TEMASEK JUNIOR COLLEGE
2022 JC2 Preliminary Examination
Higher 2

NAME

CG

PHYSICS

9749/02

Paper 2 Structured Questions

23 August 2022

2 hours

READ THESE INSTRUCTIONS FIRST

Write your name and civics group in the spaces at the top of this page.

Write in dark blue or black pen on both sides of the paper.

You may use an HB 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	
2	
3	
4	
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6	
7	
s.f	
Total	

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_o	=	8.85×10^{-12} F m^{-1} or $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} Js
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	=	$\dfrac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\dfrac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin\omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos\omega t$
		=	$\pm\omega\sqrt{(x_o{}^2 - x^2)}$
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	=	$\dfrac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	x	=	$x_o \sin\omega t$
magnetic flux density due to a long straight wire	B	=	$\dfrac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\dfrac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\dfrac{ln2}{t_{1/2}}$

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

1 A propeller driven boat of mass 800 kg is traveling in still water in a straight line. When the boat is moving at a constant speed of 15 m s^{-1}, the power delivered to the propeller is 90 kW.

(a) Calculate the total resistive force on the boat.

total resistive force = ... N [2]

(b) If the power delivered is then suddenly increased to 120 kW, determine the initial acceleration of the boat.

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

(c) Explain how the acceleration will vary over time as the power is maintained at 120 kW.

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2 **(a)** A star and a planet orbit their mutual centre of mass as shown in Fig. 2.1. The diagram is not to scale.

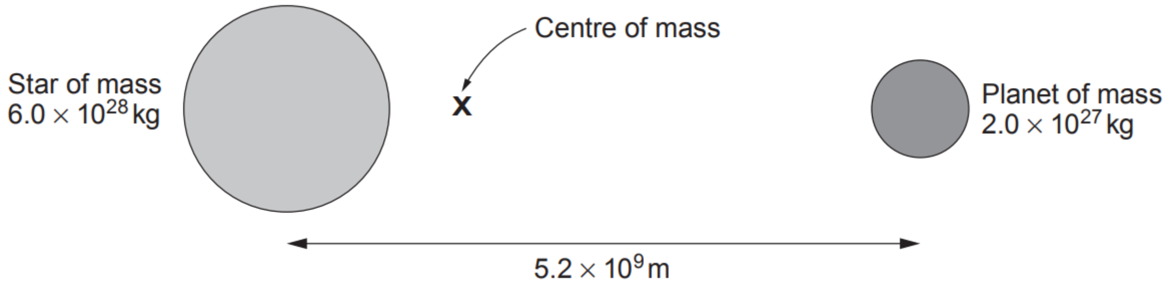

Fig. 2.1

(i) Calculate the distance of the centre of mass from the centre of the star. Explain your working clearly.

distance = ... m [2]

(ii) Calculate the period of orbit.

period = ... s [2]

(iii) Astronomers note a periodic dip in the brightness of the star as shown in Fig. 2.2.

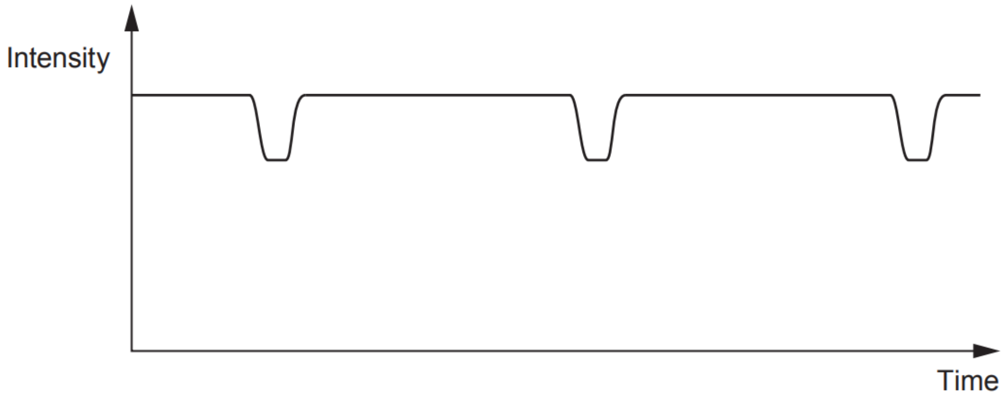

Fig. 2.2

Explain this observation.

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(b) The satellite NOAA-20 was launched in November 2017. The satellite has an approximately circular orbit at an altitude of 825 km above the Earth's surface. The radius of the Earth = 6.4×10^6 m.

Fig. 2.3 shows how the gravitational field strength g of the Earth varies with distance r from the centre of the Earth.

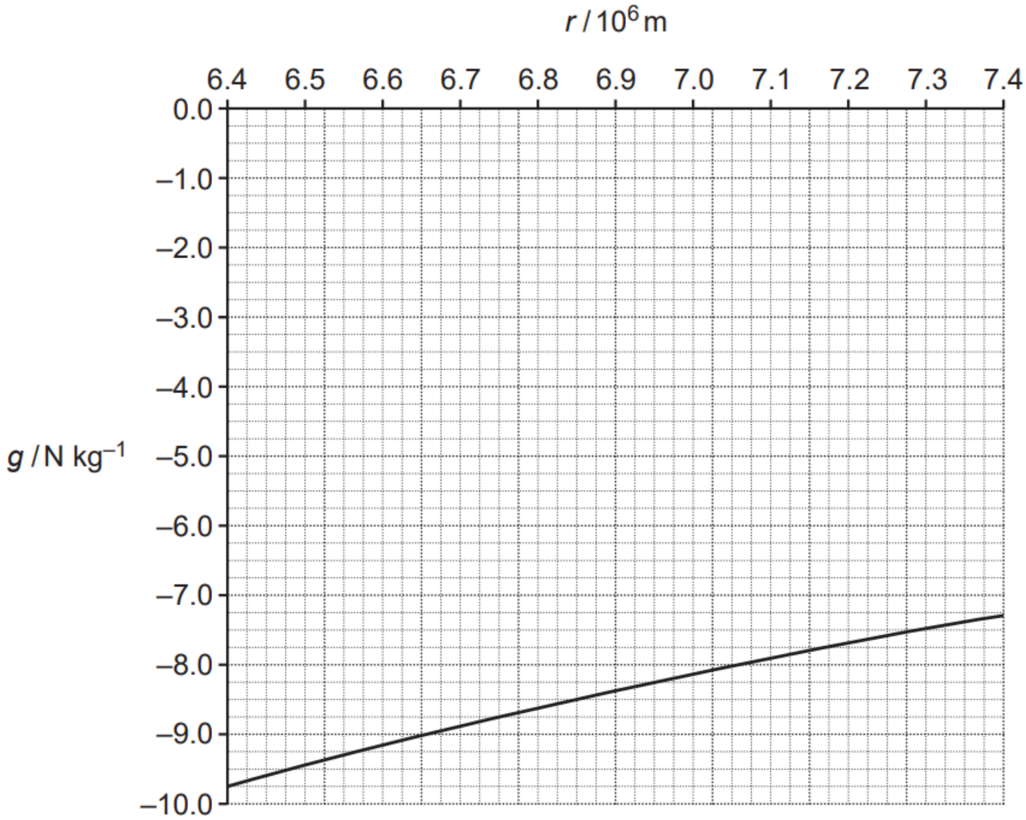

Fig. 2.3

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(i) The mass of the satellite is 2300 kg. Use the graph to show that the change in gravitational potential energy of the satellite between its launch and its position in orbit is about 1.6×10^{10} J. Explain your working clearly.

[3]

(ii) Use the value for the change in potential energy from **(b)(i)** to determine the mass of the Earth.

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mass of Earth = ... kg [2]

(iii) The satellite takes a polar orbit, revolving around the Earth from pole to pole, as shown in Fig. 2.4. Geostationary satellites orbit at a greater distance from the Earth.

Fig. 2.4

Explain why a low, polar orbit is useful for satellites used for weather forecasting and suggest why geostationary satellites are used for telecommunications

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....[2]

3 A diffraction grating is set up at the centre of a rotating table which completes a revolution in every 3.0 s. The grating is illuminated normally by monochromatic light of wavelength λ from a source which is also mounted on the table as shown in Fig. 3.1.

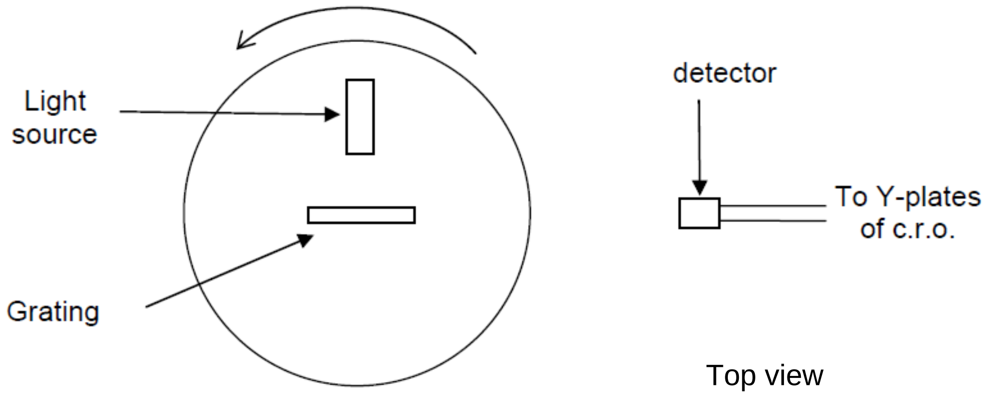

Fig. 3.1

The emergent beams of light from the grating are monitored by means of a stationary detector. The output from the detector is displayed on a cathode ray oscilloscope (c.r.o.). With the time-base set at 0.10 s cm^{-1}, the trace obtained is shown in Fig. 3.2. The relative positions of the peaks are as indicated.

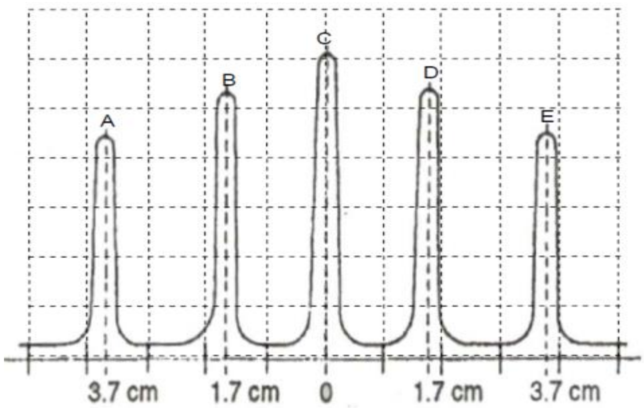

Fig. 3.2

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(a) Calculate the angular speed of rotation of the grating.

angular speed = ... rad s^{-1} [1]

(b) Explain why the peaks in Fig. 3.2 do not have the same intensity.

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.... [2]

(c) **(i)** If θ is the angle between the emergent ray and the normal. Use your answer in **(a)**, determine θ for peak E.

θ = ... radian [2]

(ii) Using peak E, hence calculate the wavelength of the light if the grating has 550 lines per mm.

wavelength = ... nm [2]

(iii) Explain why

1. it is preferable to calculate the wavelength using peak E rather than peak D.

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2. only 5 peaks are observed with some calculations.

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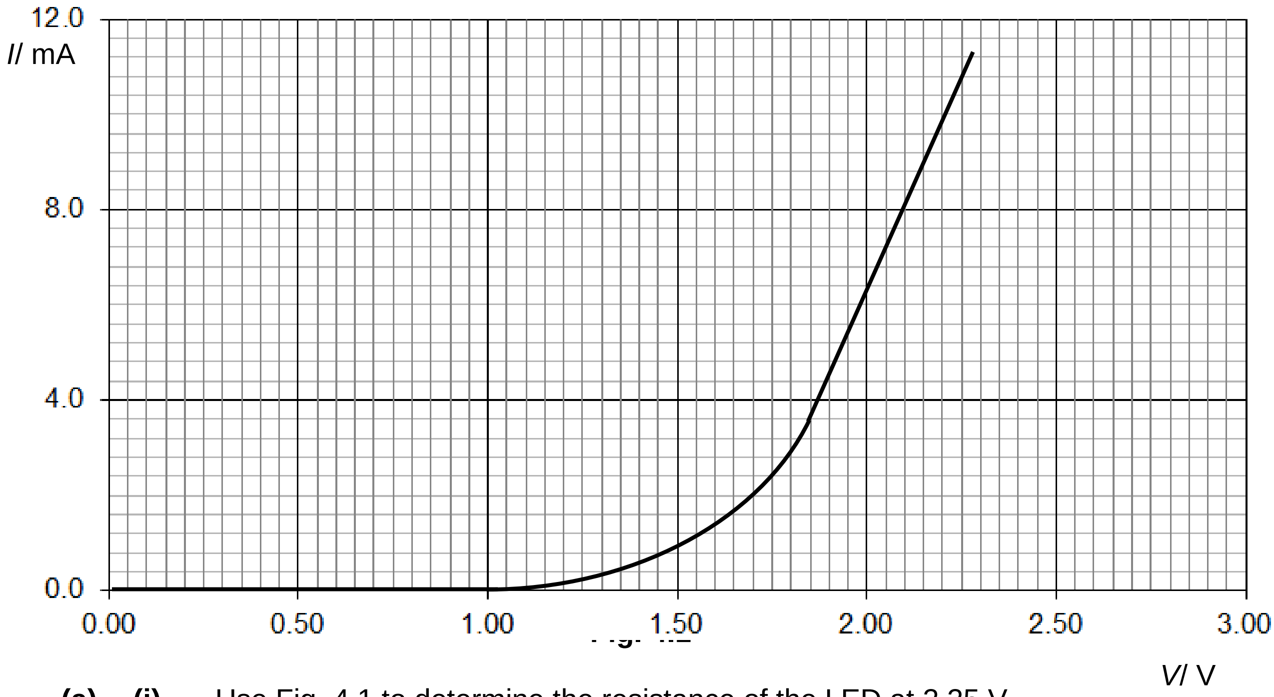
.... [2]

(d) Sketch, in Fig. 3.2, the trace on the c.r.o, if the diffraction grating is replaced by a double slit of the same slit separation and slit width as the diffraction grating.

[1]

4 The variation with potential difference V of current I for a light emitting diode (LED) is shown in Fig. 4.1.



(a) **(i)** Use Fig. 4.1 to determine the resistance of the LED at 2.25 V.

resistance = ... Ω [1]

(ii) Shade in Fig. 4.1 the area that represent the increase in power dissipation in the LED if the potential difference across the LED is increased from 1.50 V to 1.75 V.

[1]

(b) Two of these LEDs are connected to a 3.0 V battery with negligible internal resistance and a 160 Ω resistor as shown in Fig. 4.2.

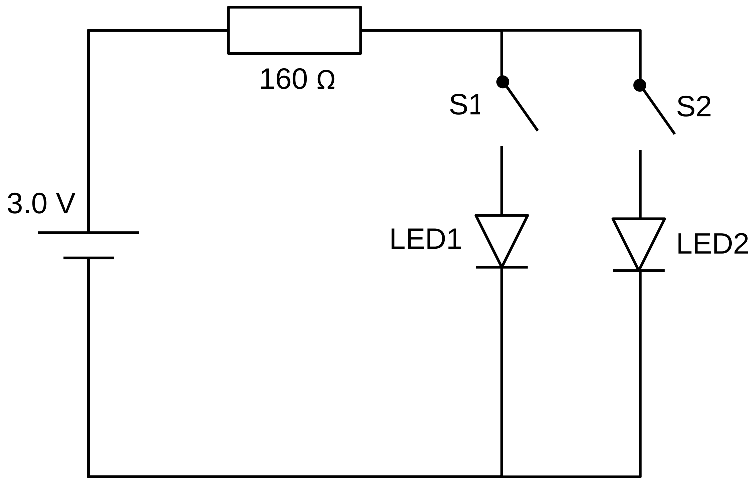


Fig. 4.2

(i) Draw in Fig. 4.1 the variation with potential difference of current for the 160 Ω resistor. Label the line **R**

[1]

(ii) Hence, or otherwise, determine the current in LED1 when switch S1 is closed and switch S2 remaining open. Show your working clearly.

current = ... mA [2]

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(iii) Explain why LED1 becomes dimmer when S2 is also closed.

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(c) It is possible for LED1 to have the same brightness regardless of whether S2 is open or closed with the addition of another 160 Ω resistor and rearrangement of the circuit in Fig. 4.2.

Draw this circuit in the space below.

[1]

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5 (a) A thin slice of conducting material is placed normal to a uniform magnetic field of flux density *B*, as shown in Fig. 5.1.

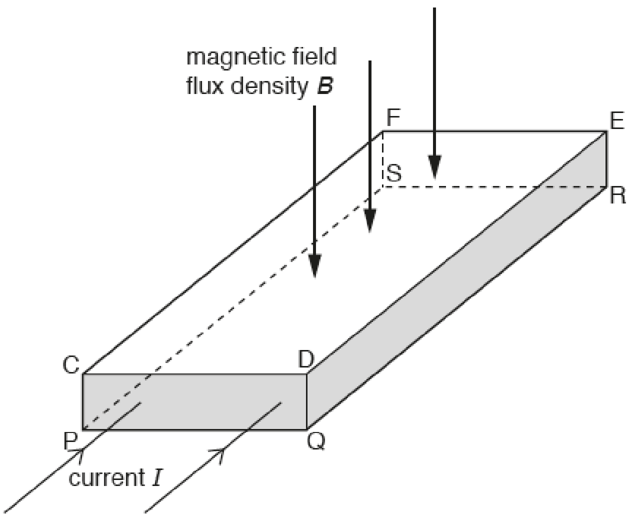

Fig. 5.1

The magnetic field is normal to face CDEF and to face PQRS.

A current I passes through the slice and is normal to the faces CDQP and FERS.

A potential difference, V_H, is developed across the slice at steady state.

(a) State the faces between which V_H is developed.

.... [1]

(b) The current I is produced by charge carriers, each of charge $+q$ moving at speed v in the direction of the current. The number density of the charge carriers is n.

(i) Derive an expression relating V_H to v, B and d, where d is one of the dimensions of the slice.

[3]

(ii) Use your answer in **(b)(i)** and an expression for the current I in the slice to derive the Expression

$$V_H = \frac{BI}{ntq}$$

where t is another of the dimensions of the slice. Explain your working.

[2]

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(iii) Suggest why V_H is difficult to detect in a thin slice of copper.

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6 (a) The plan view (from top down) of a train braking system is illustrated in Fig 6.1. The train carriage of mass *m* is mounted on a rectangular metal frame ABCD of length *L* and width *w*, the effective resistance of the frame is *R.* The train carriage is initially moving at a constant speed along the rails.

A uniform magnetic field *B* is directed perpendicularly into the ground over a rectangular region of length *L*. Line P denotes the start of this region while line Q denotes the end of the region. After passing through the magnetic field, the train speed is expected to be reduced to a very low speed (exit speed) after which brakes can be applied to stop it completely. You may assume that friction is negligible.

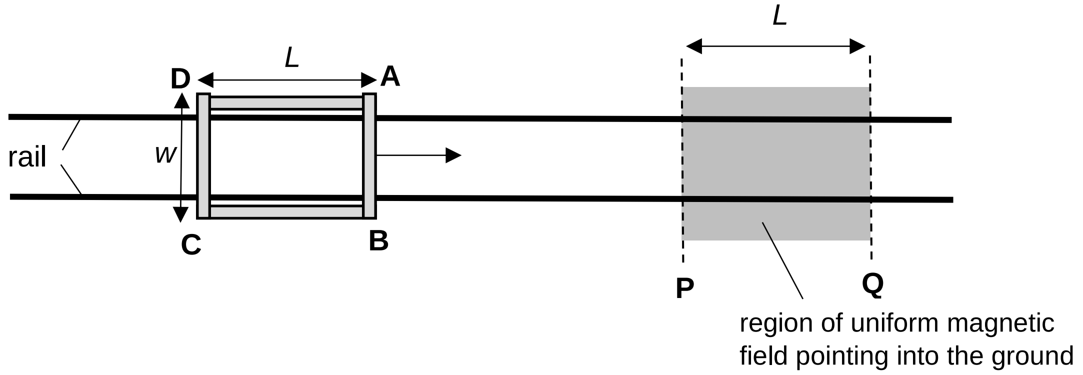

Fig 6.1

(i) Define *magnetic flux density.*

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....[2]

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(ii) Explain how the train carriage is slowed down as AB moves through the magnetic field from P to Q.

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(iii) Show that the braking force acting on the frame is given by $F = \frac{B^2 w^2 v}{R}$ where *v* is the speed of the train carriage. Explain your working clearly.

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[4]

(b) The graph in Fig 6.2 shows the speed of the train carriage as it moves through the magnetic field, from the instant AB crosses line P to the instant CD crosses line Q.

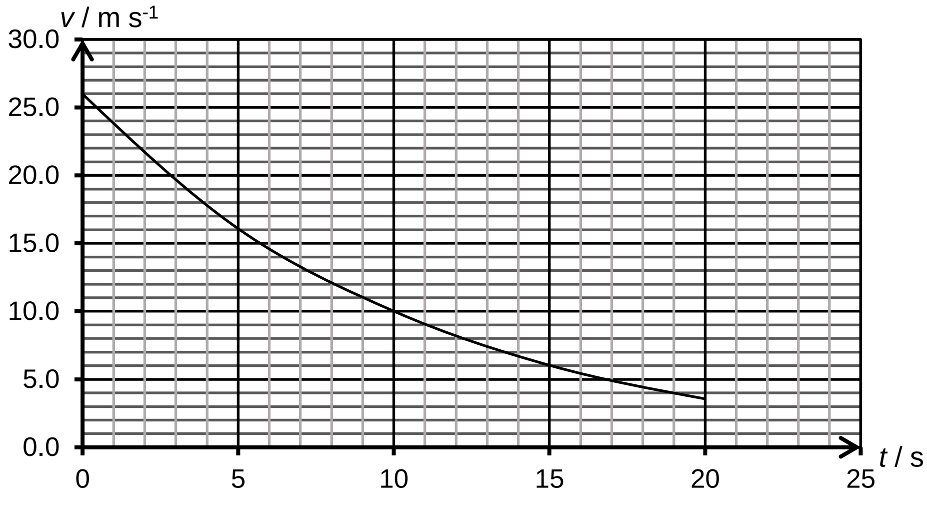

Fig 6.2

(i) Use Fig 6.2 to estimate the distance PQ.

distance PQ = ...m [2]

(ii) Discuss how increasing the region of magnetic field (distance between P and Q) would affect, if at all, the exit speed of the train after passing through it.

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7 The Earth receives radiant energy from the Sum every second. If the Earth radiates or reflect energy back into space at the same rate, then it will be in thermal equilibrium and its average temperature will remain constant. If the Earth radiates or reflect less energy than it receives it will get hotter.

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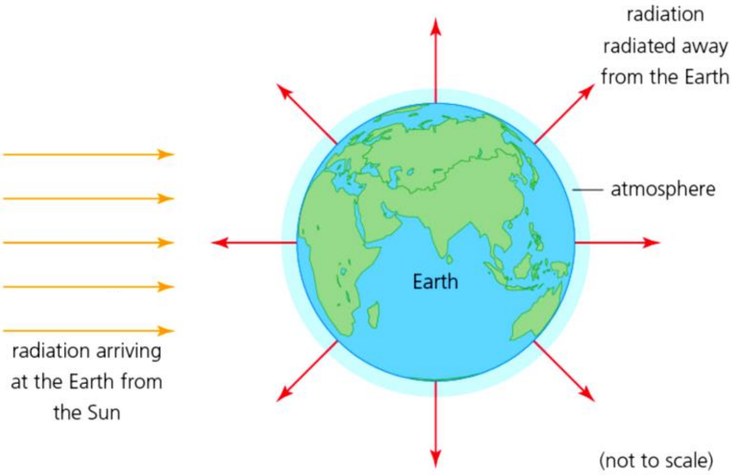

The greenhouse effect is the name that is given to the natural effect a planet's atmosphere has in increasing the temperature of the planet to a value higher than it would be without an atmosphere. The Earth has a beneficial greenhouse effect because it has an atmosphere. The Earth's atmosphere is a good transmitter of visible radiation and a good absorber of infrared radiation. The visible light that reaches the Earth's surface is absorbed and reradiated as infrared light, which in turn is absorbed (trapped) by the Earth's atmosphere.

If the Earth did not have an atmosphere it would be about 30ºC cooler and without life. The Moon and the Earth are approximately the same distance from the Sun, but the surface of the Earth is hotter and therefore human life exists.

However, most scientists now believe that the greenhouse effect has become enhanced. This is attributed to human activities, primarily fossil fuel burning, As fossil fuels (coal, oil, and natural gas) are burned, large amounts of carbon dioxide, which is one of the most significant greenhouses gases, are released into the atmosphere. According to one estimate, doubling the carbon dioxide content in the atmosphere will cause temperatures to increase by 2°C. This is probably the most important cause of current global warming.

There is little doubt that global warming has led to consequences such as climate change and changes to the sea level. During December 2006, New York had one of its highest temperatures for a winter while Melbourne has snow in the hinterlands during summer. Global warming is causing global mean sea level to rise in two ways. Firstly, glaciers and ice sheets worldwide are melting and secondly, the volume of the ocean is expanding as the water warms.

(a) Solar radiation falling on the Earth's surface is absorbed by the Earth.

(i) This solar radiation has an average intensity of 5.0×10^2 Wm^{-2} and falls on an area of 2.6×10^{14} m^2 on the Earth.

Calculate the energy per second that is absorbed by the Earth due to this solar radiation.

energy per second = ... $J\ s^{-1}$ [2]

(ii) The Earth has acquired a mean equilibrium temperature due to the energy per second absorbed from the Sun being in balance with the power radiated from the Earth's surface into Space.

State the power that must be radiated from the Earth's surface so that it achieves a steady equilibrium temperature.

power = ... W [1]

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(iii) Assuming that the Earth radiates this power uniformly from all points on its surface and the radius of the Earth is 6400 km, show that the Earth radiates a power of 250 W per square metre of the Earth's surface

[2]

(b) Fig. 7.1 shows the variation with wavelength, λ, of the intensity of electromagnetic radiation emitted by a blackbody at a surface temperature of 2900 K.

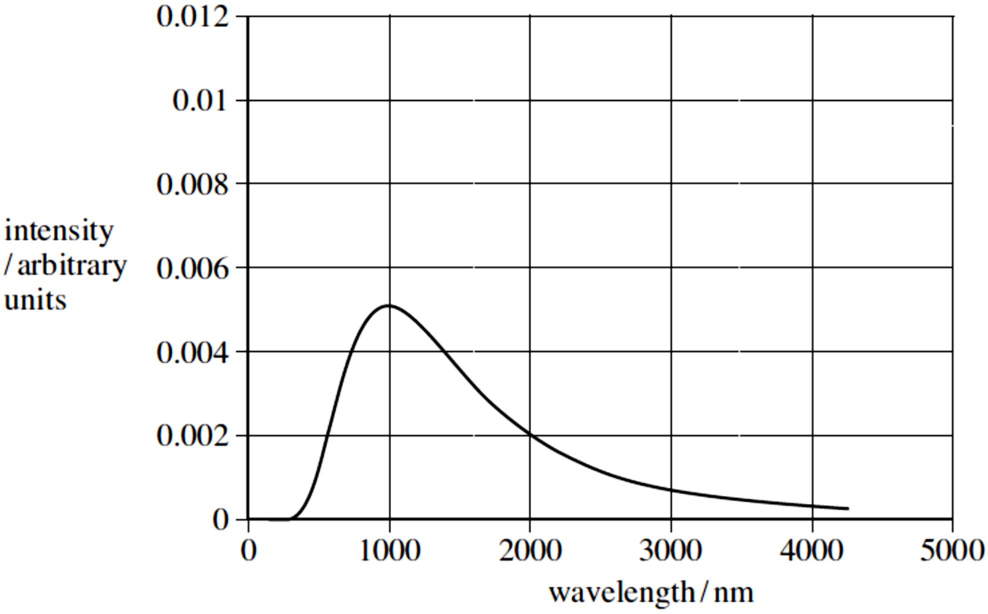

Fig. 7.1

At any surface temperature T *in kelvin*, there is a peak intensity corresponding to a wavelength λ_{max} of radiation. The wavelength λ_{max} is related to temperature T by the equation

$$\lambda_{max} T = k$$

where k is a constant. This equation is also known as Wien's Law.

(i) Mark, with an arrow labelled **M** on Fig. 7.1, the wavelength λ_{max} that correspond to the peak intensity of radiation from the blackbody.
[1]

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(ii) Use Fig. 7.1 to calculate the value of *k*.

k = ... nm K [2]

(iii) The surface of the Sun is at a temperature of 5800 K and that of the Earth is 290 K. They may both be considered to radiate energy as black bodies.

Calculate the wavelengths, in nm, corresponding to the peak intensity for the radiation emitted by the Sun and the Earth.

wavelength for the Sun = ... nm

wavelength for the Earth = ... nm [2]

(iv) Draw on Fig. 7.1 the emission curve for the Sun. Label it **(iv).**

[1]

(c) Fig. 7.2 shows how the percentage of electromagnetic radiation, absorbed by carbon dioxide, varies with the wavelength of the radiation.

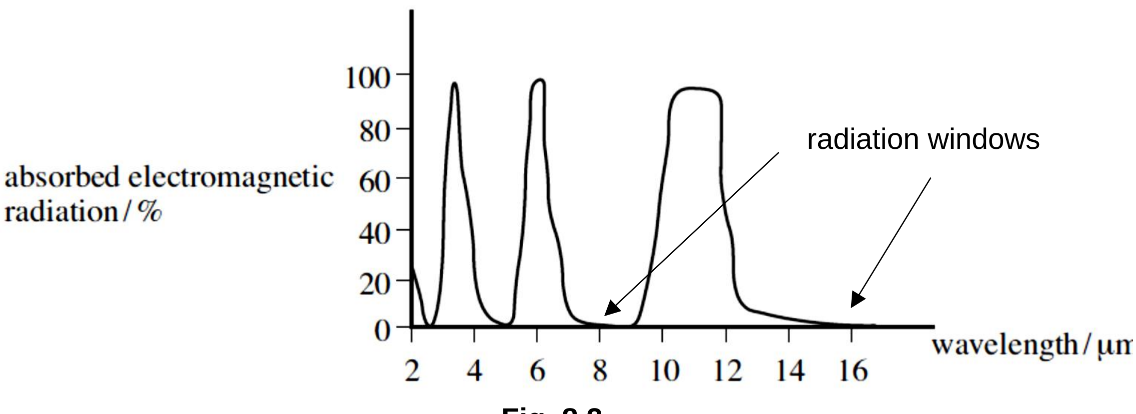

Fig. 8.2

(i) The graph indicates that carbon dioxide has radiation windows.
Suggest what is meant by the term *radiation windows* in this context.

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(ii) State whether carbon dioxide has a radiation window for radiation of wavelength 11 μm.

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(d) Explain how Wien's law and knowledge of the radiation windows for carbon dioxide can be used to account for the greenhouse effect that contributes to global warming.

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(e) Large proportions of the Earth's ice will melt if the Earth's equilibrium temperature increases.

(i) Greenland has an ice sheet that covers a land area of 1.7×10^6 km^2. The mass of the ice in this sheet is 2.8×10^{18} kg.
Calculate the volume of water produced if all of this ice were to melt.
density of water = 1.0×10^3 kg m^{-3}

volume = ... m^3 [2]

(ii) Arctic pack ice mostly consists of frozen salt water that floats on the surface of the Arctic Ocean. Until recently, this ice remained frozen but now significant amounts of it melt during the summer.
State and explain any change in sea levels that may occur should all of this floating pack ice melt.

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