Cambridge Assessment International Education

Cambridge Pre-U

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

1808445386

PHYSICS **9792/02**

Paper 2 Written Paper **May/June 2023**

2 hours

You must answer on the question paper.

You will need: Insert (enclosed)

INSTRUCTIONS
- Section 1: answer **all** questions.
- Section 2: answer **the** question. The question is based on the material in the insert, which is a copy of the pre-release material.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION
- The total mark for this paper is 100.
- The number of marks for each question or part question is shown in brackets [ ].

This syllabus is regulated for use in England, Wales and Northern Ireland as a Cambridge International Level 3 Pre-U Certificate.

This document has **28** pages. Any blank pages are indicated.

DC (ST/JG) 322857/3

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Data

gravitational field strength close to Earth's surface	$g = 9.81\,\mathrm{N\,kg^{-1}}$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
speed of light in vacuum	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$
electron mass	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
proton mass	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
unified atomic mass constant	$u = 1.66 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
	$s = \left(\frac{u+v}{2}\right)t$
heating	$\Delta E = mc\Delta\theta$
change of state	$\Delta E = mL$
refraction	$n = \frac{\sin\theta_1}{\sin\theta_2}$
	$n = \frac{v_1}{v_2}$

diffraction	
single slit, minima	$n\lambda = b\sin\theta$
grating, maxima	$n\lambda = d\sin\theta$
double slit interference	$\lambda = \dfrac{ax}{D}$
Rayleigh criterion	$\theta \approx \dfrac{\lambda}{b}$
photon energy	$E = hf$
de Broglie wavelength	$\lambda = \dfrac{h}{p}$
simple harmonic motion	$x = A\cos\omega t$
	$v = -A\omega\sin\omega t$
	$a = -A\omega^2\cos\omega t$
	$F = -m\omega^2 x$
	$E = \frac{1}{2}mA^2\omega^2$
energy stored in a capacitor	$W = \frac{1}{2}QV$
capacitor discharge	$Q = Q_0 e^{-\frac{t}{RC}}$
electric force	$F = \dfrac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$
electrostatic potential energy	$W = \dfrac{Q_1 Q_2}{4\pi\varepsilon_0 r}$
gravitational force	$F = -\dfrac{Gm_1 m_2}{r^2}$
gravitational potential energy	$E = -\dfrac{Gm_1 m_2}{r}$
magnetic force	$F = BIl\sin\theta$
	$F = BQv\sin\theta$
electromagnetic induction	$E = -\dfrac{d(N\Phi)}{dt}$
Hall effect	$V = Bvd$
time dilation	$t' = \dfrac{t}{\sqrt{1-\frac{v^2}{c^2}}}$
length contraction	$l' = l\sqrt{1-\frac{v^2}{c^2}}$
kinetic theory	$\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$
work done on/by a gas	$W = p\Delta V$
radioactive decay	$\dfrac{dN}{dt} = -\lambda N$
	$N = N_0 e^{-\lambda t}$
	$t_{\frac{1}{2}} = \dfrac{\ln 2}{\lambda}$
attenuation losses	$I = I_0 e^{-\mu x}$
mass-energy equivalence	$\Delta E = c^2\Delta m$
hydrogen energy levels	$E_n = \dfrac{-13.6\,\text{eV}}{n^2}$
Heisenberg uncertainty principle	$\Delta p\Delta x \geqslant \dfrac{h}{2\pi}$
Wien's displacement law	$\lambda_{max} \propto \dfrac{1}{T}$
Stefan's law	$L = 4\pi\sigma r^2 T^4$
electromagnetic radiation from a moving source	$\dfrac{\Delta\lambda}{\lambda} \approx \dfrac{\Delta f}{f} \approx \dfrac{v}{c}$

Section 1

You are advised to spend about 1 hour 30 minutes on this section.

1 A cannon is mounted on the edge of a sea cliff, as shown in Fig. 1.1.

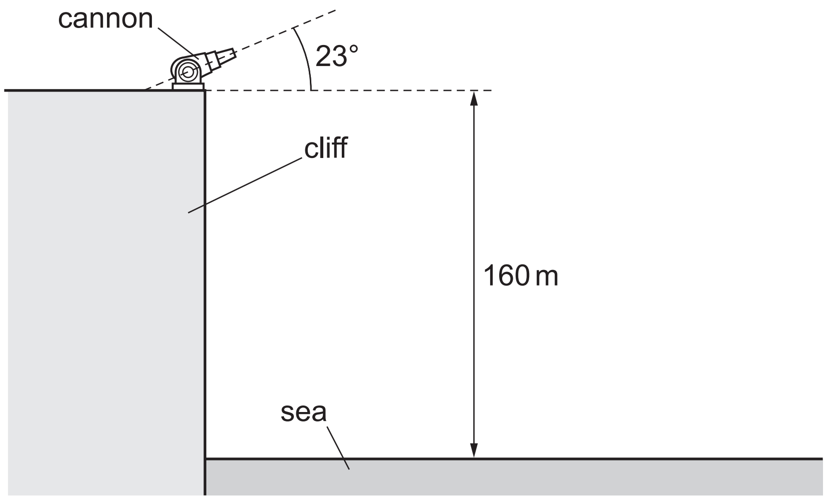

Fig. 1.1

The cannon fires a projectile over the sea at a speed of 210 $m s^{-1}$ at an angle of 23° to the horizontal.

(a) **(i)** Calculate the vertical component of the initial velocity of the projectile.

vertical component of velocity = ... $m s^{-1}$ [1]

(ii) Calculate the time taken for the projectile to reach the highest point in its travel. Ignore any effects of air resistance.

time taken = ... s [3]

(b) **(i)** Calculate the horizontal component of the initial velocity of the projectile.

horizontal component of velocity = ... $m s^{-1}$ [1]

(ii) Calculate the horizontal distance between the bottom of the cliff and the point where the projectile enters the sea. Ignore any effects of air resistance.

horizontal distance = ... m [4]

(c) In reality, air resistance will act on the moving projectile.

State, with reasons, the effect of air resistance on your answers to **(a)(ii)** and **(b)(ii)**.

effect on time to reach highest point

....

....

effect on horizontal distance travelled

....

....

....

[3]

[Total: 12]

2 The acceleration of free fall near the surface of the Moon is 1.6 m s^{-2}.

(a) Describe the difference between weight and gravitational field strength.

....

....

.... [2]

(b) Fig. 2.1 shows a spacecraft of mass 4500 kg taking off from the surface of the Moon.

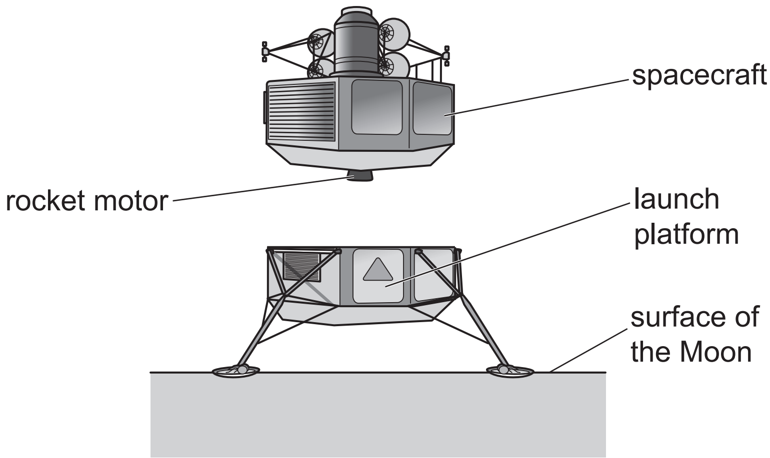

Fig. 2.1

Sketch **four** field lines in the space above the surface of the Moon in Fig. 2.1 to represent the Moon's gravitational field. [2]

(c) The thrust of the rocket motor shown in Fig. 2.1 is 16 kN.

Calculate the acceleration of the spacecraft as it starts to leave the surface of the Moon.

acceleration = ... m s^{-2} [3]

[Total: 7]

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3 A student measures the extension of a rubber band produced by attaching loads that increase from 0 N to 6 N, one newton at a time. The extension Δx is then measured as the load F is decreased, one newton at a time, until there is no stretching force.

The graph of Fig. 3.1 shows the results of this experiment.

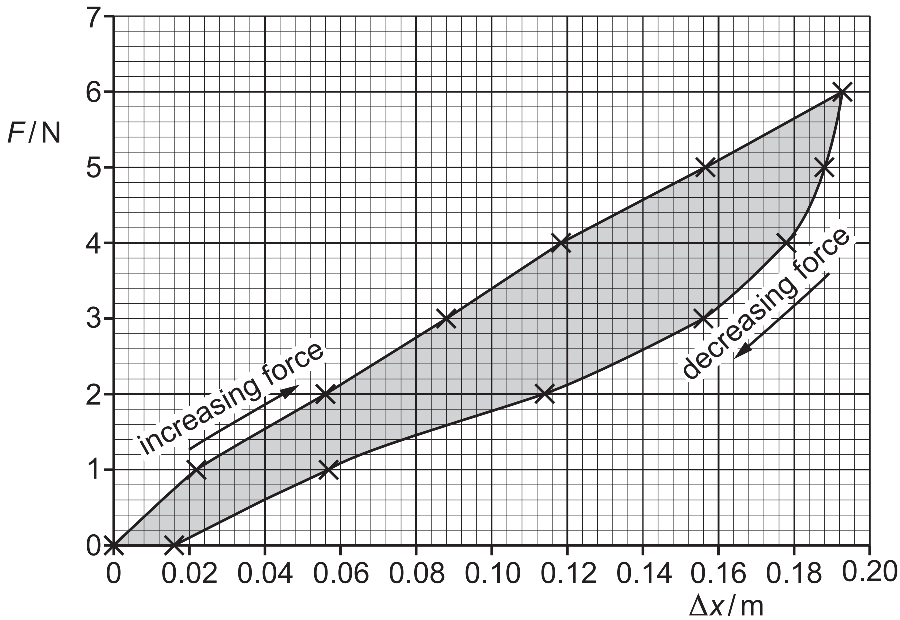

Fig. 3.1

(a) Rubber bands are often referred to as 'elastic bands'.

Use Fig. 3.1 to explain whether this is a technically correct use of the term *elastic*.

....

.... [1]

(b) Calculate the spring constant k of the rubber band as it starts to extend.

k = ... $N\,m^{-1}$ [2]

(c) Use Fig. 3.1 to determine a value for the work done in stretching the rubber band from the beginning of the experiment up to its maximum extension. Show your working.

work done = ... J [3]

(d) On Fig. 3.1, the area between the *increasing force* region and the *decreasing force* region is shaded grey.

Explain what this area represents.

....

....

.... [2]

[Total: 8]

4 An electric car of mass 1900 kg accelerates from 0 to 62 mph in 8.9 s. 1 mph = 0.45 m s^{-1}.

(a) Show that the mean accelerating force *F* produced by the electric motor is approximately 6 kN.

[3]

(b) The car is travelling at its top speed of 99 mph on a straight horizontal test track with the electric motor delivering its maximum power of 110 kW. The electric motor has an efficiency of 90%.

Show that the drag force acting on the car is approximately 2 kN.

[3]

(c) When fully charged, the car battery has an energy storage capacity of 55 kW h (it could deliver a power of 55 kW for 1 hour).

A review of this car claims that it has a maximum range of 270 km.

Use the data in parts **(a)** and **(b)** to explain whether this claim is valid.

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.... [4]

[Total: 10]

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5 A battery X of electromotive force (e.m.f.) E = 4.50 V and internal resistance r has an external resistance of 18 Ω connected to it.

A power supply of e.m.f. 4.70 V and with negligible internal resistance is also connected to the 18 Ω resistor.

The circuit is shown in Fig. 5.1.

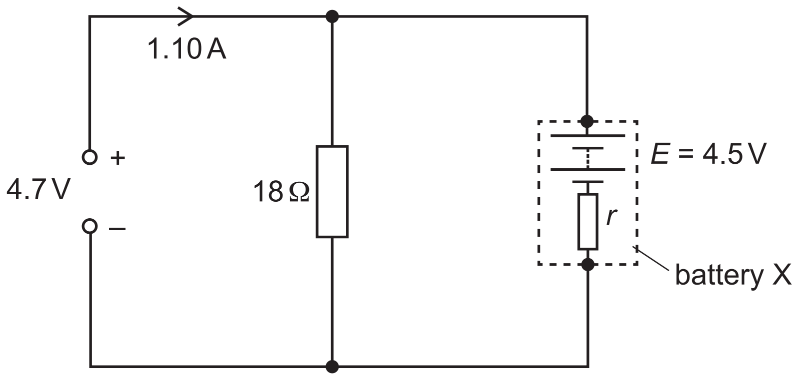

Fig. 5.1

The current in the power supply is 1.10 A.

(a) **(i)** Show that the current in battery X is 0.84 A.

[2]

(ii) Battery X has a charge storage capacity of 9000 C.

Assuming that it is initially uncharged, calculate the time taken, in hours, for a current of 0.84 A to charge battery X.

time = ... hours [1]

(b) Calculate the internal resistance *r* of battery X.

r = ... Ω [2]

(c) As battery X becomes charged, its internal resistance falls.

Explain how this affects the time to charge the battery fully from an uncharged state.

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.... [2]

[Total: 7]

6 Fig. 6.1 shows two rectangular blocks, one perspex and one glass, in contact.

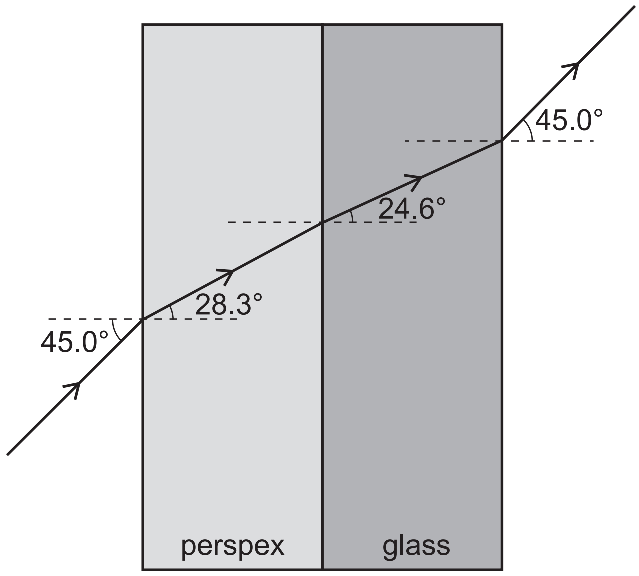

Fig. 6.1

A ray of light passes from the surrounding air through the two blocks and then out again. Assume that the refractive index of air = 1.00.

(a) Calculate the refractive index n_p of the perspex.

n_p = ... [1]

(b) Calculate the speed v_g of light in the glass.

v_g = ... $m\,s^{-1}$ [2]

(c) State whether the speed, the frequency and the wavelength of the light decrease, increase or stay the same as the light travels from perspex into glass.

speed ....

frequency ....

wavelength ....

[1]

[Total: 4]

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7 Fig. 7.1 shows the arrangement for an experiment involving superposition of microwaves.

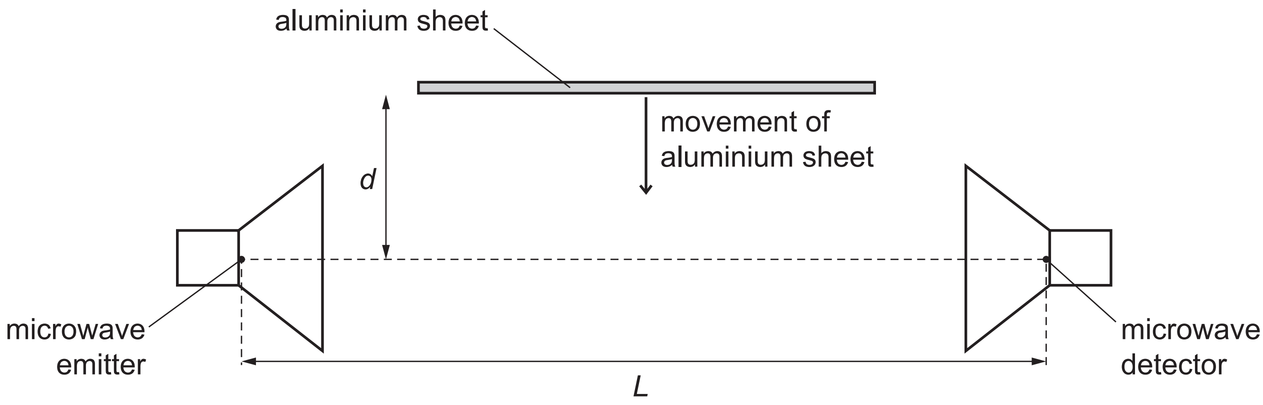

Fig. 7.1 (not to scale)

A microwave emitter and microwave detector face each other with a distance L separating the electronic components which generate and sense microwaves. A reflecting aluminium sheet is placed a vertical distance d above the direct path between the microwave emitter and the microwave detector.

(a) When the aluminium sheet is moved in the direction shown by the arrow, the intensity of microwaves received by the detector fluctuates.

Describe and explain this variation in the microwave intensity.

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.... [2]

(b) As d decreases, the microwave detector has a maximum reading at d = 21.2 cm and the next maximum at d = 17.7 cm. The distance L stays constant at 80.0 cm.

Use this information to calculate the wavelength λ of the microwaves.

λ = ... m [4]

(c) Some waves undergo a phase change when they reflect.

When d is much less than the wavelength of the microwaves, it is observed that the detector reading is a minimum.

Explain why this observation demonstrates that microwaves undergo a phase change on reflection from the aluminium sheet.

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.... [2]

[Total: 8]

8 A radioactive nuclide X decays by alpha-emission to a nuclide Y, which is itself radioactive. Y decays by beta-emission to a nuclide Z.

Two counters are used to monitor the activity of a radioactive sample of X: one which detects only alpha-particles and one which detects only beta-particles.

The count rates measured by the counters are shown in Fig. 8.1.

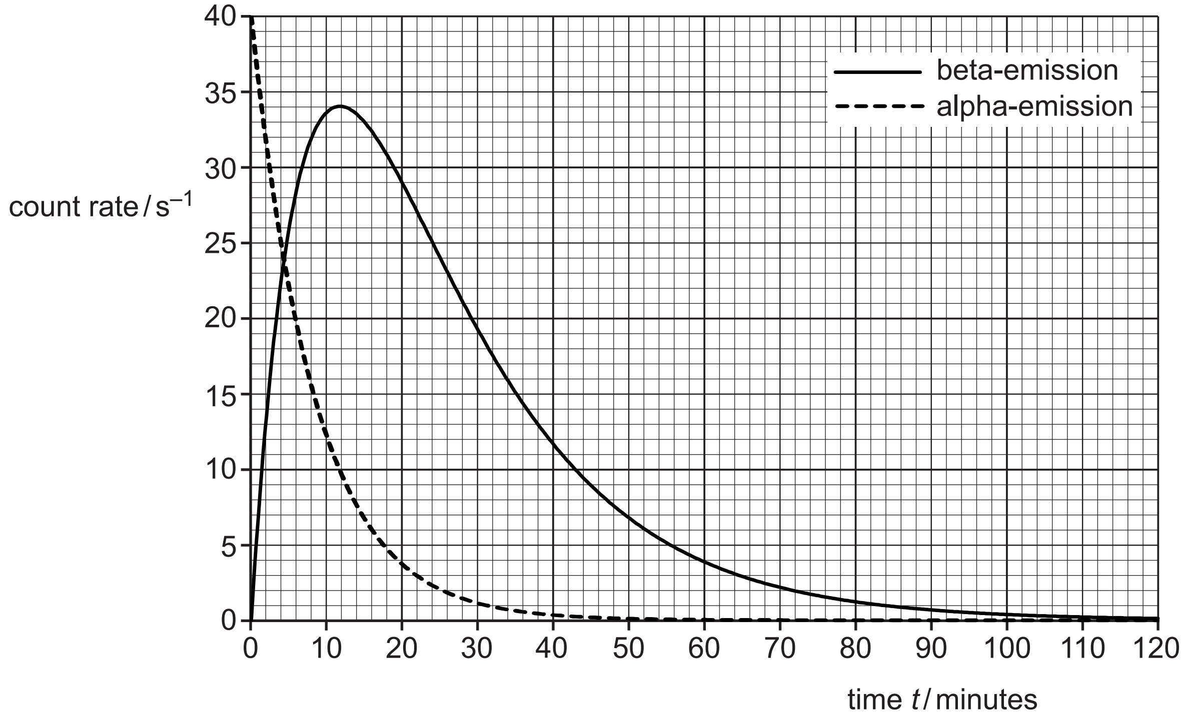

Fig. 8.1

Explain what can be deduced from this information.

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.... [8]

9 A monochromatic light-emitting diode (LED) is used to make a measurement of the Planck constant *h*. To do this, it is necessary to know the frequency of light emitted by the LED.

(a) Light from the LED is viewed through a diffraction grating of known line spacing *d*. Orders of diffraction are visible to each side of the zero-order image (the 'straight-through' view), as shown in Fig. 9.1.

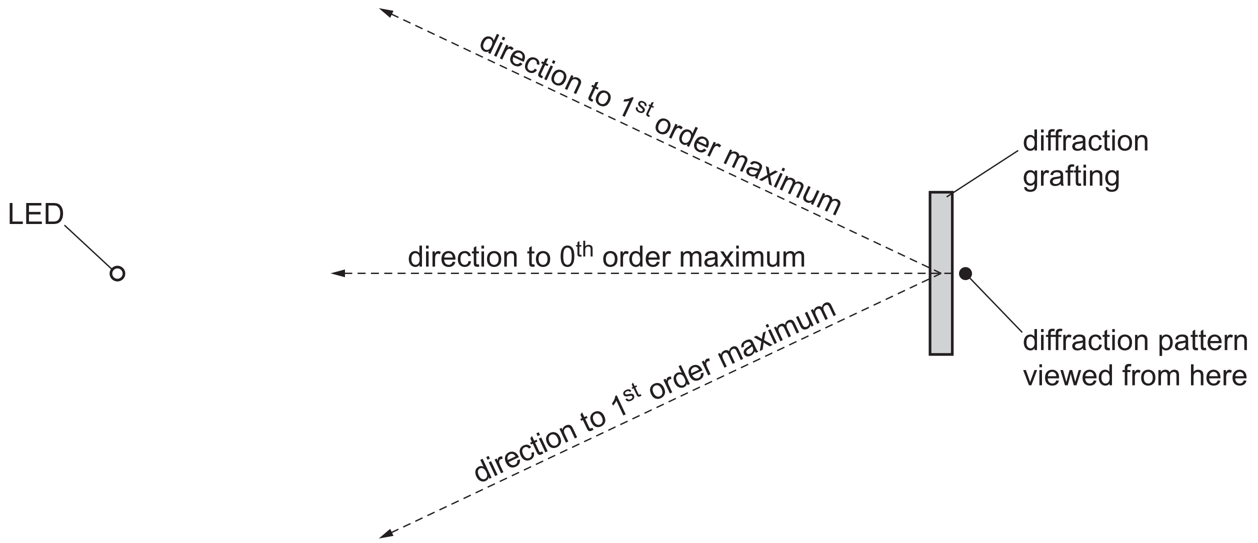

Fig. 9.1

Describe how students could use this diffraction grating, together with metre rules, to determine the frequency *f* of light emitted by the LED. You may add to Fig. 9.1 to help your explanation. You should aim for as accurate a value of *f* as possible.

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.... [5]

(b) An LED emits light of frequency 6.45×10^{14} Hz. The potential difference (p.d.) across the LED is increased gradually from 0 until the LED begins to emit light. The p.d. at this point is measured to be 2.8 V.

Assume that the energy of each emitted photon is equal to the energy released when one electron 'falls' through the p.d. of 2.8 V.

(i) Calculate the value of the Planck constant h given by these data. Give your answer to an appropriate number of significant figures.

h = ... J s [4]

(ii) When the p.d. across the LED is 2.8 V, the current in the LED is 5.6 mA.

Calculate the number of photons emitted by the LED each second. Assume that all energy provided by the power supply becomes the energy of emitted photons.

number of photons = ... [2]

[Total: 11]

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Section 2

You are advised to spend about 30 minutes on this section.

The questions in this section refer to the pre-release material provided as an insert to the question paper.

Your answers should, where possible, make use of any relevant physics.

10 **(a)** During the mid-1800s, many scientists supported the caloric theory of heat.

Describe how the changes produced by burning wood would be explained in the caloric theory.

....

....

.... [2]

(b) Count Rumford's cannon experiment convinced many scientists that the caloric theory could not be true.

(i) Explain why Rumford could state that his results contradicted the caloric theory.

....

....

.... [1]

(ii) Explain whether Rumford was right to claim that the generation of heat in his experiment could be continued for ever.

....

....

.... [1]

(c) James Prescott Joule used the apparatus shown schematically in Fig. 10.1.

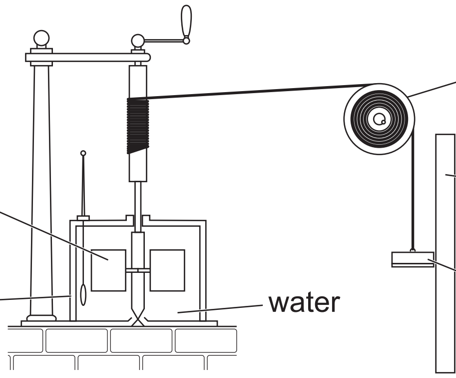

Fig. 10.1

(i) Joule allowed the weights to fall a distance of 3.20 m and repeated the drop for a total of 20 falls. He then measured the increase in temperature of the water, brass container and paddles as the rotating paddles dissipated the energy in the water.

Table 10.1

quantity	value
mass of falling weight	26.3 kg
friction at pulley	1.80 N
mass of water in container	6.04 kg
mass of brass container and paddles	3.00 kg
specific heat capacity of water	4180 J kg^{-1} °C^{-1}
specific heat capacity of brass	380 J kg^{-1} °C^{-1}

Use the data in Table 10.1 to show that Joule's measured temperature rise would have been between 0.5 °C and 1 °C.

[5]

(ii) Joule took care to minimise heat losses and to compensate for any possible heating of the apparatus by radiation or convection. He also repeated his measurements 20 times.

Suggest and explain **two** advantages of his procedure.

1 ....

....

2 ....

....
[2]

(d) Early steam engines, such as that shown in Fig. 10.2, had a heat (energy) source at 100 °C and a heat (energy) sink at room temperature, typically 0 °C to 20 °C.

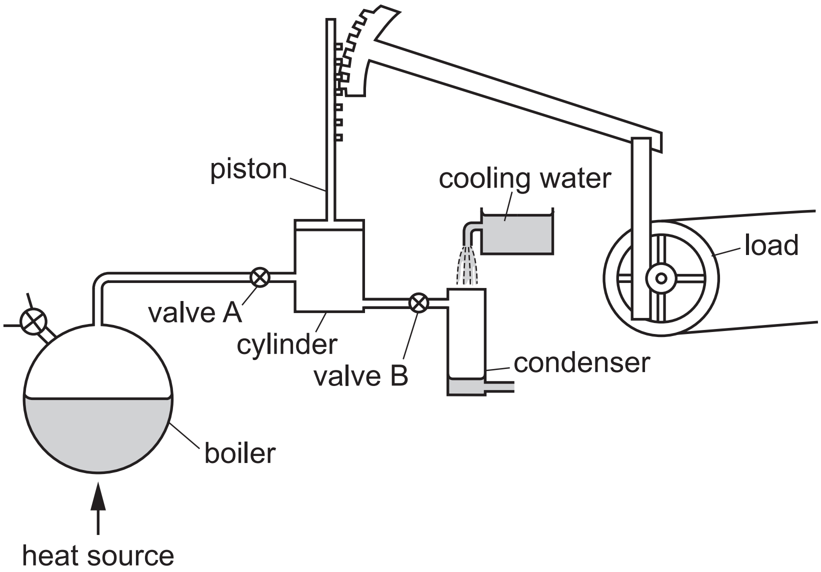

Fig. 10.2

Modern thermal power stations use super-heated steam at 560 °C with the heat sink typically at 5 °C.

(i) Show that the maximum possible efficiency of an early steam engine is less than half that of a modern power station.

[4]

(ii) Early steam engines had efficiencies very much less than their maximum possible efficiencies.

Suggest **two** reasons for this.

1 ....

....

2 ....

....

[2]

(e) A refrigerator has a coefficient of performance (COP) of 3.5 and an average annual energy consumption of 1.1 GJ. Assume that all of the energy consumption is used by the heat engine to do work.

(i) Calculate the mean daily work *W* done by the heat engine in reducing the internal energy of the refrigerator and its contents.

W = ... J [1]

(ii) Calculate the thermal energy Q_c removed daily from the refrigerator and its contents.

Q_c = ... J [2]

(f) Heat pumps are increasingly popular replacements for fossil fuels used to heat houses.

For a heat pump, the COP is defined as

$$COP = \frac{Q_h}{W}.$$

(i) Calculate the COP for a simple electrical resistance heater.

....

.... [1]

(ii) Explain, with reference to the COP, why heat pumps are more energy-efficient than simple electrical resistance heaters when used for space heating.

....

.... [1]

(iii) Suggest **one** reason why air-source heat pumps are more widely used than ground-source heat pumps.

....

.... [1]

(iv) Explain why ground-source heat pumps have higher COP values than air-source heat pumps.

....

....

....

.... [2]

[Total: 25]

