Oxford Cambridge and RSA

AS Level Physics B

H157/01 Foundations of physics

Question Set 4

1. A sound system records signal frequencies from 200 Hz up to 11.5 kHz.

The sound is to be digitally sampled.

(a) State the minimum rate of sampling that should be used.

minimum sampling rate = ... Hz **[1]**

(b) In this system the $\frac{\text{total signal variation (including noise)}}{\text{noise variation}} = 3000$.

Calculate the number of bits that should be used per sample for this system.

number = ... bits **[2]**

2.

Fig. 2.1 shows a transmission electron microscope (TEM) image of a metal from the year 2010 with a scale marker of 1 nm.

Fig. 2.2 shows the approximate resolution of TEM technology against time.

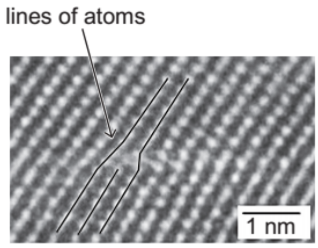

Fig. 2.1

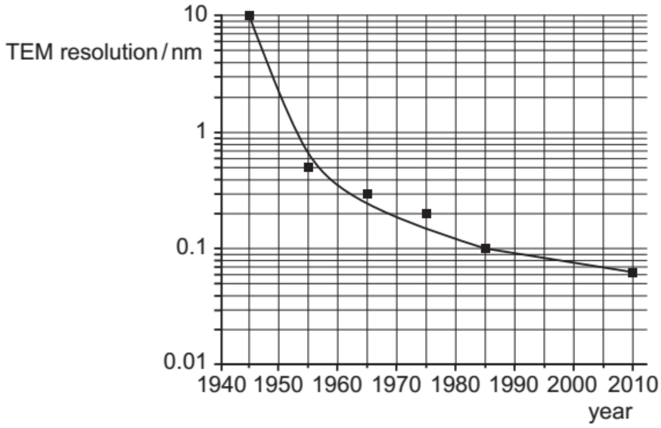

Fig. 2.2

(a) Name the feature represented by the lines of atoms added to the image in **Fig. 2.1**.

name of feature ………………………………………………………….. **[1]**

(b) Using **Fig. 2.2** determine the factor by which TEM resolution has improved between theyears 1945 and 2010.

factor = ……………………………………… **[1]**

3. The Cassini-Huygens spacecraft took images of Saturn's moon Enceladus when the spacecraft was about 6000 km from Enceladus. One such image is shown in **Fig. 3.1**.

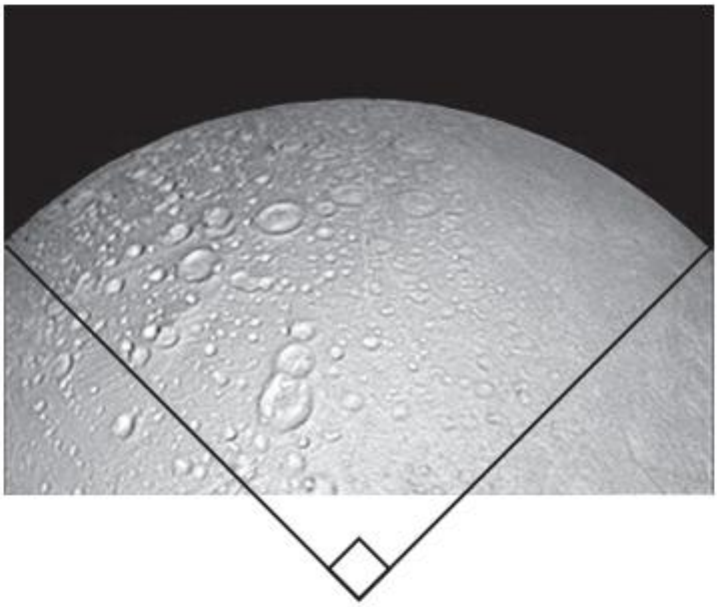

Fig. 3.1

(a) The image is 1024 × 711 pixels. The original data transmitted for this image was 5.8 Mbits.

(i) Calculate the number of bits per pixel in the original data.

bits per pixel = ………………………………………………………… **[1]**

(ii) The 5.8 Mbits was downloaded to an Earth receiver at a rate of 110 kbit s^{-1}.

Calculate the time taken to download this data.

time taken = ………………………………………… s **[1]**

(b) **(i)** Two radii of the moon Enceladus have been added to **Fig. 3.1**. The resolution of the image is 330 m per pixel.

Show that the diameter of Enceladus is less than 500 km. **[3]**

(ii) The image was taken with a sensor of square pixels of width 5 μm. **Fig. 3.2** shows the formation of this image (not to scale).

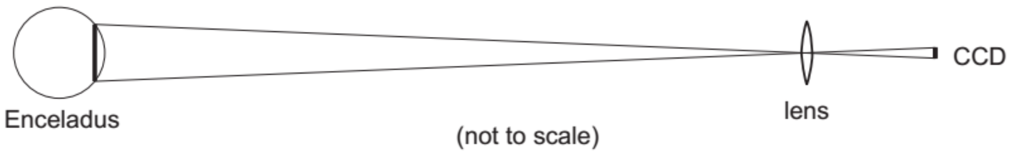

Fig. 3.2

Estimate the focal length of the camera lens that produced the image using data from earlier in the question.

Make your method clear.

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

4. This question is about a high-tensile steel cable used by a tugboat to tow large ships. **Fig. 4** shows the force *F* against extension *x* graph for the steel cable up to the breaking point.

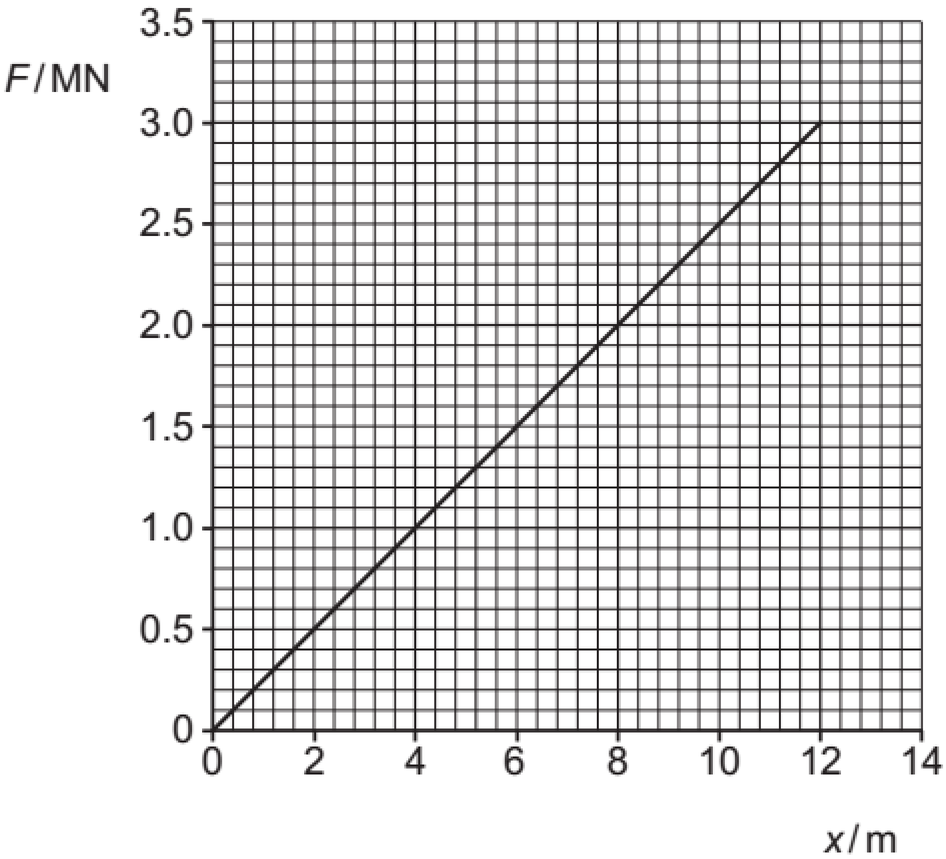

Fig. 4

(a) **(i)** Calculate the force constant $k = \frac{F}{x}$ in $MN\,m^{-1}$ for this cable.

force constant *k* = ………………………………………… **[1]**

(ii) Use algebraic reasoning to show that the force constant k is related to the Young modulus E of the steel by the equation:

$$k = \frac{E\,A}{L}$$

where *A* is the cross-sectional area of cable and *L* is the length of cable. **[1]**

For the cable in the graph, $E = 2.1 \times 10^{11}$ Pa and $A = 1.0 \times 10^{-3}\,m^2$.

(iii) Calculate the length *L* of the cable used.

L = …………………………… m **[2]**

(b) **(i)** Use **Fig. 4** to show that the elastic potential energy stored by the cable at its breaking point is less than 20 MJ. **[1]**

(ii) When a cable breaks, most of its stored elastic energy is transferred to kinetic energy.

Estimate the speed that the cable would reach, assuming all its mass moves at the same speed.

$$\text{density, } \rho = \frac{\text{mass}}{\text{volume}} = 7.9 \times 10^3\,\text{kg m}^{-3} \text{ for steel}$$

speed = ……………………………………………m s^{-1} **[3]**

5. This question is about a temperature sensor.

It constants a thermistor in a potential divider circuit as shown in **Fig. 5.1**.
Fig. 5.2 shows the output p.d. *V* against temperature θ graph for the sensor.

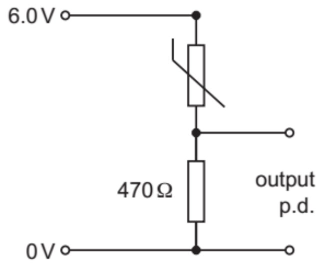

Fig. 5.1

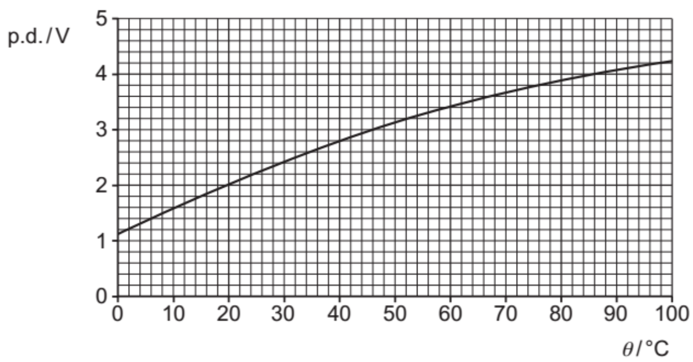

Fig. 5.2

(a) State suitable apparatus (other than indicated in **Fig. 5.1**) and describe how to use it to obtain the calibration graph shown in **Fig. 5.2**.

You may wish to include a labelled diagram in your answer. **[4]**

(b) The p.d. across the terminals of the power supply is 6.0 V and the resistance of the fixedresistor in the potential divider is 470 Ω.

Calculate the resistance of the thermistor at 46 °C. Make your reasoning clear.

resistance = ……………………………………….. Ω **[2]**

(c) The sensitivity of the sensor is the ratio $\frac{\text{change of output p.d.}}{\text{change in temperature}}$.

(i) Describe how the sensitivity of the sensor varies between 0 °C and 100 °C.

Explain your reasoning.

[2]

(ii) Use **Fig. 5.2** to estimate the sensitivity of the sensor at 50 °C. Make your method clear.

sensitivity = …………………………………………….V $°C^{-1}$

[3]

(d) The readings of p.d. for **Fig. 5.2** were taken with a digital voltmeter. Five consecutive values were recorded at each temperature.

The calculated mean output p.d. data for five of the temperatures are shown in the table with calculated uncertainty values.

Temperature/ °C		0	20	40	60	100
Output p.d./ V	Mean	1.127	2.041	2.795	3.389	4.097
	uncertainty	± 0.003	± 0.024	± 0.020	± 0.012	± 0.003

Analyse and comment on the uncertainties in the data in the table.

Suggest a cause of the limitations in the data and what might be done to improve the procedure or apparatus used in the calibration to avoid the limitations.

[4]

Total Marks for Question Set 4: 35