R equal to $5.0 \text{ M}\Omega$.

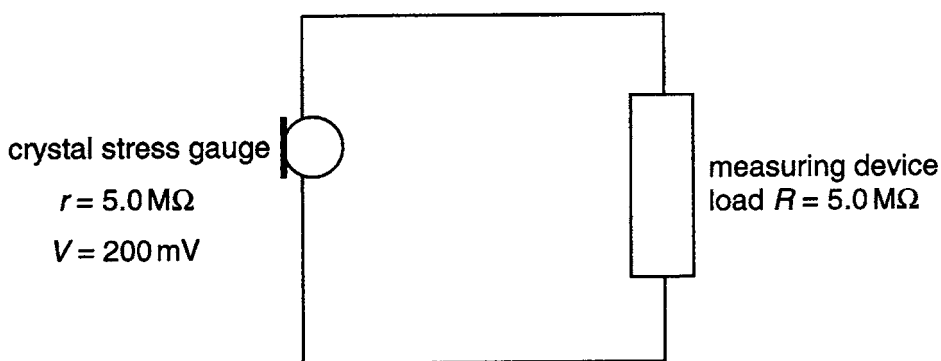


Fig. 10.1

- (ii) Show that the maximum current that can be drawn from the crystal in this arrangement is $2.0 \times 10^{-8} \text{ A}$.

[1]

- (iii) Calculate the value of the p.d. across the measuring device under this electrical load.

p.d. = V [2]

You are asked to choose an instrument to measure the output from the crystal, when measuring variations in stress.

The maximum output voltage from the crystal is 200 mV.

The instruments available are

instrument	full scale deflection	sensitivity	internal resistance	resolution
moving coil ammeter	300 mm	50 mm μA^{-1}	15 Ω	± 0.5 mm
cathode ray oscilloscope	10 cm	0.01 to 10 V cm^{-1}	25 M Ω	± 0.1 cm
digital voltmeter	20 V	0.01 V steps	2.0 M Ω	± 0.01 V

(b) (i) Which instrument would you choose?

[1]

(ii) Use the data in the table to explain your choice.

[2]

(iii) For the instrument you have chosen, calculate the output it would measure for a 200 mV signal from the crystal.

[2]

[Total: 10]

- 11 This question is about the demister of the rear view window of a motorcar. A conducting material is fused onto the glass surface, to make an electrical heater. There are 10 conducting tracks, as illustrated below.

- (a) On Fig. 11.1 draw a **series** connection of the conductors to the battery and on Fig. 11.2 draw a **parallel** connection to the battery.

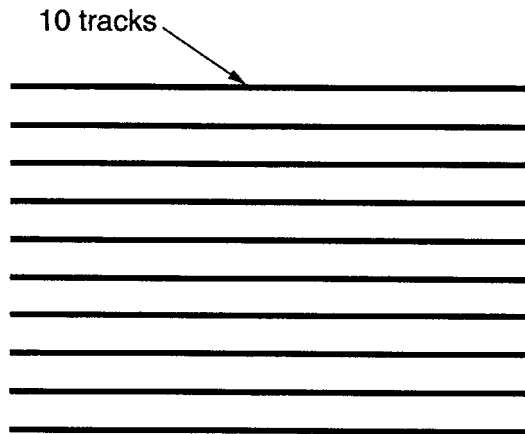


Fig. 11.1 (draw a series circuit)

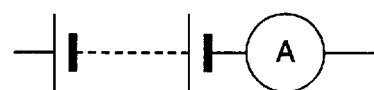
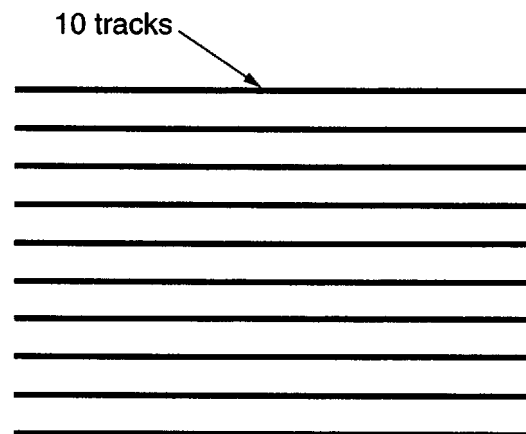


Fig. 11.2 (draw a parallel circuit)

[1]

To demist effectively, each track in the heater needs to dissipate a power of 24 W. The battery operates at 12 V d.c. (ignore the effects of internal resistance).

- (b) Complete the table.

	series connection	parallel connection
p.d. across each track / V		
current in each track / A		
conductance of each track / S		

[5]

The material from which the tracks are made has a conductivity of $4.2 \times 10^5 \text{ S m}^{-1}$. The tracks are 1.0 m long and 0.20 mm thick, as shown in Fig. 11.3.

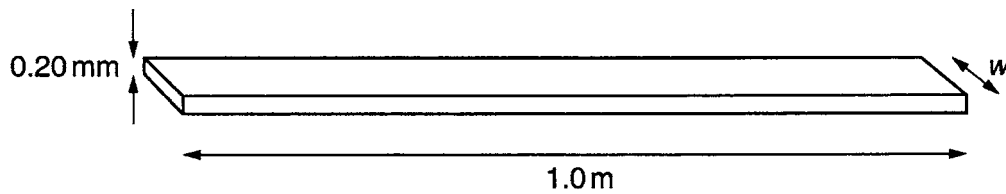


Fig. 11.3 (not to scale)

- (c) (i) Show that the width w of each of the parallel connected tracks needs to be about 2.0 mm to achieve a conductance of 0.17 S per track.

[3]

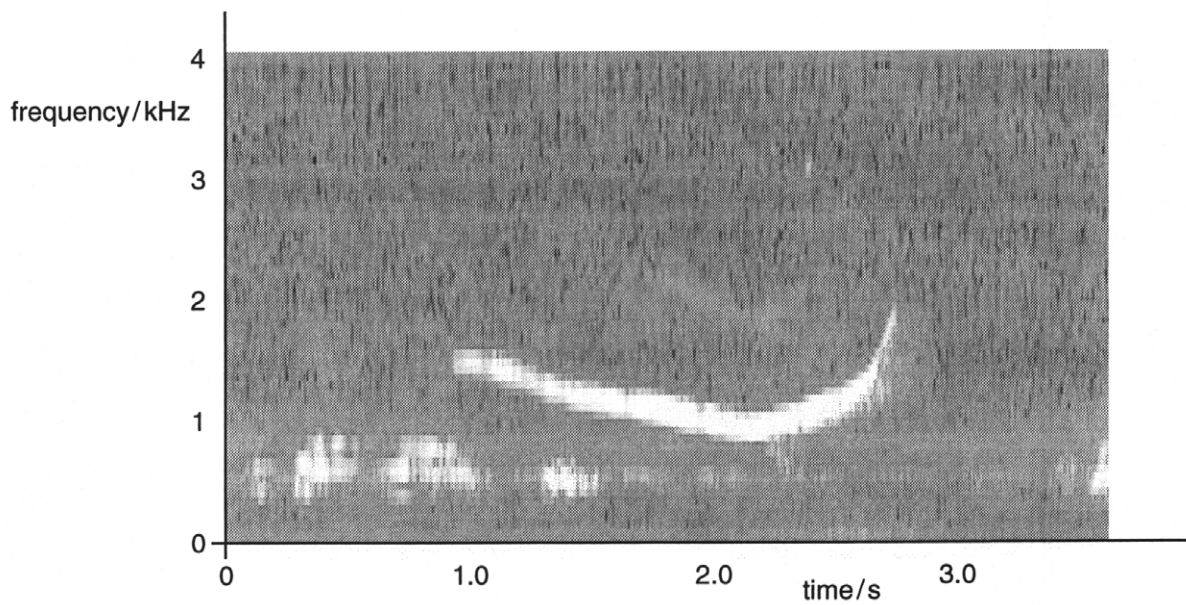
- (ii) Would you choose series or parallel connected tracks for a demister?

Give your reason.

[1]

[Total: 10]

12 A sound spectrograph, lasting about 4 s is shown below.



(a) Suggest **one** example where this type of display could be useful.

[1]

(b) The spectrograph shows some speech, and includes a whistle lasting from $t = 1.0$ to $t = 3.0$ seconds approximately.

Describe **two** features of the whistle, from the spectrograph data.

[2]

- 13 This question is about signalling and imaging in television.
 Fig. 13.1 shows a t.v. aerial being pointed towards the transmitter and receiving a plane polarised signal.

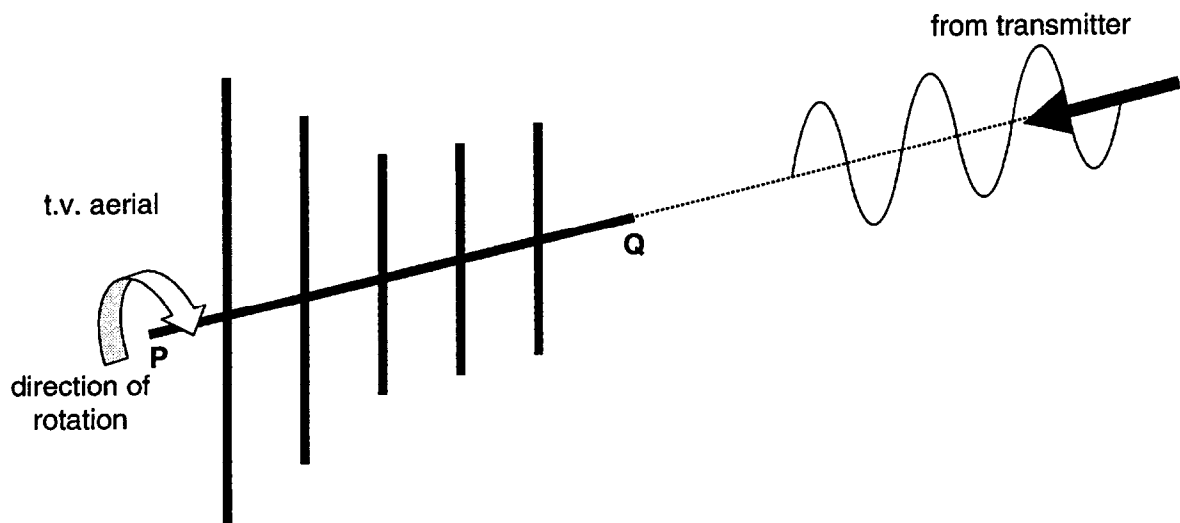


Fig. 13.1

- (a) The aerial is rotated about the axis **PQ**, starting from the position shown, where the received signal is a maximum.
 Complete the table to show the variation in the received signal, as the aerial is rotated 180° about the axis **PQ**.

angle of rotation	received signal
0°	maximum
90°	
180°	

[2]

- (b) Suggest an explanation for the variation you indicated in the table.

[2]

- (c) A digital t.v. transmission uses a carrier wavelength of 0.14 m.

- (i) Show that the frequency of the carrier waves is about 2.0 GHz.
 speed of light $c = 3.0 \times 10^8 \text{ m s}^{-1}$

[2]

- (ii) There is a total of about 2×10^6 pixels in the screen of a typical t.v. Each pixel requires one **byte** of information to code its intensity value. The screen is refreshed 25 times every second.

Show that the information transmission rate required in this system is $400 \times 10^6 \text{ bits s}^{-1}$.

[2]

- (iii) Fig. 13.2 shows the carrier wave being switched on and off, as bits 1 and 0 are being transmitted.

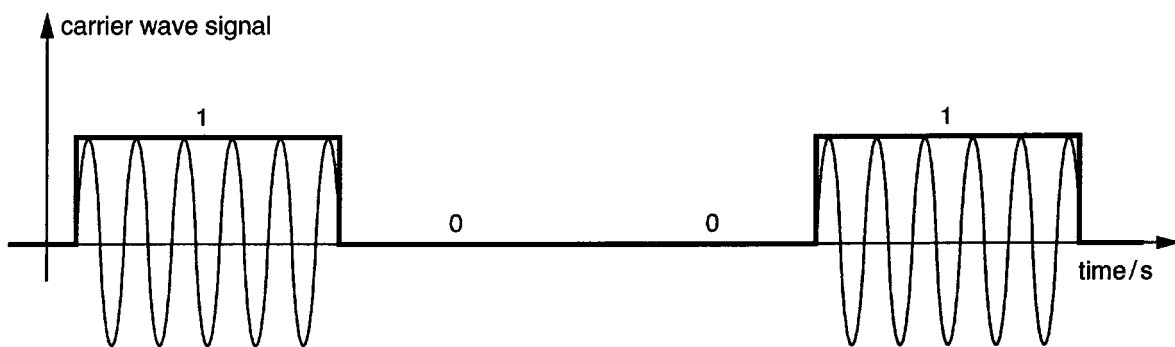


Fig. 13.2

Calculate the time to transmit one bit on this transmission system.

time..... s [2]

[Total: 10]

14 This question is about the conversion of signals from analogue to digital. Figure 14.1 shows 2.0 ms of a sampled sound waveform.

(a) State and explain one advantage and one disadvantage of a signal in digital rather than analogue form.

Advantage:

Disadvantage:

[4]

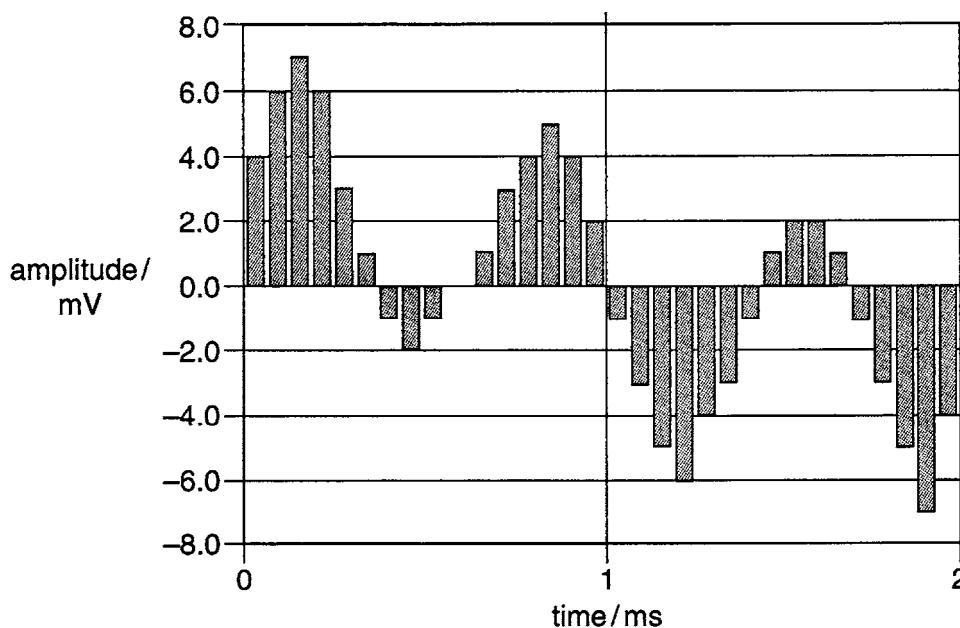


Fig. 14.1

(b) (i) State the number of different voltage levels used in this sampled waveform.

number of voltage levels used = [1]

(ii) State how many bits are needed to code for this number of levels, justifying your answer.

(iii) State the sampling frequency of the digital converter. [2]

sampling frequency = [1]

(iv) Calculate the information transmission rate in bits per second for this digitised signal.

information transmission rate = bit s⁻¹ [2]

[Total: 10]

15 A kitchen freezer of total mass 300 kg (including contents) rests on a vinyl plastic floor covering.

- (a) Calculate the weight of the freezer and its contents
 $g = 9.8 \text{ N kg}^{-1}$

weight = N [1]

- (b) The feet of the freezer have a **total** cross-sectional area of $8.0 \times 10^{-4} \text{ m}^2$.
The vinyl plastic floor covering has a compressive yield stress of 3.5 MPa.

Show that the feet of the freezer can cause permanent damage to the vinyl plastic floor covering.

[2]

16 This question is about steel wires in tension.

Guitar strings can be made from tensile steel wire. A sample of steel wire is tested in the laboratory. Fig. 16.1 shows the force–extension graph obtained when the wire is stretched.

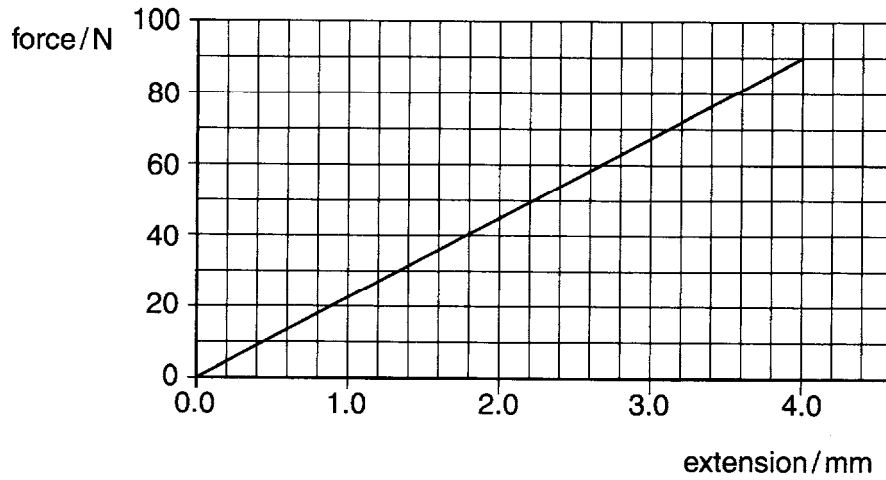


Fig. 16.1

(a) Describe how the extension varies as the force is increased.

[1]

(b) The area under the force against extension graph equals the energy stored in the stretched wire.

(i) Calculate the energy stored when the force in the wire is 90 N.

energy = unit [3]

- (ii) This sample of steel wire had an original length of 2.0 m and cross-sectional area of $2.5 \times 10^{-7} \text{ m}^2$.

Use these facts and information from the graph, to calculate the Young modulus of the steel.

Young modulus = N m^{-2} [5]

- (c) The test is repeated using another sample of the same wire, but of only **half** the original length.

- (i) **Sketch on the axes of Fig. 16.1** the force–extension graph you would expect for this wire, as the force is increased to 90 N.

[1]

- (ii) How does the Young modulus for this wire compare with that of the sample used in the first test?
Explain your reasoning.

[2]

[Total: 12]

17 The images **A** and **B** show two different kinds of fracture.

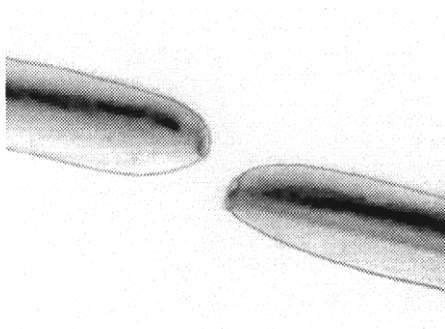


image **A**

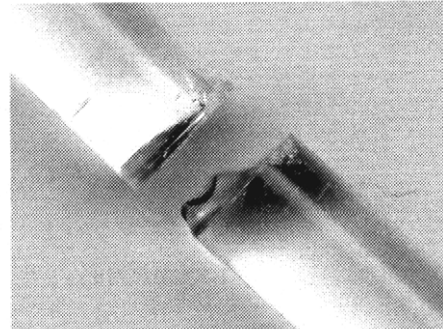


image **B**

(a) State the two kinds of fracture, for each suggesting a material that fractures in this way.

A shows fracture,
a possible material is

B shows fracture,
a possible material is

[4]

(b) The two kinds of fracture have different mechanisms, which depend on the atomic structure of the material.

For each of the materials you have suggested **describe in terms of its atomic structure** how the material deforms and fractures.

Material **A**

[3]

Material **B**

[3]

[Total: 10]

- 18 Read the paragraph below about a telephone signalling system before answering the questions about it.

The frequency range of sound transmitted by a telephone system ranges from 300 Hz to about 3400 Hz. When the signal is digitised, digital samples are taken 8000 times per second. Each sample of the signal is transmitted using 16 bits of information.

- (a) State the meaning of the term **frequency**.

[1]

- (b) Explain what is meant by **digital samples**.

[2]

- (c) State the meaning of the term **bit of information**.

[1]

- 19 Fig. 15.1 shows a very simple way of coding each letter in the word 'My' into a 12 x 8 block of pixels. Each pixel can be either black or white.

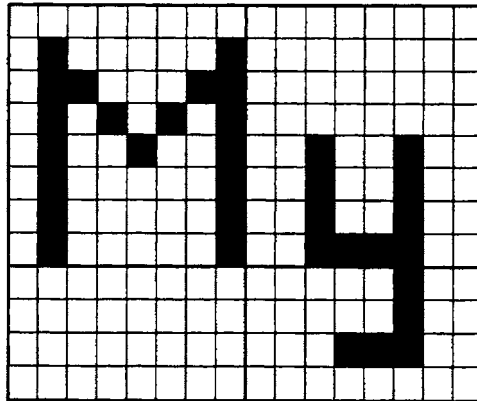


Fig. 19.1

- (a) (i) Explain why each pixel needs only a single binary digit (bit) to code its intensity.

[1]

- (ii) The letter 'M' is 2.6 mm tall. Show that each pixel on the page is about 4×10^{-4} m in size.

[1]

- (iii) A page measures about 300 mm tall x 200 mm wide.
Calculate the amount of information, in bits, in a page of A4 covered with text.

[2]

- (b) Fig. 15.2 shows an attempt to code each letter in the word 'My' into a 6 x 4 block of 24 pixels.

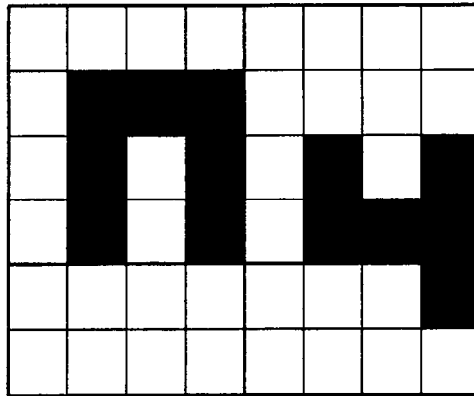


Fig. 19.2

Explain why 24 pixels is not enough to encode each letter in this way.

[1]

20 This question is about electric cars.

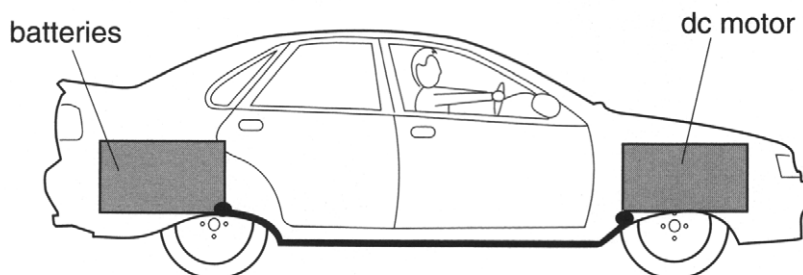


Fig. 20.1

(a) The power source for an electric car consists of a rechargeable set of 10 lead-acid batteries, each with an emf of 24 V. The capacity of one such battery is 80 ampere-hours – it could deliver a current of 80 A for an hour.

(i) Show that when one battery, initially fully charged, is completely discharged, a charge of about 300 000 C has flowed.

[2]

(ii) The car has 10 such batteries in parallel, each fully charged. Show that the batteries can deliver a current of 200 A for 4 hours.

[2]

(iii) Calculate the power delivered by the ten batteries in parallel when delivering a current of 200 A.

power..... W
[2]

(iv) Explain why the answer to part (iii) is likely to be substantially greater than the rate at which the car gains kinetic energy.

[2]

[Total: 8]