Centre Number	Index Number	Name	Class
S3016			

RAFFLES INSTITUTION
2019 Preliminary Examination

PHYSICS
Higher 2

9749/02

Paper 2 Structured Questions

18 September 2019
2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your index number, name and class in the spaces at the top of this page.
Write in dark blue or black pen in the spaces provided in this booklet.
You may use a pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 10
2	/ 12
3	/ 8
4	/ 10
5	/ 10
6	/ 10
7	/ 20
Deduction	
Total	/ 80

This document consists of **18** printed pages.

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	$T/°C + 273.15$
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t = \pm \omega \sqrt{x_0^2 - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** Explain why it is technically incorrect to define speed as "distance travelled per second".

Include in your answer the correct definition of speed.

....

....

....

.... [2]

(b) A baseball player throws a ball with an initial speed of 15 m s^{-1} at an angle θ above the horizontal, at a height 2.0 m above the ground. At the maximum height above the ground, the speed of the ball is 7.5 m s^{-1}.

Neglecting air resistance, determine

(i) the angle θ,

θ = ... ° [1]

(ii) the time of flight t_f.

t_f = ... s [3]

(c) **(i)** On Fig. 1.1, sketch the variation with time t of the vertical component of velocity v_y of the ball and label it Q. Mark on the horizontal axis the instant t_1 at which the ball reaches its maximum height.

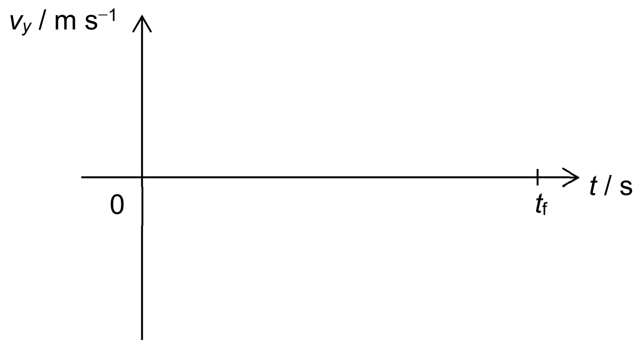

Fig. 1.1

[1]

(ii) If air resistance is not negligible, on Fig. 1.1, sketch the variation with t of v_y for the entire flight and label it R. [3]

2 A theme park ride is illustrated in Fig. 2.1. The carriage of mass 450 kg, moving at 1.0 m s^{-1}, slides down the slope and then moves over a small hill. The slope consists of two circular arcs of the same radius 15 m and the hill has a small circular arc of radius 20 m at the top.

Assume no resistive force acts on the carriage.

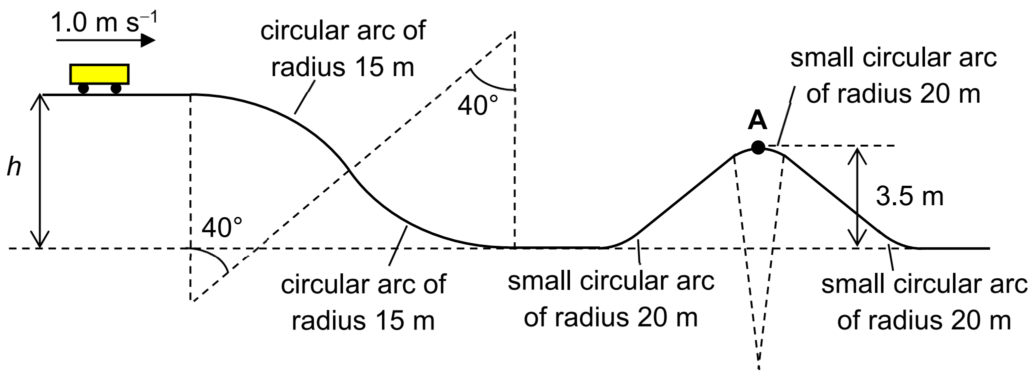

Fig. 2.1 (not to scale)

(a) Show that *h* is 7.0 m.

[1]

(b) Calculate the speed of the carriage when it reaches point A.

speed of the carriage at point A = ... m s^{-1} [2]

(c) On Fig. 2.2, draw and label the forces acting on the carriage when it is at A.

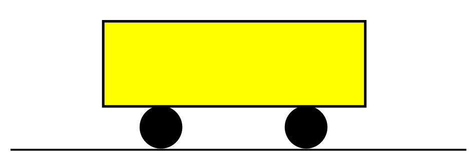

Fig. 2.2

[2]

(d) Calculate the normal contact force acting on the carriage at A.

normal contact force on carriage at A = ... N [2]

(e) During the entire journey, the carriage experiences varying normal contact force.

(i) On Fig. 2.1, mark with an "X" the point at which the carriage experiences the largest normal contact force.

[1]

(ii) Explain your answer in **(e)(i)**.

....

....

....

.... [2]

(f) Determine the maximum speed of the carriage at A such that the carriage does not lose contact with the track.

maximum speed of the carriage = ... m s^{-1} [2]

3 **(a)** Distinguish between *longitudinal* waves and *transverse* waves.

....

....

....

.... [2]

(b) State a phenomenon associated with transverse waves that is not observed with longitudinal waves.

.... [1]

(c) A point source of sound radiates energy uniformly in all directions. At a particular frequency, the intensity of sound 1.5 m away from the source is 1.2×10^{-5} W m^{-2}, corresponding to an amplitude of oscillation of the air molecules of 84 μm. A microphone with a receiving area of 1.3×10^{-3} m^{2} is placed 6.0 m away from the source.

Assuming that the sound is propagated without energy loss, determine

(i) the intensity of the sound at the microphone,

intensity = ... W m^{-2} [2]

(ii) the power of the sound incident on the microphone,

power = ... W [1]

(iii) the amplitude of vibration of the air molecules at the microphone.

amplitude = ... μm [2]

4 **(a)** Define *electric field strength* at a point.

....

.... [2]

(b) Two charged metal spheres A and B, each of diameter 0.16 m, are isolated in space as shown in Fig. 4.1.

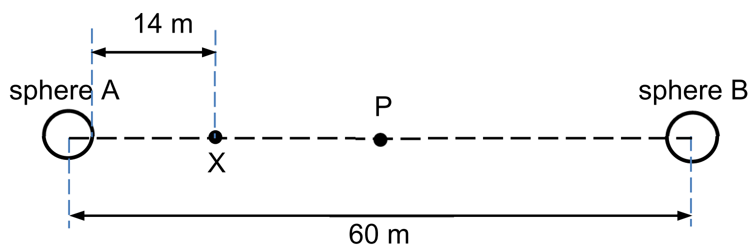

Fig. 4.1 (not to scale)

The centres of the spheres are separated by a distance of 60 m. Point P is at the mid-point along the line joining the centres of the two spheres.

Each sphere carries a charge of –0.040 nC.

(i) In Fig. 4.2, sketch the pattern of electric field lines in the region surrounding the spheres.

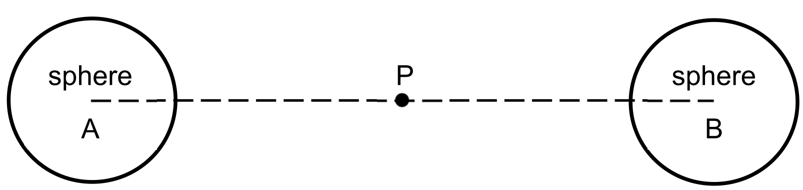

Fig. 4.2 (not to scale)

[2]

(ii) Determine the magnitude and direction of the electric field strength at point X, 14 m from the surface of sphere A along the line joining the centres of the spheres.

magnitude of electric field strength = ... $N\,C^{-1}$

direction of electric field strength = ... [3]

(c) **(i)** Calculate the potential at point P.

potential = ... V [1]

(ii) Hence or otherwise, without further calculation, sketch on Fig. 4.3 a graph to show the variation with displacement *x* along the line of centres, of potential *V* between the centres of the spheres.

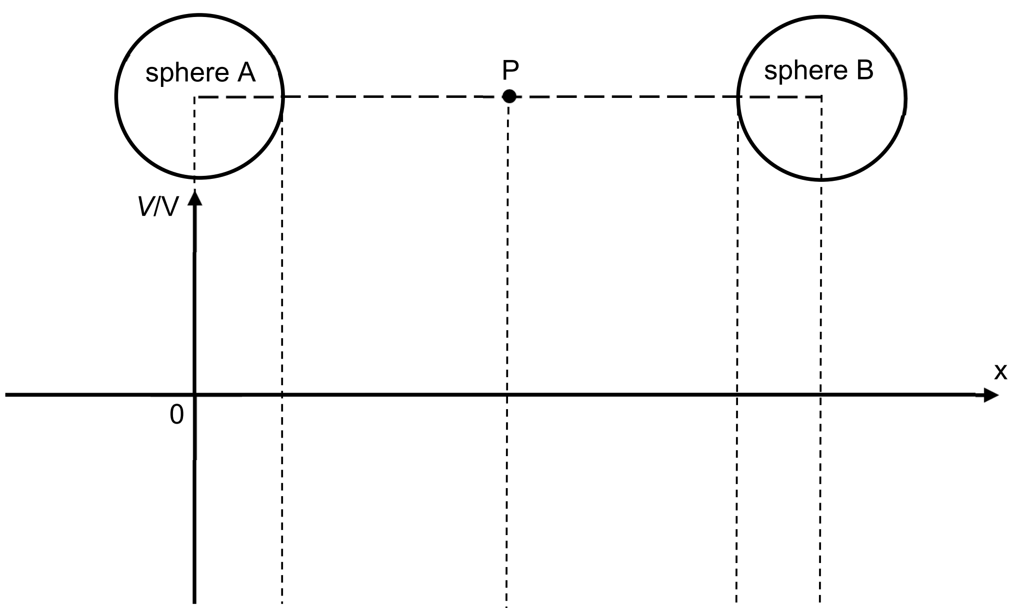

Fig. 4.3

[2]

5 **(a)** State Faraday's law of electromagnetic induction.

....

.... [1]

(b) A solenoid of length 15 cm, cross-sectional area 2.5×10^{-4} m^2, and 3000 turns is placed in the middle of a coil of 1500 turns as shown in Fig. 5.1. The solenoid is connected to a battery, a rheostat and an ammeter. The coil is connected to a galvanometer.

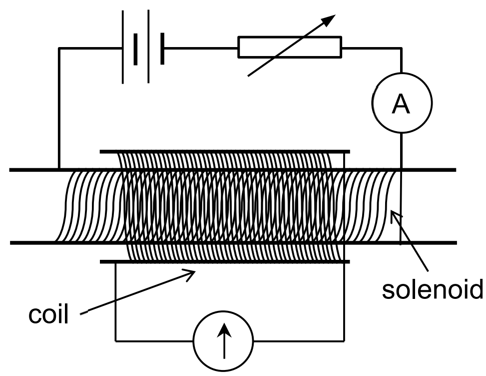

Fig. 5.1

Fig. 5.2 shows the variation with time t of the current I through the solenoid as the resistance of the rheostat is varied.

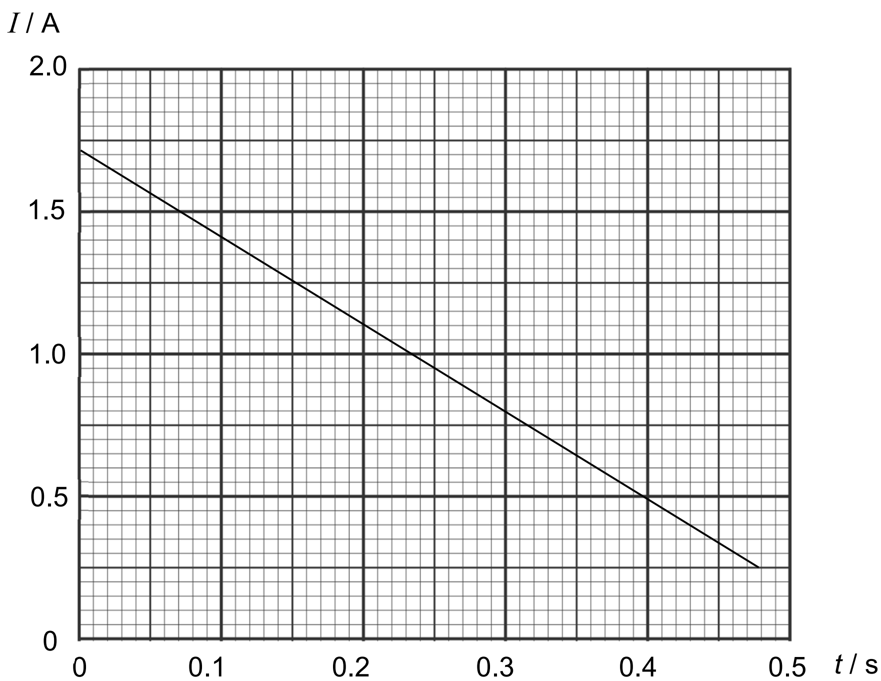

Fig. 5.2

(i) Calculate the magnetic flux density produced in the solenoid at t = 0.070 s.

magnetic flux density = ... T [3]

(ii) Calculate the e.m.f. induced in the coil.

e.m.f. = ... V [3]

(iii) State and explain the direction of the current through the galvanometer.

....

....

....

....

....

....

.... [3]

6 **(a)** **(i)** Explain what is meant by *nuclear binding energy*.

....

.... [1]

(ii) Calculate the nuclear binding energy in MeV of the gold nuclide $^{197}_{79}\text{Au}$, using the following data:

mass of proton = 1.672648×10^{-27} kg

mass of neutron = 1.674954×10^{-27} kg

mass of gold nuclide = 3.269645×10^{-25} kg

binding energy = ... MeV [3]

(b) Another gold isotope $^{198}_{79}\text{Au}$ is unstable and undergoes beta decay to mercury (Hg) with a half-life of 2.7 days.

(i) Write down the equation representing the beta decay of this gold nuclide.

[1]

(ii) Define *half-life.*

....

.... [1]

(iii) Determine the time taken for the activity of a sample of gold–198 to decrease by 85%.

time taken = ... days [2]

(iv) The beta particles emitted in the decay have a range of kinetic energies up to a maximum value of 0.83 MeV.

In Fig. 6.1 below, sketch the variation with kinetic energy of the number of beta particles emitted. Label the maximum kinetic energy of 0.83 MeV on your graph.

Fig. 6.1

[2]

7 An object that is at a higher temperature than its surroundings loses thermal energy by emitting electromagnetic radiation. Fig. 7.1 shows the variation with wavelength λ from 400 nm to 1400 nm, of the intensity I_λ of the radiation emitted by an object at 1100 K.

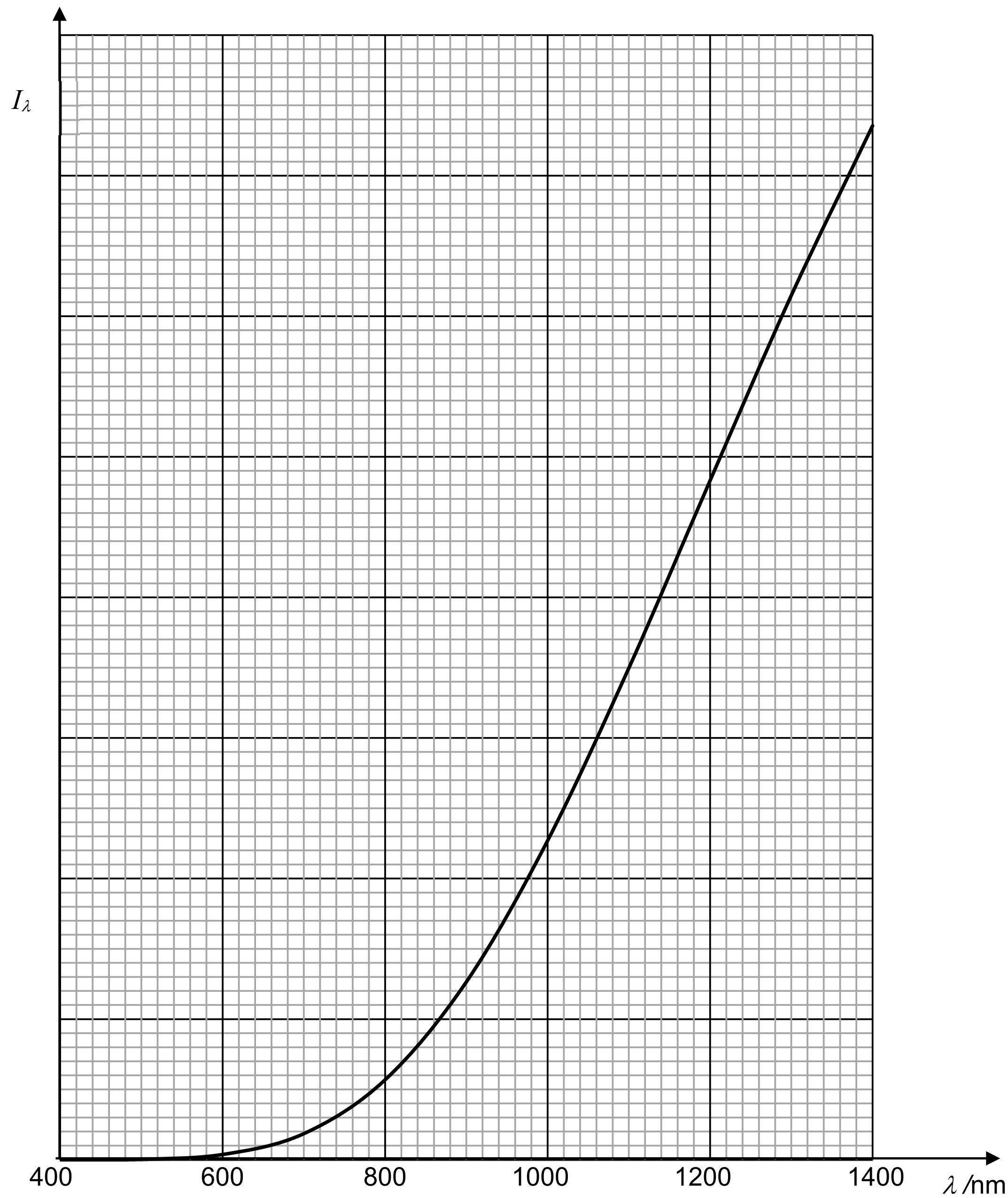

Fig. 7.1

(a) On the horizontal axis of Fig. 7.1, indicate with a cross a wavelength that is in the visible region of the electromagnetic spectrum.

[1]

(b) Hence suggest why, at a temperature of 1100 K, the object would glow with a red colour.

....

.... [2]

The distribution of intensity is different at different temperatures. This is illustrated in Fig. 7.2, which covers a larger range of wavelengths from 0 to 6000 nm.

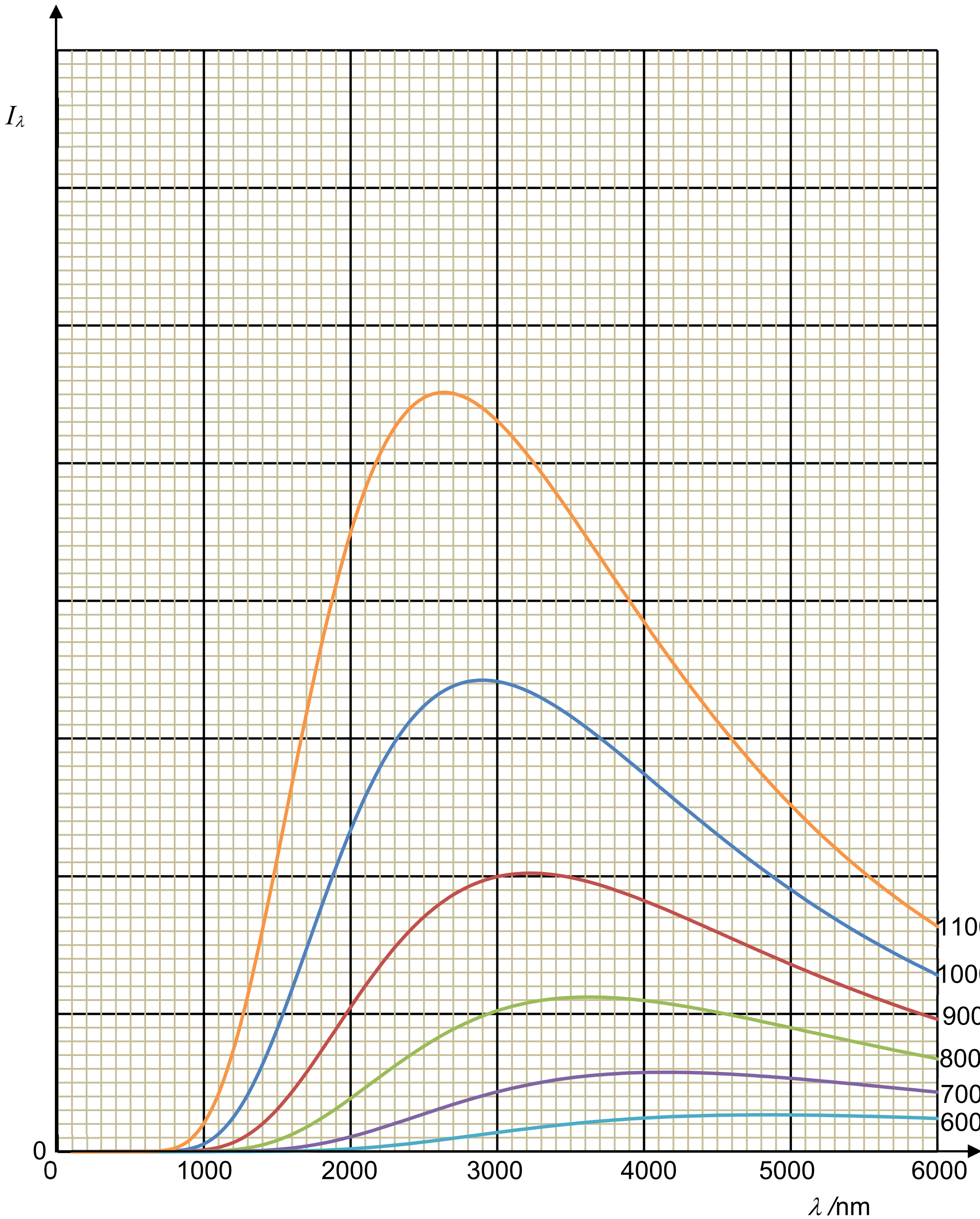

Fig. 7.2

(c) At any temperature T, the graphs in Fig. 7.2 show a peak intensity corresponding to a wavelength λ_{max}. In addition, the total intensity I_{tot} of the emitted radiation at each temperature is given by the area under the graph. Data for T and the corresponding values of λ_{max} and I_{tot} are shown in Fig. 7.3.

T/K	λ_{max} /nm	I_{tot}/W m^{-2}
600	4830	14.2
700	4140	26.0
800	3610	45.1
900	3210	69.4
1000	2900	100
1100	2630	160

Fig. 7.3

(i) Without drawing a graph, show that

$$T \times \lambda_{max} = \text{constant},$$

and determine the numerical value of the constant in metre kelvin (m K).

....

....

....

....

constant = ... m K [3]

(ii) Hence determine λ_{max} at a temperature T of 1200 K.

λ_{max} = ... m [2]

(d) Fig. 7.4 shows the values of lg(I_{tot}/W m^{-2}) plotted against the corresponding values of lg(T/K).

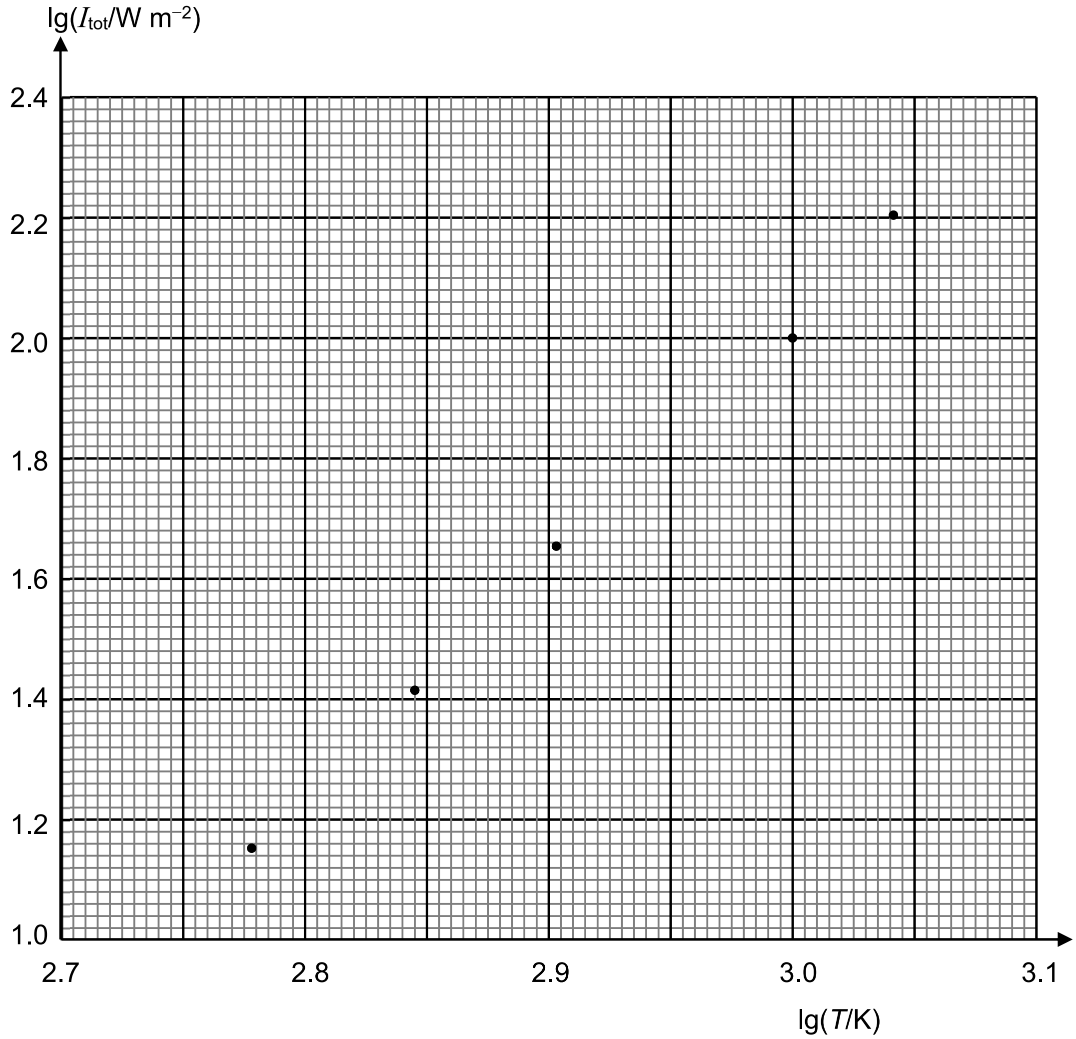

Fig. 7.4

Use the values in Fig. 7.3 to determine lg(I_{tot}/W m^{-2}) for a temperature of 900 K.

(i) On Fig. 7.4, plot the point corresponding to T = 900 K [1]

(ii) Draw the line of best fit for the points. [1]

(e) It is known that I_{tot} varies with T according to the relation

$$I_{tot} = cT^n$$

where c and n are constants.

(i) Use the line drawn to determine a value for n.

n = ... [3]

(ii) By using the values in Fig. 7.3 for T = 900 K, determine I_{tot} for the object at 1200 K.

I_{tot} = ... W m^{-2} [2]

(f) Using your answer to **(c)(ii)**, sketch on Fig. 7.2, the variation with wavelength λ of intensity I_{λ} for a temperature of 1200 K.

[3]

(g) The radiation emitted by a hot body may be used as a means of determining the temperature of the body. Suggest and explain a property of the radiation that could be used for this purpose.

....

....

....

.... [2]

[Total: 20]