4 **(a)** Explain what is meant by a *progressive wave*.

....

....

....

.... **[2]**

(b) Describe how a *transverse* wave differs from a *longitudinal* wave.

....

....

....

.... **[2]**

(c) **(i)** Explain what is meant by *diffraction* of a wave.

....

....

.... **[1]**

(ii) Describe how you would demonstrate that a sound wave of wavelength 0.10 m emitted from a loudspeaker can be diffracted.

In your answer you should make clear how your observations show that diffraction is occurring.

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.... **[4]**

Turn over

(d) Fig. 4.1 shows two loudspeakers connected to a signal generator, set to a frequency of 1.2 kHz. A person walks in the direction **P** to **Q** at a distance of 3.0 m from the loudspeakers.

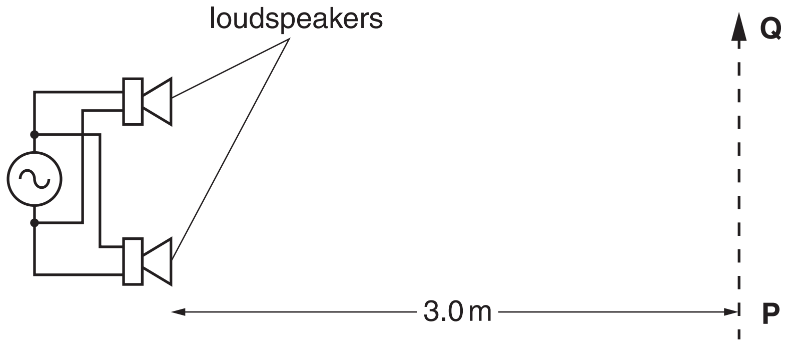

Fig. 4.1

(i) Calculate the wavelength λ of the sound waves emitted from the loudspeakers.

speed of sound in air = $340\,m\,s^{-1}$

λ = ... m **[2]**

(ii) Explain, either in terms of path difference or phase difference, why the intensity of the sound heard varies as the person moves along **PQ**.

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.... **[3]**

(iii) The distance x between adjacent positions of maximum sound is 0.50 m. Calculate the separation a between the loudspeakers. Assume that the equation used for the interference of light also applies to sound.

a = ... m **[2]**

(iv) The connections to one of the loudspeakers are reversed. Describe the similarities and differences in what the person hears.

....

....

....

....

....

.... **[2]**

[Total: 18]

5 Fig. 5.1 shows a uniform string which is kept under tension between a clamp and a pulley. The frequency of the mechanical oscillator close to one end is varied so that a stationary wave is set up on the string.

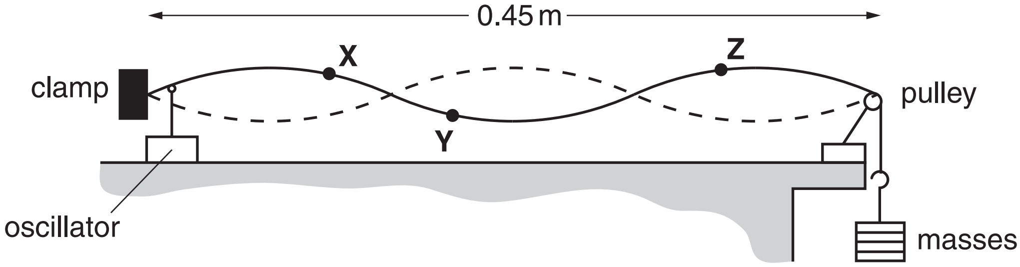

Fig. 5.1

(a) State two features of a stationary wave.

....

....

....

.... **[2]**

(b) Explain how the stationary wave is formed on the string.

....

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....

....

.... **[2]**

(c) The distance between the clamp and the pulley is 0.45 m. **X**, **Y** and **Z** are three points on the string. **X** and **Y** are each 0.040 m from the nearest node and **Z** is 0.090 m from the pulley. State, giving a reason for your choice, which of the points **Y** or **Z** or both oscillate

(i) with the same amplitude as **X**

....

....

....

.... **[2]**

(ii) with the same frequency as **X**

....

....

....

.... **[2]**

(iii) in phase with **X**.

....

....

....

.... **[2]**

[Total: 10]

6 **(a)** X-rays and radio waves are two examples of electromagnetic waves.

(i) Name **two** other examples of electromagnetic waves.

....

.... **[1]**

(ii) State **one** similarity and **one** difference between X-rays and radio waves.

similarity ....

....

....

difference ....

....

.... **[2]**

(iii) Explain why X-rays are easily diffracted by layers of atoms, about 2×10^{-10} m apart, but radio waves are not.

....

....

....

.... **[2]**

(b) On the Earth, we are all exposed to ultraviolet radiation coming from the Sun.
State **one** advantage and **one** disadvantage of UV-B radiation.

....

....

....

....

.... **[2]**

(c) **(i)** Circle a typical value for the wavelength of an X-ray from the list below.

2×10^{-4} m $\quad$ 2×10^{-7} m $\quad$ 2×10^{-10} m $\quad$ 2×10^{-13} m **[1]**

(ii) Use your answer to **(i)** to determine how many X-ray photons must be collected to produce an energy of 1.0×10^{-6} J.

number of photons = ... **[4]**

(d) A plane polarised radio wave is transmitted from a vertical aerial to a nearby receiving aerial as shown in Fig. 6.1.

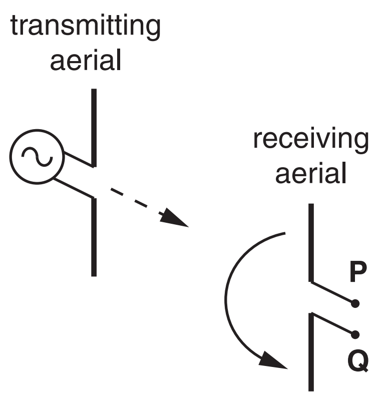

Fig. 6.1

A diode, resistor and ammeter are connected in series across the terminals **P** and **Q**.

(i) Draw the circuit between terminals **P** and **Q** on Fig. 6.1 in the space to the right of **PQ**. **[2]**

(ii) The entire receiving aerial is rotated slowly through 180° in the direction shown by the arrow. Explain clearly what will be observed on the ammeter and how the detected signal varies.

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.... **[3]**

[Total: 17]

Turn over

7 (a) State **one** experiment for each case which provides evidence that electromagnetic radiation can behave like

(i) a stream of particles, called *photons*

.... **[1]**

(ii) waves.

.... **[1]**

(b) A beam of ultraviolet light is incident on a clean metal surface. The graph of Fig. 7.1 shows how the maximum kinetic energy KE_{max} of the electrons ejected from the surface varies with the frequency f of the incident light.

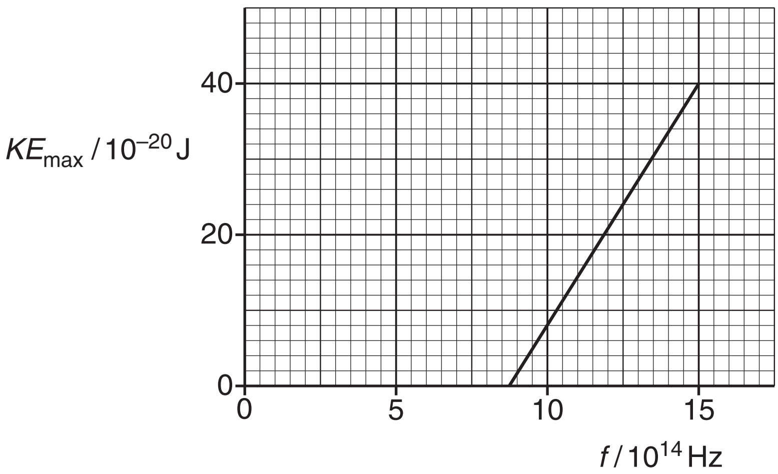

Fig. 7.1

(i) Define the work function ϕ of the metal.

....

....

....

.... **[1]**

(ii) Write down the relationship between KE_{max} and f. Use it to explain why the y-intercept of the graph in Fig. 7.1 is equal to the work function of the metal and the gradient of the line is equal to the Planck constant.

....

....

....

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.... **[3]**

(iii) Use data from Fig. 7.1 to find a value of

1 the Planck constant

Planck constant = ... J s **[2]**

2 the threshold frequency of the metal

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

3 the work function of the metal.

work function = ... J **[2]**

[Total: 11]

END OF QUESTION PAPER

Answer **all** the questions.

1 The power of a 230 V mains filament lamp is 40 W.

(a) Define *power*.

....

.... **[1]**

(b) The lamp is connected to the 230 V supply. Calculate

(i) the current I in the filament

I = ... A **[2]**

(ii) the resistance R of the filament.

R = ... Ω **[1]**

(c) The cross-sectional area of the wire of the filament is $3.0 \times 10^{-8}\,m^2$. The resistivity of the filament when the lamp is lit is $7.0 \times 10^{-5}\,\Omega\,m$. Use your answer to **(b)(ii)** to calculate the length L of the filament wire.

L = ... m **[3]**

(d) Explain whether the filament of a 60W, 230V lamp is thicker or thinner than that of the 40W, 230V lamp. The length and material of the filament are the same in both lamps.

....

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.... **[3]**

(e) The 40W filament lamp is left on for 8 hours.

(i) Calculate the charge *Q* passing through the lamp in this time.

Q = ... C **[2]**

(ii) **1** Define the *kilowatt-hour*.

....

.... **[1]**

2 Calculate the cost of leaving the lamp switched on. The cost of 1 kWh is 22 p.

cost = ... p **[2]**

[Total: 15]

2 Fig. 2.1 shows the I–V characteristic of a light-emitting diode (LED).

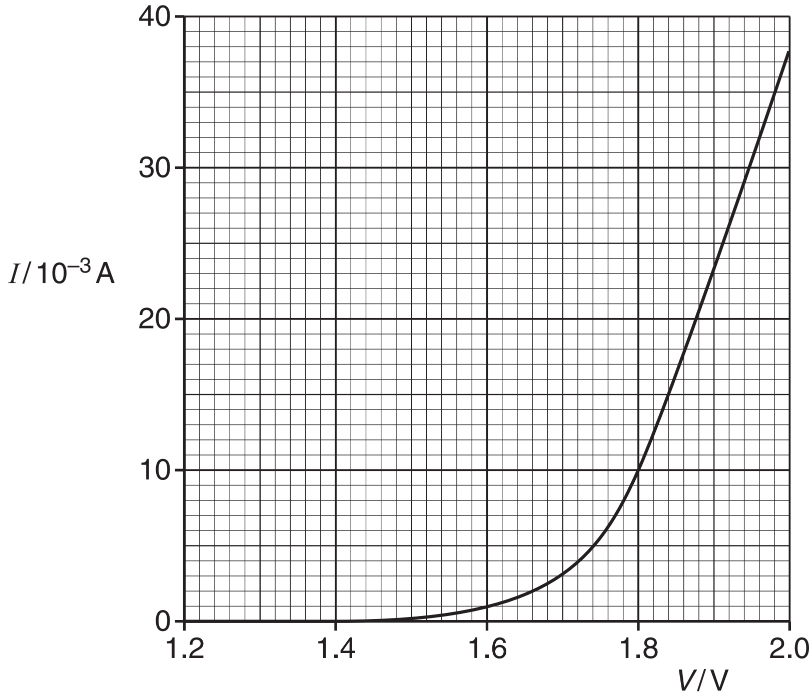

Fig. 2.1

(a) **(i)** Use Fig. 2.1 to

1 state the value of the resistance R below 1.4 V.

R = ... Ω **[1]**

2 determine the resistance R of the LED at V = 1.8 V.

R = ... Ω **[2]**

(ii) At voltages V above 1.8 V, state whether the resistance of the LED increases, remains the same or decreases as V increases. Justify your answer.

In your answer you should link features of the graph into your justification.

....

....

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....

.... **[3]**

(b) A circuit is set up to obtain the I–V characteristic shown in Fig. 2.1. It consists of a variable 0 – 6.0 V d.c. power supply connected in **series** to a 100 Ω resistor and the LED. Fig. 2.2 shows the variable supply. Draw the resistor, LED and suitable meters on the diagram between terminals **X** and **Y** to complete the circuit required for the experiment. **[4]**

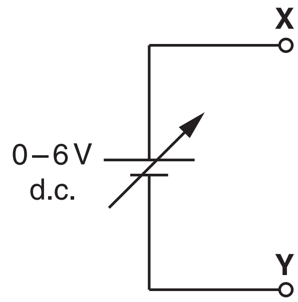

Fig. 2.2

(c) One or more LEDs are often used in places where, in the past, a filament lamp would have been used.
Give **one** example of such a situation.
Explain **one** advantage of using LEDs in place of a filament lamp in the situation you have chosen.

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.... **[2]**

[Total: 12]

3 Fig. 3.1 shows how the resistance of a thermistor varies with temperature.

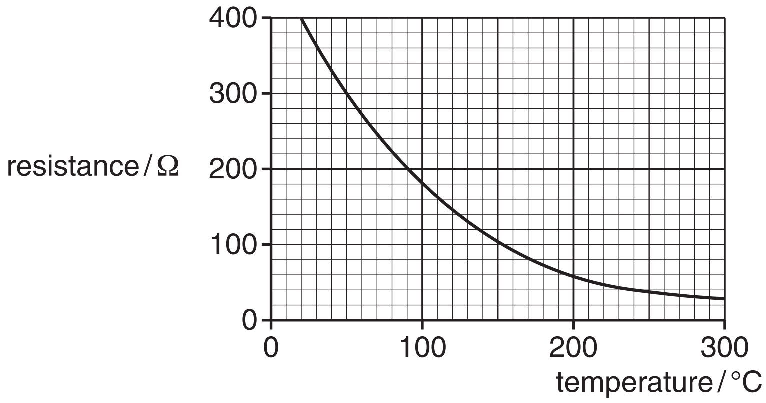


Fig. 3.1

The thermistor is used in the potential divider circuit of Fig. 3.2 to monitor the temperature of an oven. The 6.0 V d.c. supply has zero internal resistance and the voltmeter has infinite resistance.

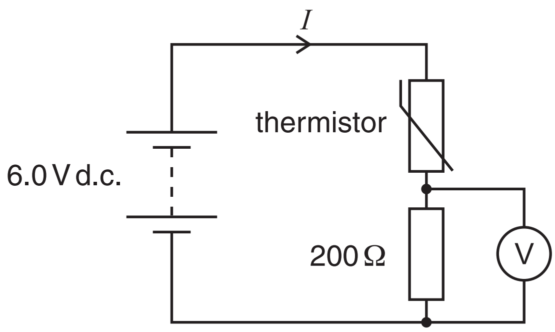


Fig. 3.2

(a) State and explain how the current I in the circuit changes as the thermistor is heated.

....

....

....

....

....

....

....

.... **[3]**

(b) Use Fig. 3.1 to calculate the voltmeter reading when the temperature of the oven is 240 °C.

voltmeter reading = ... V **[4]**

(c) A light-dependent resistor (LDR) is another component used in sensing circuits.

(i) Complete Fig. 3.3 with an LDR between **X** and **Y**.

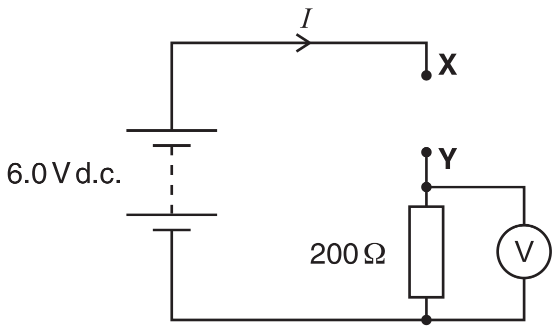


Fig. 3.3

[1]

(ii) State with a reason how the voltmeter reading varies as the intensity of the light incident on the LDR increases.

....

....

....

....

....

.... **[2]**

[Total: 10]

4 Fig. 4.1 shows part of a circuit where three resistors are connected together.

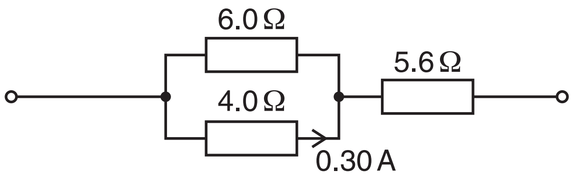


Fig. 4.1

The current in the 4.0 Ω resistor is 0.30 A.

(a) Explain why the current in the 6.0 Ω resistor is 0.20 A.

....

....

....

....

.... **[2]**

(b) **(i)** State the law which enables you to calculate the current in the 5.6 Ω resistor.

....

.... **[1]**

(ii) Calculate the current in the 5.6 Ω resistor.

current = ... A **[1]**

(c) Calculate the total resistance R of the combination of resistors.

R = ... Ω **[3]**

(d) To cause the current of 0.30 A in the 4.0 Ω resistor, the resistor combination is connected to a d.c. supply of electromotive force (e.m.f.) 5.0V.

(i) Explain the term *e.m.f.*

....

....

.... **[2]**

(ii) Show that the terminal potential difference across the supply is 4.0V.

[1]

(iii) Calculate the internal resistance of the supply.

internal resistance = ... Ω **[2]**

[Total: 12]

5 This question is about electrons and photons.

(a) Both electrons and photons can be considered as particles. State **two** differences between their properties.

....

....

.... **[2]**

(b) An electron is accelerated from rest through a p.d. of 5000 V.

(i) Show that the energy gained by the electron is 8.0×10^{-16} J.

[2]

(ii) Show that the speed of the electron is about $4 \times 10^{7}\,\mathrm{m\,s^{-1}}$.

[3]

(c) **(i)** Explain what is meant by the de Broglie wavelength of an electron.

....

....

.... **[1]**

(ii) Calculate the de Broglie wavelength of the electron in **(b)**.

wavelength = ... m **[3]**

(d) Calculate the wavelength of a photon of energy 8.0×10^{-16} J.

wavelength = ... m **[3]**

(e) Photons of energy 9.0×10^{-19} J are incident on a clean tungsten surface causing electrons to be emitted.

(i) State the name of this process.

.... **[1]**

(ii) Calculate the maximum kinetic energy of the emitted electrons. Tungsten has a work function of 7.2×10^{-19} J.

maximum kinetic energy = ... J **[2]**

(iii) Explain why your answer to **(ii)** is a maximum value.

....

....

....

....

.... **[2]**

[Total: 19]

6 **(a)** Define the following terms as applied to wave motion

(i) *displacement* and *amplitude*

....

....

....

....

....

....

.... **[2]**

(ii) *frequency* and *phase difference*.

....

....

....

....

....

....

.... **[2]**

(b) Fig. 6.1 shows a transverse pulse on a *slinky*, an open wound spring, at time $t = 0$. The pulse is travelling at a speed of $0.50\,\text{m}\,\text{s}^{-1}$ from left to right. The front of the pulse is at point **X**, 0.25 m from the point **P**.

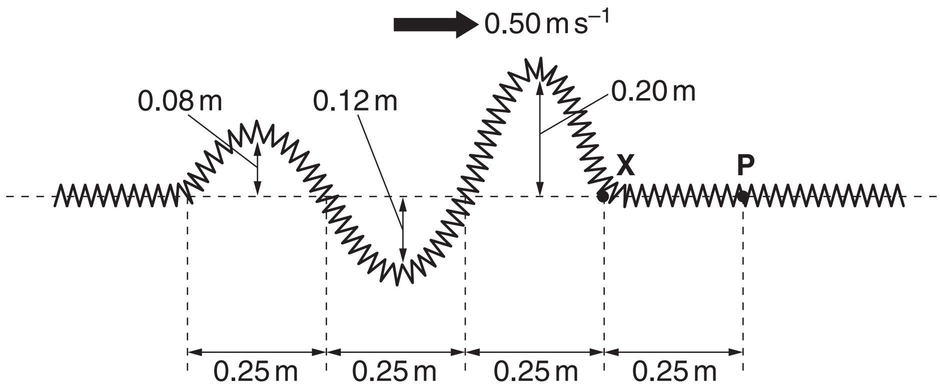


Fig. 6.1

On Fig. 6.2 draw a displacement *y* against time *t* graph of the motion of point **P** on the slinky from $t = 0$ to $t = 2.5$ s.

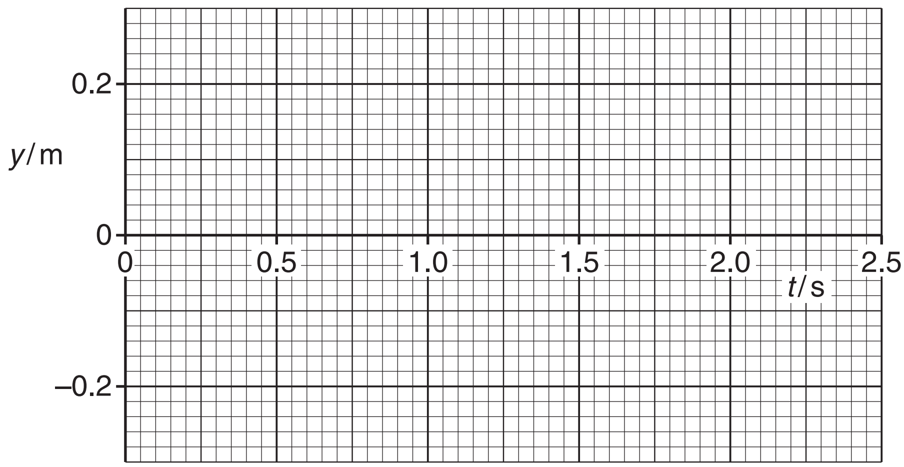


Fig. 6.2

[4]

[Total: 8]

7 Fig. 7.1 shows the three lowest energy levels of the hydrogen atom, labelled $n = 1$, 2 and 3.

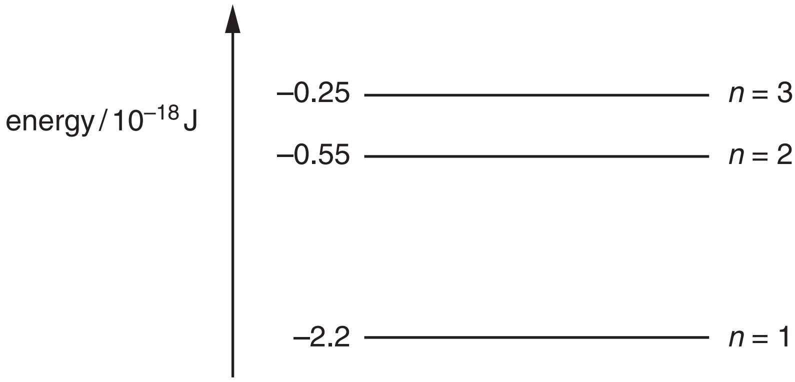


Fig. 7.1

(a) **(i)** Explain why electron transitions between the energy levels can produce three different wavelengths of radiation. You may draw lines on Fig. 7.1 to illustrate your explanation.

....

....

....

....

....

....

.... **[3]**

(ii) The strong red line in the hydrogen spectrum has a wavelength of 6.56×10^{-7} m.

1 Calculate the energy of the photon at this wavelength.

energy = ... J **[2]**

2 Use Fig. 7.1 to identify the electron transition responsible for the spectral line of this wavelength.

....

.... **[1]**

(b) A parallel beam of light from a hydrogen lamp is incident on a diffraction grating. The first order red spectral line at 6.56×10^{-7} m is seen at an angle of 11.4° as shown in Fig. 7.2.

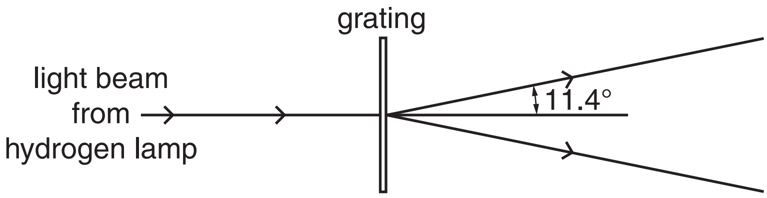


Fig. 7.2

(i) Calculate

1 the separation *d* of the lines on the grating

d = ... m **[3]**

2 the number of lines per millimetre on the grating.

number = ... lines mm^{-1} **[1]**

(ii) The hydrogen lamp also emits blue light at a wavelength of 4.86×10^{-7} m.

Draw rays on Fig. 7.2 to indicate roughly, that is without calculation, the direction of the **first** order blue spectral line as the rays leave the grating. **[1]**

[Total: 11]

Turn over

8 **(a)** State **two** properties shared by all electromagnetic waves which distinguish them from all other waves.

....

....

....

.... **[2]**

(b) The two columns below list four regions of the electromagnetic spectrum and four orders of magnitude of wavelength in m.

region	**wavelength / m**
microwaves	10^{-12}
ultra violet light	10^{-8}
gamma rays	10^{-6}
infra red light	10^{-4}

Draw a straight line from each **region** box to the corresponding **wavelength** box. **[2]**

(c) Fig. 8.1 shows a microwave receiver **R** placed between a microwave transmitter **T** and a flat metal sheet.

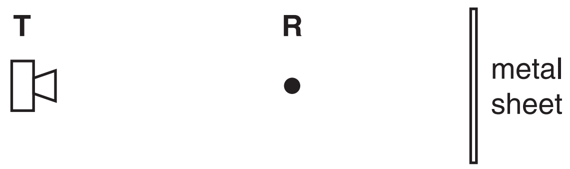


Fig. 8.1

(i) Explain why **R** receives two signals of different amplitude but of the same frequency.

....

....

....

....

.... **[2]**

(ii) Explain why the strength of the detected signal varies between maximum and minimum values as **R** is moved towards or away from the metal sheet.

In your answer you should make clear how the maxima and minima occur.

....

....

....

....

....

....

.... **[3]**

(iii) Determine the wavelength of the microwaves given that the distance between adjacent positions of maximum and minimum signal strength is 7.5 mm.

wavelength = ... mm **[1]**

(iv) The amplitude of the signal from the transmitter is *a*. The amplitude of the two signals detected at **R** are 0.8*a* and 0.6*a*. The changes in amplitude of the detected signals are negligible as **R** moves 7.5 mm. Show that the ratio

$$\frac{\text{maximum intensity of detected signal}}{\text{minimum intensity of detected signal}}$$

is about 50.

[3]

[Total: 13]

END OF QUESTION PAPER

Answer **all** the questions.

1 A set of Christmas tree lights consists of 40 identical filament lamps connected in series across a supply of 240 V.

(a) Define *resistance.*

....

.... **[1]**

(b) Each lamp when lit normally carries a current of 250 mA.

Calculate

(i) the potential difference *V* across a lamp

V = ... V **[1]**

(ii) the resistance *R* of a lamp.

R = ... Ω **[2]**

(c) Fig. 1.1 shows the results of an experiment to find how the current in one of the lamps varies with the potential difference across it.

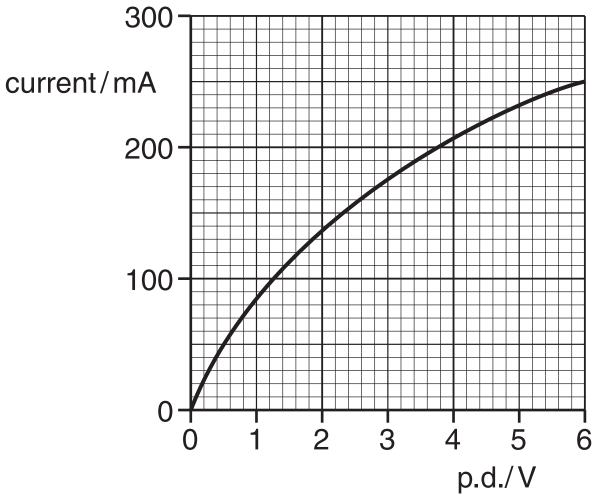


Fig. 1.1

(i) Draw a diagram of the circuit that you would use to perform this experiment.

[3]

(ii) The resistance of the lamp when at room temperature is 10 Ω. Using Fig. 1.1 sketch a graph on the axes of Fig. 1.2 of the variation of resistance *R* with current for the lamp.

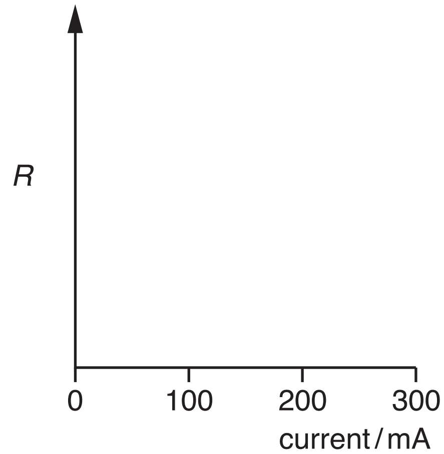


Fig. 1.2

[2]

(iii) Explain why the resistance of the lamp varies as shown by the graph you have drawn on Fig. 1.2.

....

....

....

.... **[2]**

Turn over

(d) In an alternative design for the set of Christmas tree lights, a 100 Ω resistor is connected in parallel with each lamp.

(i) Describe what happens to the brightness in each set of lamps when one lamp filament burns out.

1 *original set* ....

.... **[1]**

2 *alternative set* ....

....

.... **[1]**

(ii) Calculate the current drawn from the supply for the alternative set of lamps with all lamps working.

current = ... A **[3]**

[Total: 16]

2 **(a)** A battery of e.m.f. E and internal resistance r delivers a current I to a circuit of resistance R.

Write down an equation for E in terms of r, I and R.

.... **[1]**

(b) A 'flat' car battery of internal resistance 0.06 Ω is to be charged using a battery charger having an e.m.f. of 14 V and internal resistance of 0.74 Ω, as shown in Fig. 2.1.

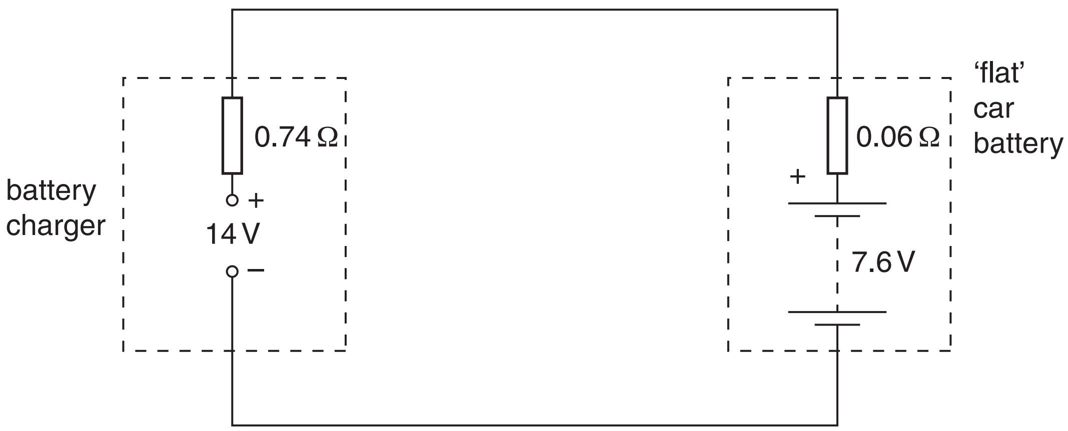


Fig. 2.1

You can see that the battery to be charged has its positive terminal connected to the positive terminal of the battery charger.

At the beginning of the charging process, the e.m.f. of the 'flat' car battery is 7.6 V.

(i) For the circuit of Fig. 2.1, determine

1 the total resistance

resistance = ... Ω **[1]**

2 the sum of the e.m.f.s in the circuit.

e.m.f. = ... V **[1]**

(ii) State Kirchhoff's second law.

....

.... **[1]**

(iii) Apply the law to this circuit to calculate the initial charging current.

current = ... A **[2]**

(c) For the majority of the charging time of the car battery in the circuit of Fig. 2.1, the e.m.f. of the car battery is 12 V and the charging current is 2.5 A. The battery is charged at this current for 6.0 hours. Calculate, for this charging time,

(i) the charge that passes through the battery

charge = ... C **[2]**

(ii) the energy supplied by the battery charger of e.m.f. 14 V

energy = ... J **[2]**

(iii) the percentage of the energy supplied by the charger which is dissipated in the internal resistances of the battery charger and the car battery.

percentage of energy = ... % **[2]**

[Total: 12]

3 Fig. 3.1 shows a thermistor and fixed resistor of 200 Ω connected through a switch **S** to a 24 V d.c. supply of negligible internal resistance. The voltmeter across the fixed resistor has a very high resistance.

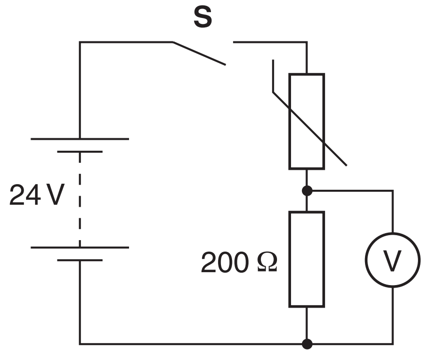


Fig. 3.1

(a) When the switch **S** is closed the voltmeter initially measures 8.0 V.

Calculate

(i) the current I in the circuit

I = ... A **[2]**

(ii) the potential difference V_T across the thermistor

V_T = ... V **[1]**

(iii) the resistance R_T of the thermistor

R_T = ... Ω **[2]**

(iv) the power P_T dissipated in the thermistor.

P_T = ... W **[2]**

(b) A few minutes after closing the switch **S** the voltmeter reading has risen to a steady value of 12 V. The value of the fixed resistor remains at 200 Ω.

Explain why

(i) the potential difference across the fixed resistor has increased

....

....

....

.... **[3]**

(ii) the resistance of the thermistor must now be 200 Ω.

....

.... **[1]**

(c) Sketch, on the labelled axes of Fig. 3.2 below, a possible I-V characteristic for:

(i) the fixed resistor. Label it **R**. **[2]**

(ii) the thermistor. Label it **T**. **[2]**

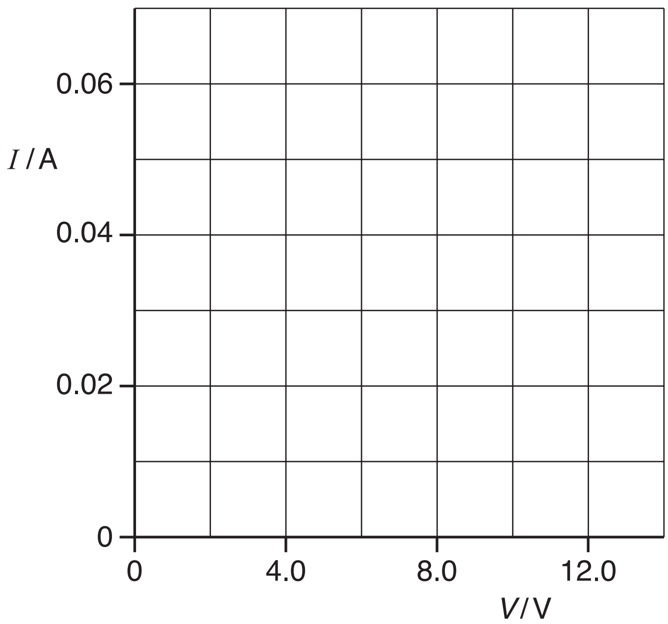


Fig. 3.2

[Total: 15]

4 **(a)** **(i)** Both electromagnetic waves and sound waves can be **reflected**. State **two** other wave phenomena that apply to both electromagnetic waves and sound waves.

1. ....

2. .... **[2]**

(ii) Explain why electromagnetic waves can be polarised but sound waves cannot be polarised.

....

.... **[1]**

(iii) Describe briefly an experiment to demonstrate the polarisation of microwaves in the laboratory.

In your answer you should make clear how your observations demonstrate polarisation.

....

....

....

.... **[4]**

(b) A sound wave emitted by a loudspeaker consists of a single frequency. Fig. 4.1 shows the displacement against time graph of the air at a point **P** in front of the speaker.

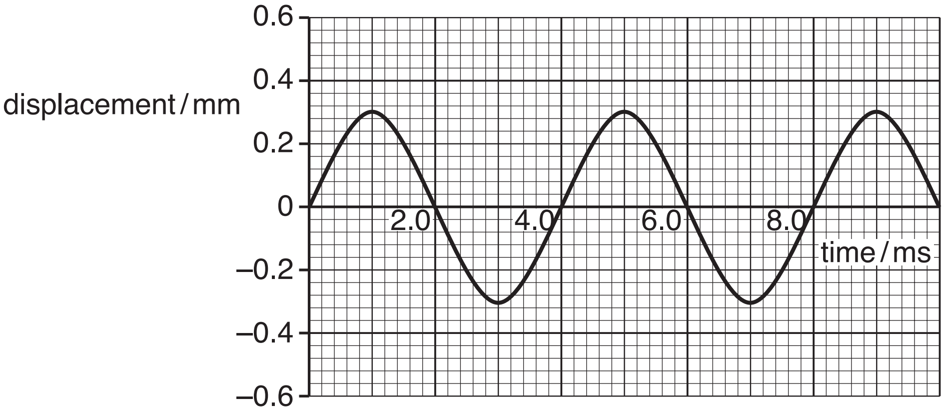


Fig. 4.1

(i) Use Fig. 4.1 to find

1 the amplitude of the air motion

amplitude = ... mm **[1]**

2 the frequency of the sound wave.

frequency = ... Hz **[2]**

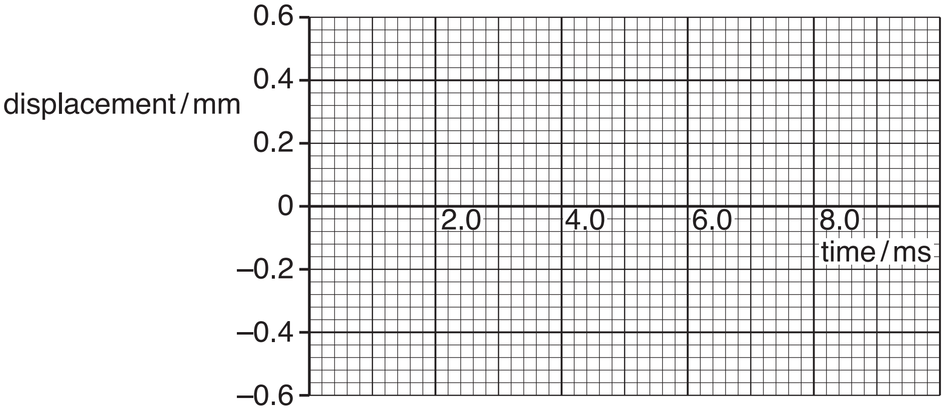
Turn over

(ii) The sound generator is adjusted so that the loudspeaker emits a sound at the original frequency and twice the **intensity**. Sketch on Fig. 4.2 the new displacement against time graph at point **P**. Explain your reasoning.

....

....

....



[3]

Fig. 4.2

(iii) Suggest, with reasons, the apparatus that you would choose to detect and measure the frequency of the sound wave at **P**.

....

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....

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....

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.... **[2]**

[Total: 15]

5 (a) When used to describe stationary (standing) waves explain the terms

(i) node ....

.... [1]

(ii) antinode. ....

.... [1]

(b) Fig. 5.1 shows a string fixed at one end under tension. The frequency of the mechanical oscillator close to the fixed end is varied until a stationary wave is formed on the string.

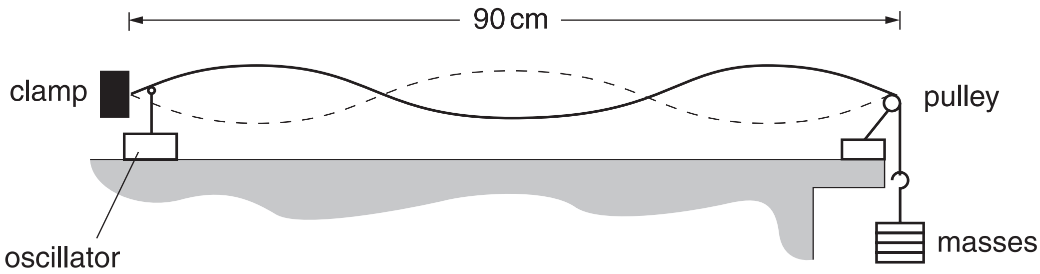

Fig. 5.1

(i) Explain with reference to a progressive wave on the string how the stationary wave is formed.

....

....

....

....

....

....

.... [3]

(ii) On Fig. 5.1 label one node with the letter **N** and one antinode with the letter **A**. [1]

(iii) State the number of antinodes on the string in Fig. 5.1.

number of antinodes = ... [1]

(iv) The frequency of the oscillator causing the stationary wave shown in Fig. 5.1 is 120 Hz.

The length of the string between the fixed end and the pulley is 90 cm.

Calculate the speed of the progressive wave on the string.

speed = ... $m\,s^{-1}$ **[3]**

(c) The speed v of a progressive wave on a stretched string is given by the formula

$$v = k\sqrt{W}$$

where k is a constant for that string. W is the tension in the string which is equal to the weight of the mass hanging from the end of the string.

In **(b)** the weight of the mass on the end of the string is 4.0 N. The oscillator continues to vibrate the string at 120 Hz. Explain whether or not you would expect to observe a stationary wave on the string when the weight of the suspended mass is changed to 9.0 N.

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.... **[3]**

[Total: 13]

6 **(a)** A parallel beam of red light of wavelength 6.3×10^{-7} m from a laser is incident normally on a diffraction grating as shown in Fig. 6.1.

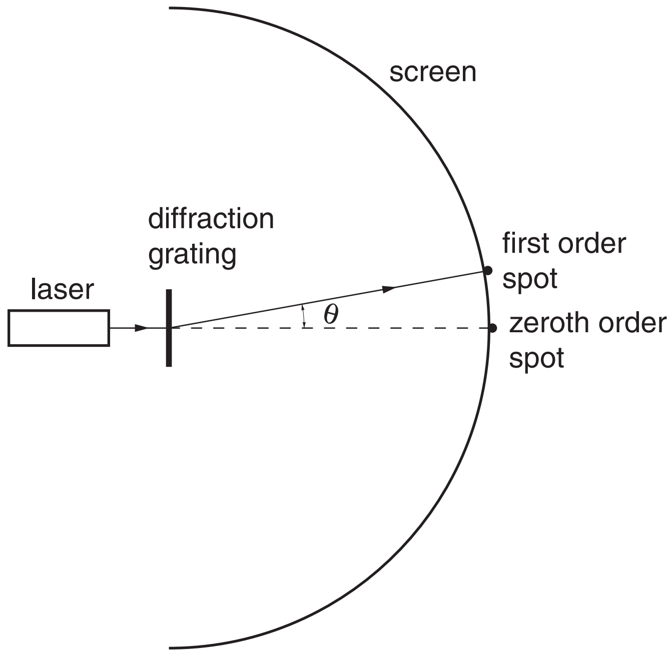

Fig. 6.1

Bright red spots are observed on the curved screen placed beyond the grating.

(i) The diffraction grating has 300 lines per millimetre. Show that the separation d between adjacent lines of the grating is 3.3×10^{-6} m.

[1]

(ii) Calculate the angle θ at which the first order red spot is seen. This is the first spot away from the straight through position.

θ = ... degrees **[3]**

(iii) The screen curves around the full 180° in front of the grating. Explain why there are eleven bright red spots on the screen.

....

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.... **[3]**

(b) Calculate

(i) the energy of each photon of light emitted by the laser at a wavelength of 6.3×10^{-7} m

energy = ... J **[2]**

(ii) the number of photons emitted each second to produce a power of 0.50 mW.

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

(c) **(i)** A beam of electrons in a vacuum can travel through a thin sheet of graphite perpendicular to the beam to produce a diffraction pattern of rings on a fluorescent screen beyond the graphite sheet. Explain why this pattern is produced.

....

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.... **[3]**

(ii) Calculate

1 the speed v of electrons with a de Broglie wavelength of 5.0×10^{-11} m

v = ... m s^{-1} **[2]**

2 the potential difference V required to accelerate the electrons to this speed.

V = ... V **[3]**

[Total: 19]

Turn over

7 In 1905 Einstein presented a theory to explain the photoelectric effect using the concept of quantisation of radiation proposed by Planck in 1900.

(a) Show, with the aid of a suitably labelled diagram, the arrangement of apparatus that could be used to demonstrate the photoelectric effect. Describe how you would use the apparatus and what would be observed.

In your answer you should make clear how your observations provide evidence for the photoelectric effect.

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.... **[5]**

(b) Describe how the photoelectric effect can be explained in terms of the physics of quantum behaviour.

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.... **[5]**

[Total: 10]

END OF QUESTION PAPER