RAFFLES INSTITUTION
2022 YEAR 5 PROMOTION EXAMINATION

30 September 2022 Time: 2 hr 30 min

H2 PHYSICS

Section A

INSTRUCTIONS TO CANDIDATES

There are 3 sections in this paper.

Section A consists of **15** multiple-choice questions. For each question, there are four possible answers **A**, **B**, **C** and **D**. Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Optical Mark Sheet.

You are advised to attempt Section A first. The Optical Mark Sheets will be collected after the first **30** minutes.

Section B consists of **5** structured questions. You are to write your answers in the spaces provided.

Section C consists of **1** long structured question and **1** data analysis question. You are to write your answers in the spaces provided.

Attempt **all** questions in Sections A, B and C.

There are **9** printed pages, inclusive of the cover page and data & formulae page, in this booklet.

 [Turn over

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	=	$\ln 2/t_{1/2}$

1 The period T of a simple pendulum of length L is given by the following equation

$$T = 2\pi\sqrt{\frac{L}{g}}$$

where g is the acceleration of free fall.

The fractional uncertainty of the period T is 0.020 and that in the measurement of the length L is 0.030.

What is the fractional uncertainty of the calculated value of g?

A 0.010 **B** 0.050 **C** 0.070 **D** 2.8

2 An equation of the theory of gas flow through small diameter tubes at low pressures is

$$Q = \frac{kr^3\left(p_1 - p_2\right)}{Lc}$$

where k is a dimensionless constant,
r is the radius of the tube,
p_1 and p_2 are the pressures at each end of the tube of length L,
c is the speed of the gas molecules

What are the base units of Q?

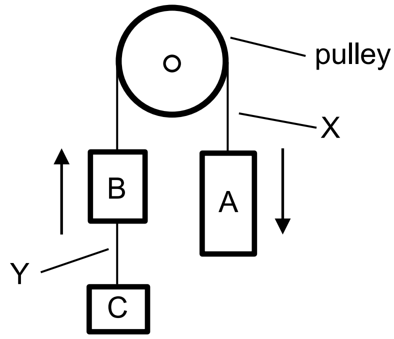
A 1 **B** kg s^{-1} **C** m^3 s^{-1} **D** m s

3 A baseball at a height of 0.80 m above a flat horizontal ground is projected with a velocity of 12 m s^{-1} at an angle 25° to the horizontal. Air resistance is negligible.

What is the horizontal displacement of the ball when it reaches the ground?

A 1.5 m **B** 9.1 m **C** 11.6 m **D** 12.8 m

4 Two blocks A and B, hang from a light inextensible cord X that passes over a frictionless pulley. A third block C is suspended from block B with a light inextensible cord Y. The masses of blocks B and C are 2.0 kg and 1.0 kg respectively. When the masses are released from rest, they move in the direction of the arrows and the tension in cord Y is 12 N.

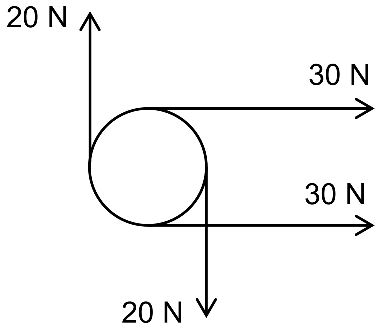


What is the mass of block A?

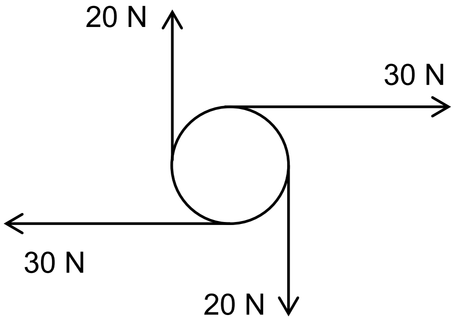
A 3.2 kg **B** 3.7 kg **C** 4.0 kg **D** 4.7 kg

5 Four forces are applied to a circular object. In which scenario would the object have a non-zero net force but no net torque?

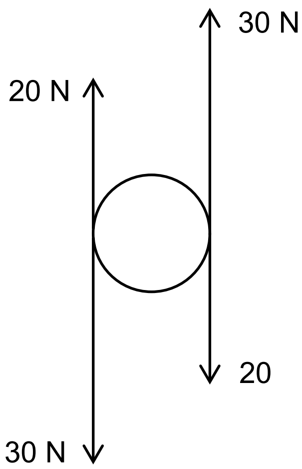
A



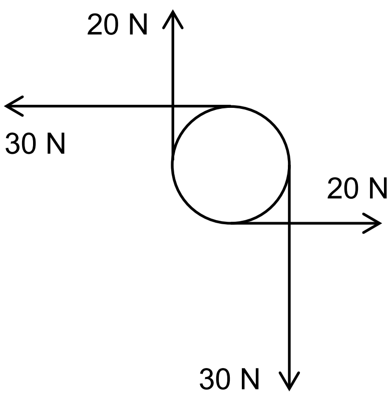
B



C



D



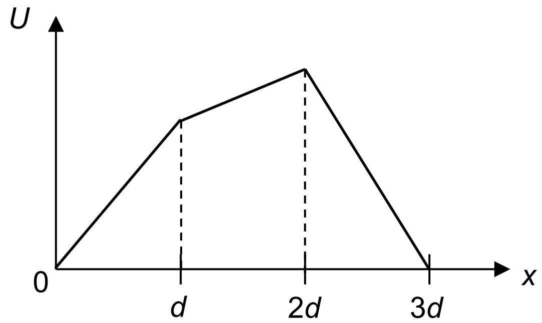
6 An electric vehicle of mass 1800 kg, travelling along a horizontal road at a constant speed of 14 m s^{-1}, requires a power of 5.0 kW.

What is the required power when the vehicle is moving up a slope of 5.0° at the same constant speed of 14 m s^{-1}?

A 5.1 kW **B** 16.5 kW **C** 26.5 kW **D** 251 kW

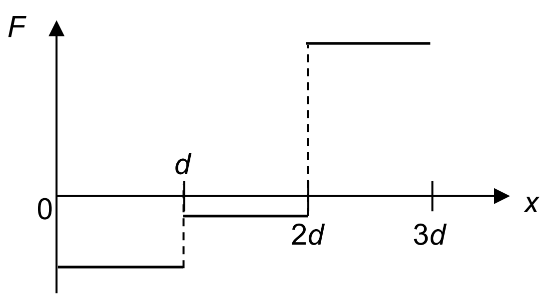
7 A particle moves in a straight line from a point O.

The graph shows how its potential energy U varies with its displacement x from point O.

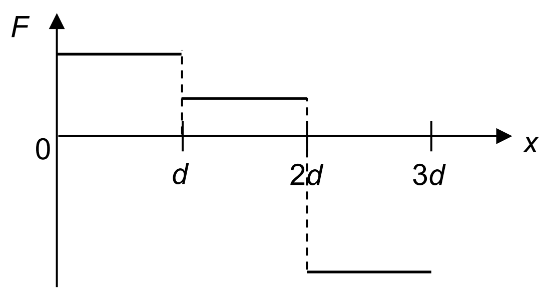


Which graph shows how the force F acting on the particle varies with displacement x?

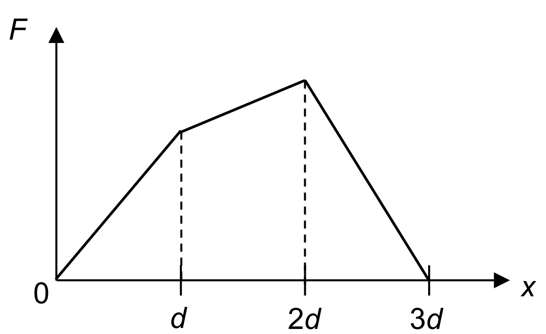
A



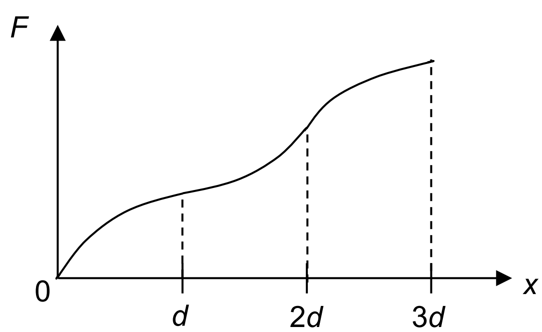
B



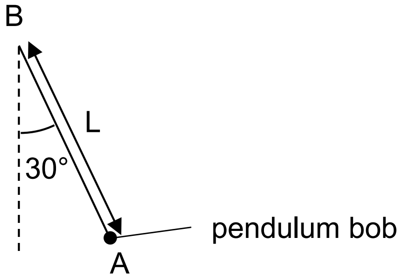
C



D



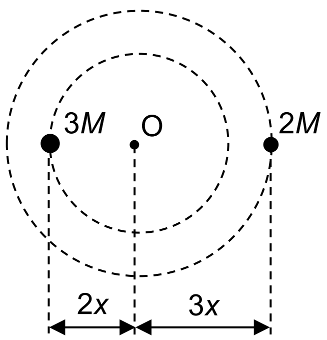
8 A pendulum bob of mass m is attached to a light inextensible string of length L that is fixed to point B. The pendulum bob is released from rest at point A.



What is the tension in the string when the pendulum bob is vertically below B?

A mg **B** 1.3 mg **C** 1.5 mg **D** 2.0 mg

9 Two stars of masses 3M and 2M, orbit in circles about their common centre of mass O, with radii of 2x and 3x respectively.



What is the angular speed ω of rotation of the stars?

A $0.20\sqrt{\dfrac{GM}{x^3}}$ **B** $0.33\sqrt{\dfrac{GM}{x^3}}$ **C** $0.45\sqrt{\dfrac{GM}{x^3}}$ **D** $0.50\sqrt{\dfrac{GM}{x^3}}$

10 A satellite orbits a planet at a distance r from its centre. Its gravitational potential energy is –5.6 MJ.

Another identical satellite orbits the planet at a distance 2r from its centre.

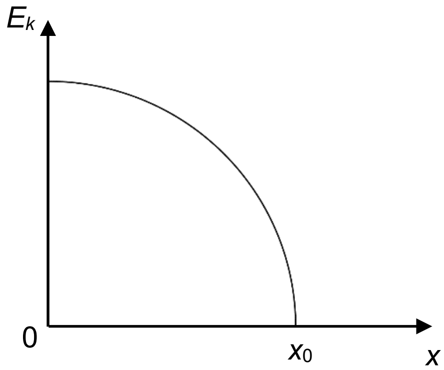
What is the sum of the kinetic energy and the gravitational potential energy of this second satellite?

A – 0.70 MJ **B** – 1.4 MJ **C** – 2.8 MJ **D** – 11.2 MJ

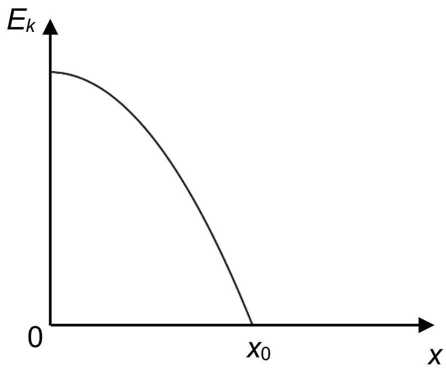
11 A mass undergoes simple harmonic motion with amplitude x_0.

Which graph shows the variation of the kinetic energy E_k of the mass with its displacement x?

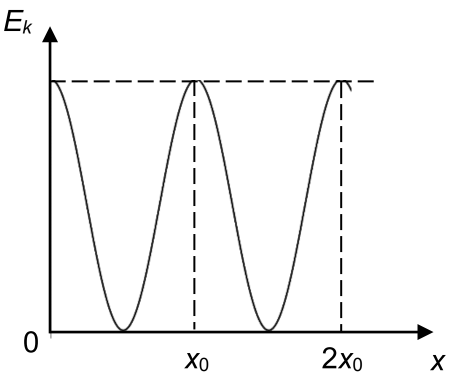
A



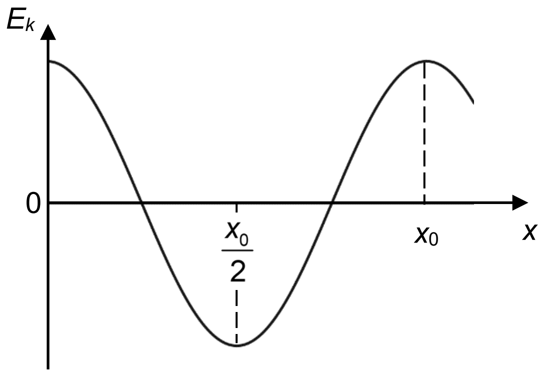
B



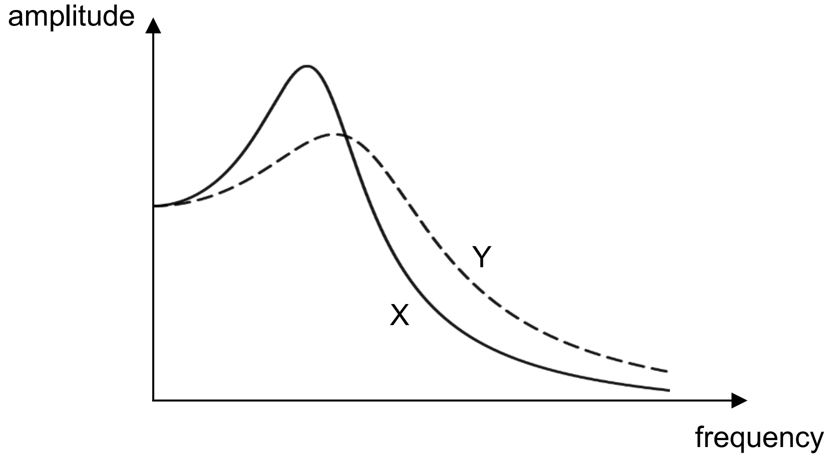
C



D



12 A spring-mass system is connected to a driving oscillator. The solid curve X on the graph shows how the amplitude of the spring-mass system varies with the frequency of the driving oscillator. A certain change in condition causes the response of the system to shift to the dashed curve Y.



What is the change in condition?

A The mass decreases.

B There is less damping.

C The amplitude of the driving oscillator increases.

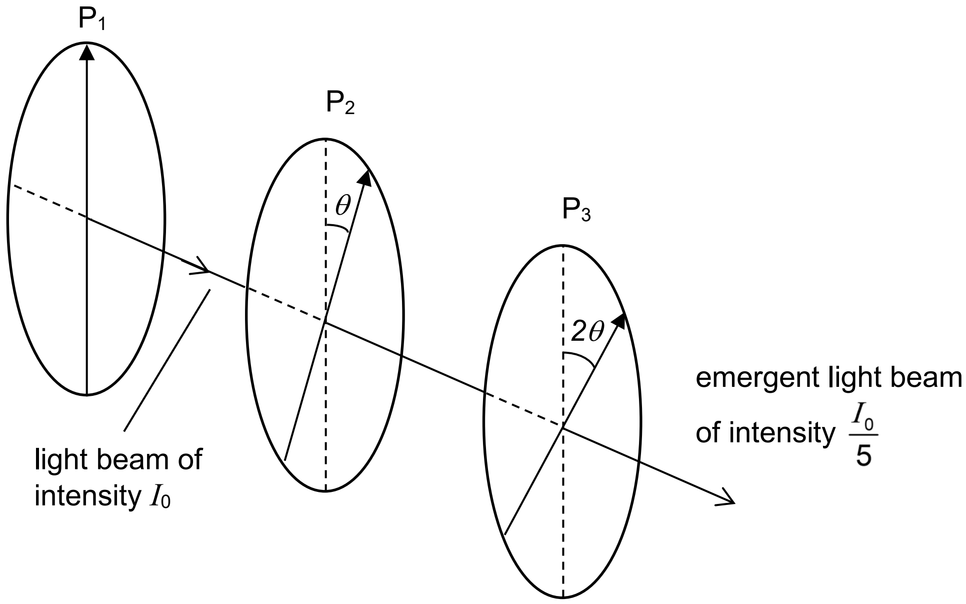
D The frequency of the driving oscillator decreases.

13 A point source of sound emits energy uniformly in all directions at a power P. At a distance r from the source, the air molecules oscillate with an amplitude of A.

If P is halved, what is the amplitude of oscillation of the air molecules at a distance $3r$ from the source?

A $0.056A$ **B** $0.17A$ **C** $0.24A$ **D** $4.2A$

14 A beam of light passes through three polaroids P_1, P_2 and P_3. The intensity of light is I_0 after passing through P_1.

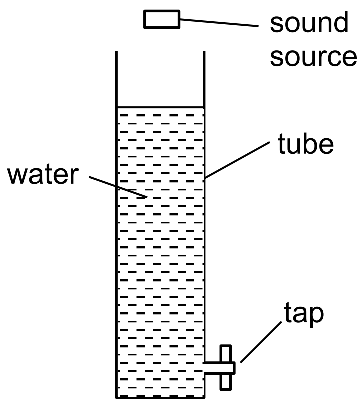


The polarising axes of P_1 and P_2 are at an angle θ to one another and the polarising axes of P_1 and P_3 are at an angle 2θ to one another. The emergent light beam has an intensity of $\frac{I_0}{5}$.

What is the value of θ?

A 30° **B** 32° **C** 48° **D** 63°

15 A vertical tube is completely filled with water. A small sound source of constant frequency is held directly above the top opening of the tube and water is run out from a tap at the bottom.



A number of resonance positions are detected. The third of these occurs when the water surface is 1.3 m below the top of the tube.

At which of the following distances will resonance **not** be detected?

A 0.26 m **B** 0.78 m **C** 0.87 m **D** 1.82 m

Name: ________________________ (   ) CT Group: 23S0 ____

RAFFLES INSTITUTION

2022 YEAR 5 PROMOTION EXAMINATION

30 September 2022

H2 PHYSICS

Section B

INSTRUCTIONS TO CANDIDATES

Write your name, index number and CT Group.

Write your answers to Section B in the spaces provided in this booklet.

For Examiner's Use		
Section A	MCQ	/ 15
Section B	16	/ 10
	17	/ 10
	18	/ 9
	19	/ 11
	20	/ 10
Section C	21	/ 15
	22	/ 15
Deductions		
Total		/ 95

There are **13** printed pages, inclusive of the cover page, in this booklet

16 A man of mass 50 kg is standing in a lift that starts from rest on the ground floor at t = 0 s and rises to the top floor over a 10 s interval.

The acceleration a of the man changes with time t as shown in Fig. 16.1. The value of the acceleration at t = 9.0 s is q.

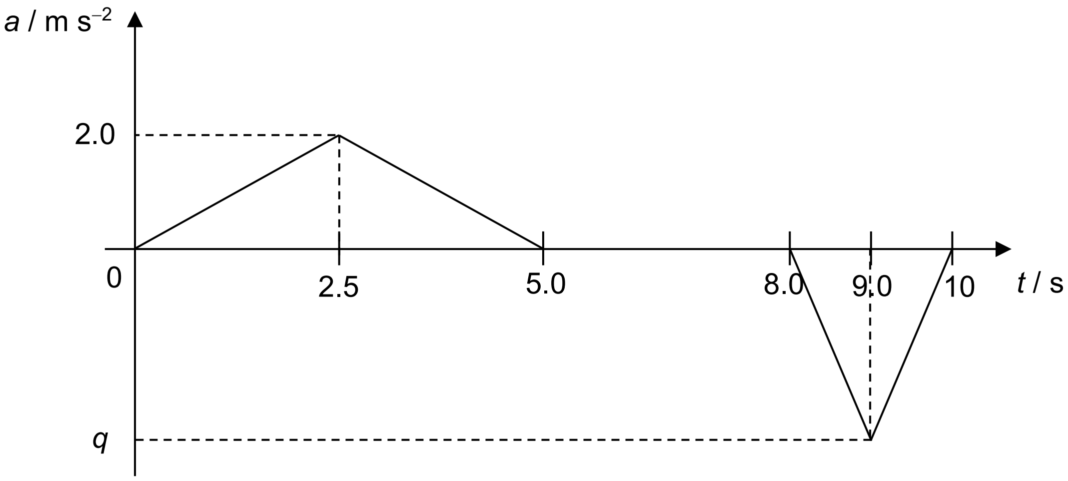


Fig. 16.1

(a) By considering the forces acting on the man, explain why the magnitude of q cannot exceed g, the acceleration due to free fall of the Earth.

....

....

....

.... [2]

(b) The man comes to rest at the top floor.

Determine q, the acceleration of the man at t = 9.0 s.

q = ... m s^{-2} [2]

(c) **(i)** On Fig. 16.2, sketch a graph to show how the velocity v of the man varies with time t. Label the vertical axis with appropriate values.

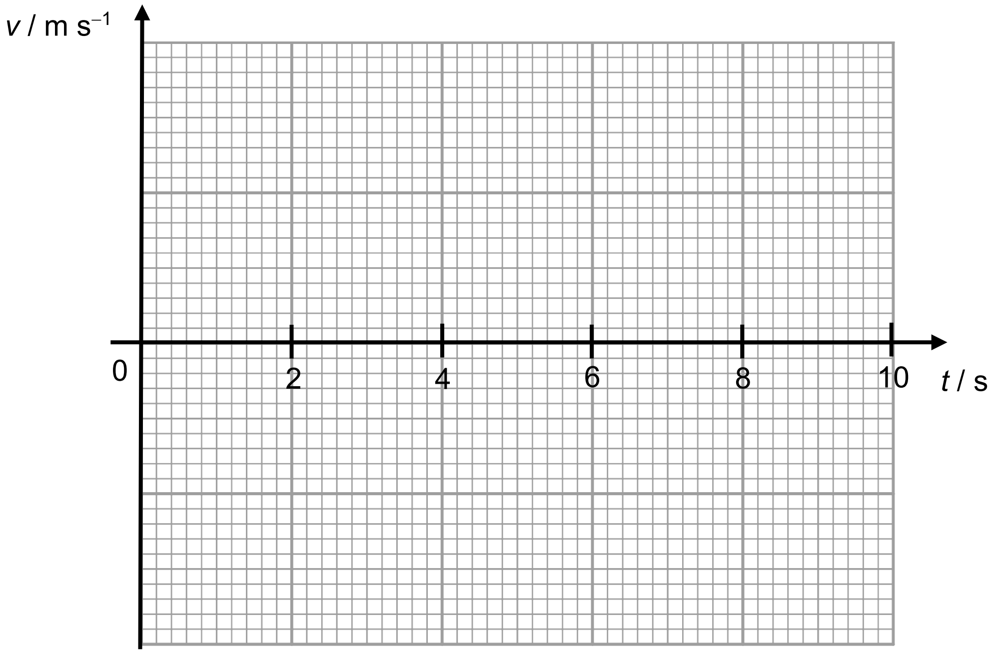


Fig. 16.2

[3]

(ii) Using your answer in **(c)(i)** or otherwise, calculate the distance travelled by the man during the first 5.0 seconds.

distance travelled = ... m [1]

(iii) Determine the work done by the normal contact force on the man during the first 5.0 seconds.

work done = ... J [2]

17 At the San Antonio Zoo, it is possible to have a tug of war battle with a lion cub. The lion enclosure is landscaped to mimic a savanna with uneven ground and grass. A light rope is passed through a hole in the glass wall of the lion enclosure, where on one end, a lion cub pulls on the rope, while the other end is pulled by a "contender" standing outside the enclosure on even concrete ground.

(a) In one such battle, the rope is held straight and horizontal between the lion cub and the man as shown in Fig 17.1 and the tension in the rope is 500 N.

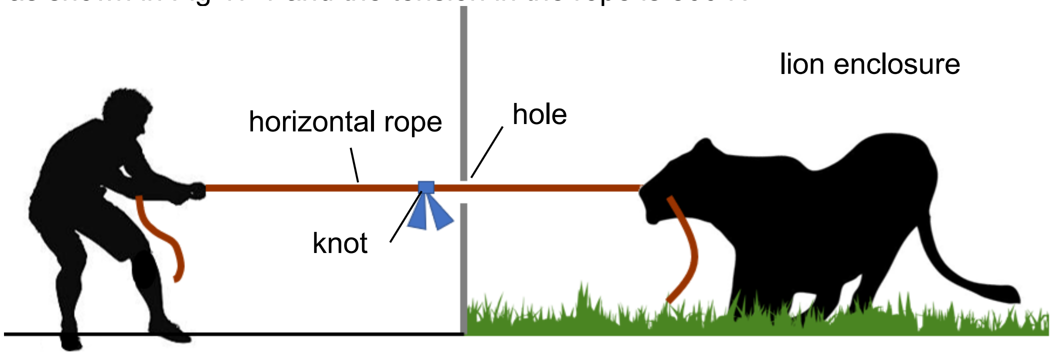


Fig. 17.1

(i) An observer states that there will be no winners in this battle since the rope exerts a force of 500 N on both the man and the lion, but in opposite directions. Comment on this statement.

....

....

....

....

....

.... [3]

(ii) The man changes his stance such that his centre of gravity is 0.50 m away from the tip of his toes as shown in Fig. 17.2, with the rope horizontal and 0.80 m above the ground. The man is about to topple forward when the tension is 500 N.

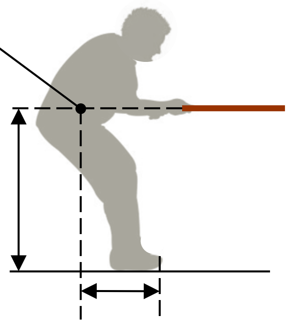


Fig. 17.2

1. Determine the mass of the man.

mass = ... kg [2]

2. If the tension in the rope increases, explain what the man can do to maintain a stable position.

....

....

.... [1]

(b) The zookeepers then reposition the man such that he now pulls at the rope at an angle of 25° to the glass enclosure wall using a fixed smooth vertical pole. Fig. 17.3 shows the cross-sectional view from the top.

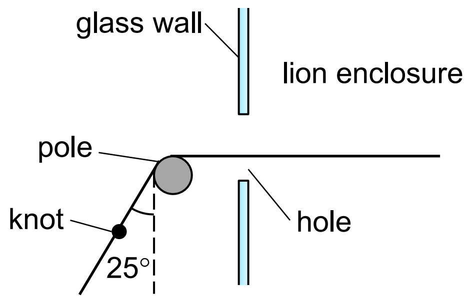


Fig. 17.3 (top view)

He now increases the tension to 1000 N and the rope is stationary.

Determine the magnitude and direction with respect to the glass wall of the reaction force R exerted on the rope by the pole.

magnitude of R = ... N

direction of R = ... [4]

18 In a stationary car, a cup of water with an ice cube is placed on the dashboard and a pendant is hang from the roof as shown in Fig. 18.1.

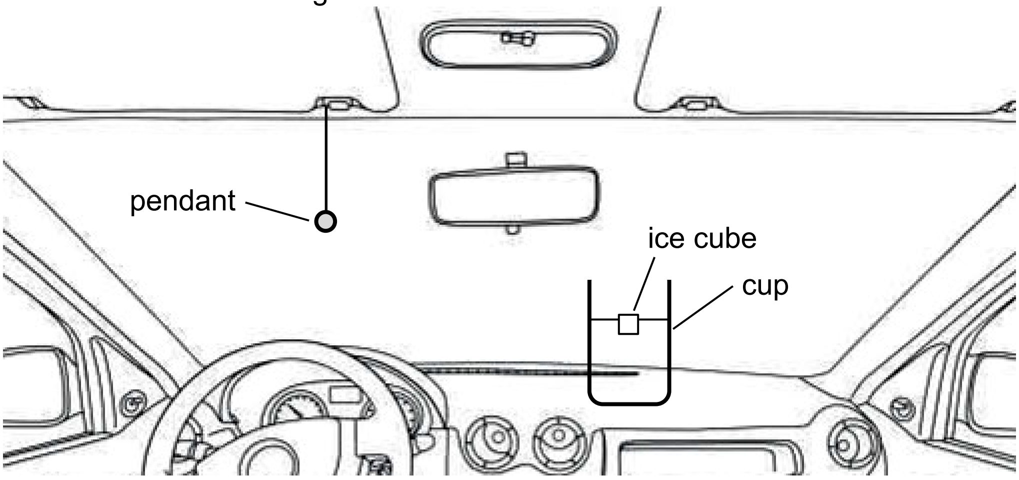


Fig. 18.1

The car makes a right turn along a circular path of radius 8.5 m on a horizontal road surface at a constant speed of 7.0 m s^{-1}. The plane of the water surface is inclined at an angle θ to the horizontal as shown in Fig. 18.2 while the pendant is inclined to the left at the same angle θ to the vertical as shown in Fig. 18.3.

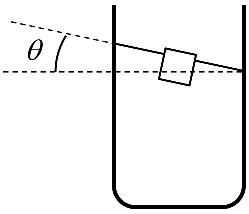


Fig. 18.2

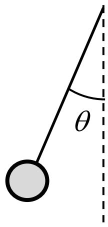


Fig. 18.3

(a) Explain how the centripetal force acting on the ice cube is produced.

....

....

....

.... [2]

(b) On Fig. 18.3, draw and label arrows to show the forces acting on the pendant.

[1]

(c) Determine

(i) the angular speed of the car,

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

(ii) the angle θ.

θ = ... ° [3]

(d) The car continues its right turn on a road surface that is banked at 10°, as shown in Fig. 18.4, with the same radius and speed.

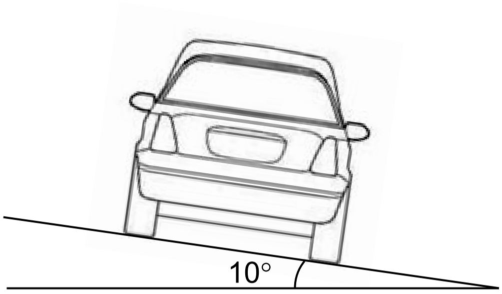


Fig. 18.4

State and explain what happens to angle θ of the pendant to the vertical.

....

....

....

.... [2]

19 A uniform spherical planet of mass 1.3×10^{22} kg and radius 1.2×10^{6} m has a uniform spherical moon with half the radius of the planet. Both the planet and its moon have the same density.

(a) Show that the mass of the moon is 1.6×10^{21} kg.

[1]

(b) Define *gravitational field strength*.

....

.... [1]

(c) Determine the magnitudes of the gravitational field strengths g_p and g_m on the surfaces of the planet and its moon respectively.

g_p = ... N kg^{-1} [1]

g_m = ... N kg^{-1} [1]

(d) The distance between the centres of the planet and its moon is 2.0×10^7 m.

(i) Determine the distance d from the centre of the planet and along the straight line joining both centres to the point where the resultant gravitational field strength g is zero.

d = ... m [2]

(ii) On the axes in Fig. 19.1, sketch the variation with distance of the resultant gravitational field strength g from the surface of the planet to the surface of its moon, along the straight line joining their centres.

Label the axes with appropriate values.

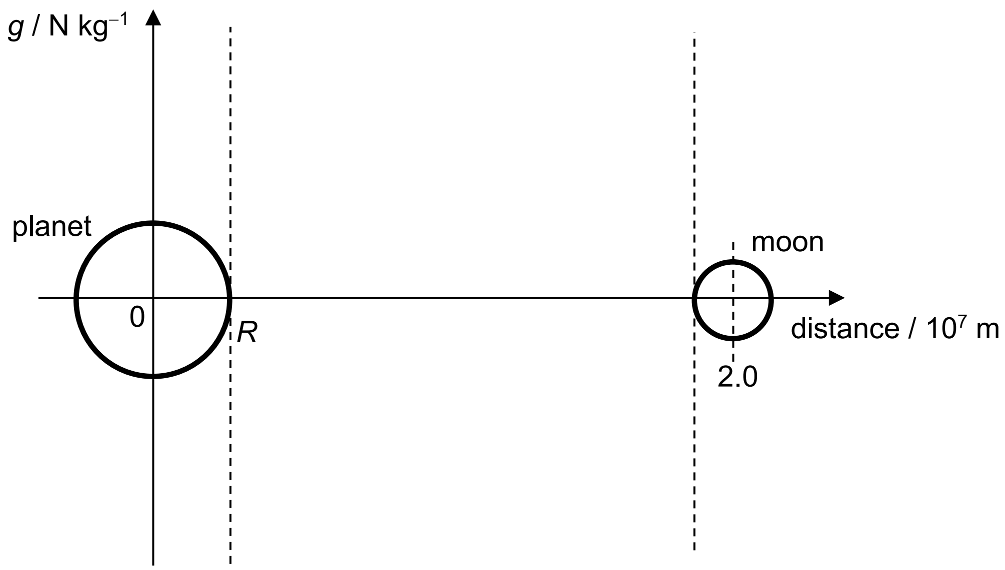


Fig. 19.1 [3]

(iii) A piece of rock of mass *m* is to be launched from the surface of the planet such that it will land on the surface of its moon.

Explain how your graph in Fig.19.1, if accurately drawn, may be used to determine the minimum amount of energy required to launch the rock.

....

....

....

.... [2]

20 A block moving with an initial speed of 2.0 m s^{-1} on a horizontal smooth surface collides with a horizontal spring, as shown in Fig. 20.1.

Fig. 20.1

The mass of the block is 0.50 kg, and the force constant of the spring is 50 N m^{-1}.

(a) Determine the maximum compression of the spring.

maximum compression = ... m [2]

(b) **(i)** Determine the time taken for the block to move from the point of contact to the point of maximum compression of the spring.

time = ... s [3]

(ii) Determine the magnitude of the acceleration of the block at the point of maximum compression of the spring.

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

(c) Take the initial point of contact between the block and the spring as zero displacement, and direction towards the left as positive.

(i) On the axes of Fig. 20.2, sketch the variation with displacement x of the velocity v of the block, from the moment of contact to the moment of maximum compression of the spring. Label the axes with appropriate values.

[2]

(ii) On the axes of Fig. 20.3, sketch the variation with displacement x of the acceleration a of the block, from the point of contact to the point of maximum compression of the spring. Label the axes with appropriate values.

[1]

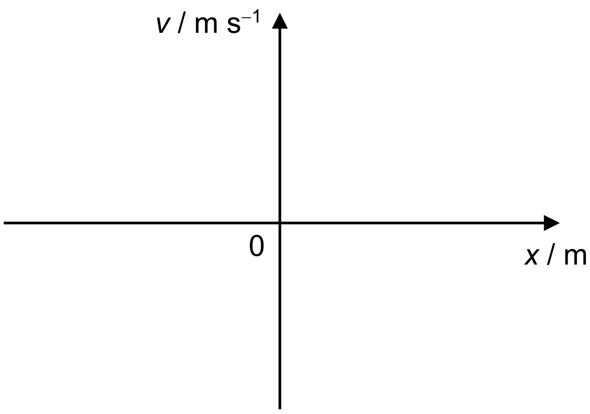


Fig. 20.2

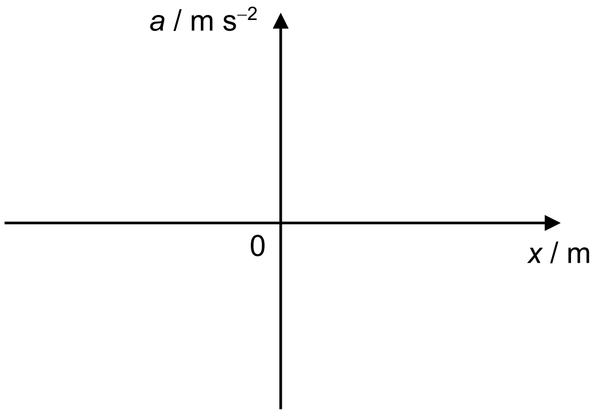


Fig. 20.3

Name: ________________________ (   ) CT Group: 23S0 ______

RAFFLES INSTITUTION

2022 YEAR 5 PROMOTION EXAMINATION

30 September 2022

H2 PHYSICS

Section C

INSTRUCTIONS TO CANDIDATES

Write your name, index number and CT Group.

Write your answers to Section C in the spaces provided in this booklet.

For Examiner's Use		
Section C	21	/ 15
	22	/ 15

There are **10** printed pages, inclusive of the cover page, in this booklet

21 (a) In an experiment to demonstrate the double-slit interference pattern, parallel light of wavelength 589.0 nm from a sodium lamp is incident on a pair of slits S_1 and S_2 each of width 0.150 mm and separated by 0.450 mm. The interference pattern is observed at a screen located 2.000 m away from the slits as illustrated in Fig. 21.1.

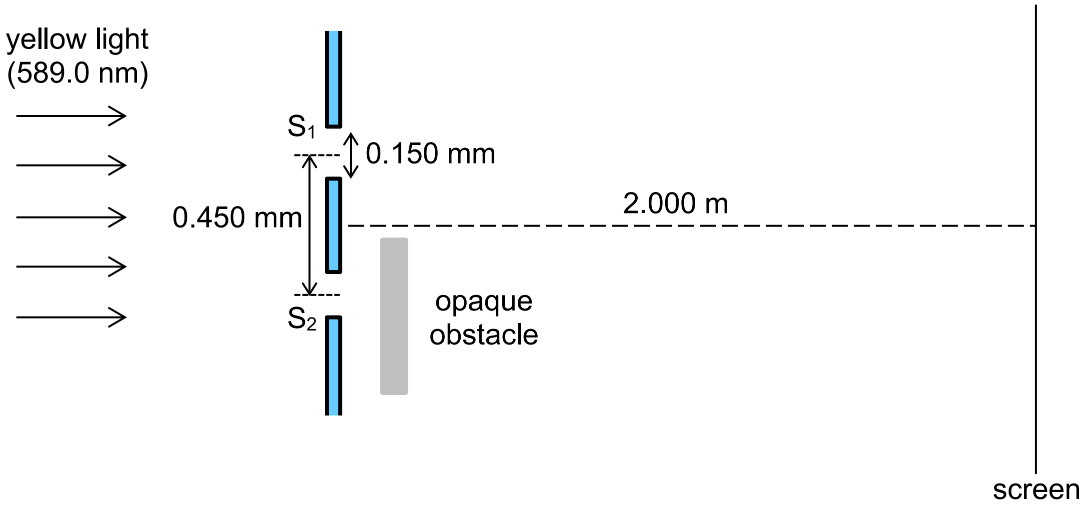


Fig. 21.1 (not to scale)

At the start of the experiment, an opaque obstacle was carefully positioned in front of the double-slit system such that only the light passing through S_1 is incident on the screen.

Determine the distance of the first minimum from the centre of the central bright fringe.

distance = ... m [3]

(b) The opaque obstacle is now removed so that an interference pattern is observed.

(i) Determine the separation between two neighbouring fringes of the interference pattern.

fringe separation = ... m [2]

(ii) On Fig. 21.2, sketch the variation with distance x from the centre of the interference pattern of the intensity observed on the screen up to the fourth order maxima on both sides of the centre.

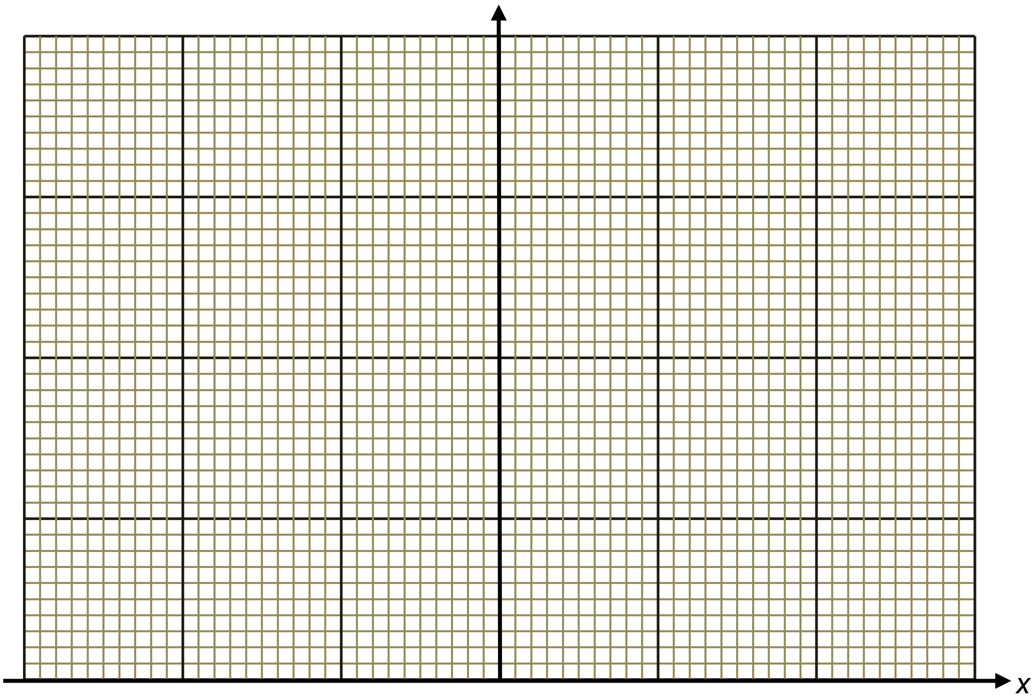


Fig. 21.2 [2]

(c) Fig. 21.3 shows the individual waveforms from slit S_1 and slit S_2 at a point P between the zeroth order and the first order maxima of the interference pattern.

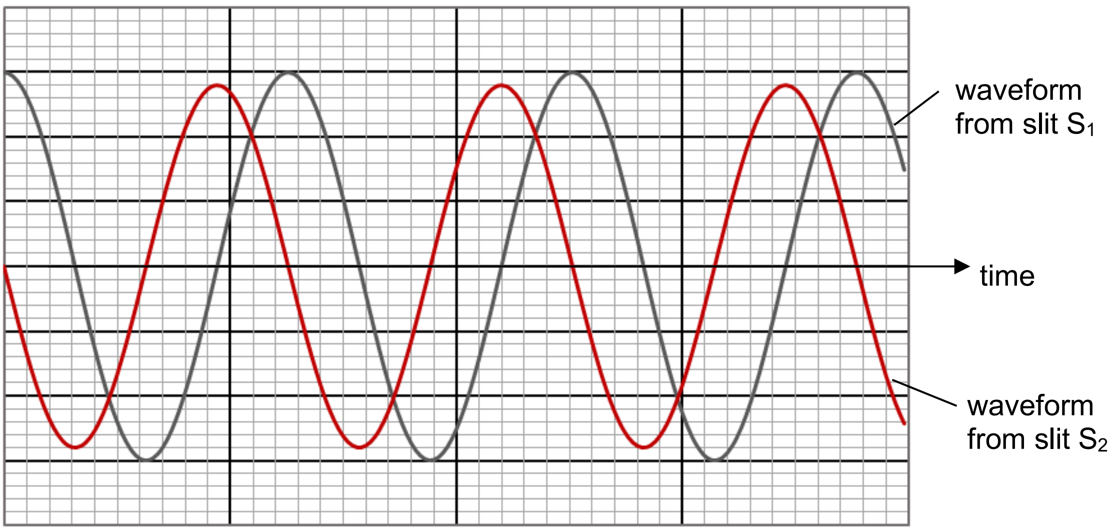


Fig. 21.3

(i) Using Fig. 21.3,

1. state the phase difference between the waves at point P.

phase difference = ... rad [1]

2. determine the ratio

$$\frac{\text{intensity of wave from } S_1}{\text{intensity of wave from } S_2}$$

at point P.

ratio = ... [2]

(ii) On the horizontal axis of Fig. 21.2 mark the approximate position of point P. Label it with the letter "P".

[1]

(d) The yellow light from the sodium lamp consists of a second wavelength of 589.6 nm. To show the presence of this wavelength, the double slit of Fig. 21.1 is replaced by a diffraction grating of 500 lines per mm.

(i) Calculate the angular separation in radians of the second order maxima for the two wavelengths 589.0 nm and 589.6 nm.

angular separation = ... rad [2]

(ii) The maxima are viewed using a telescope with an objective lens of diameter D. The telescope is placed *very near* to the diffraction grating as shown in Fig. 21.4.

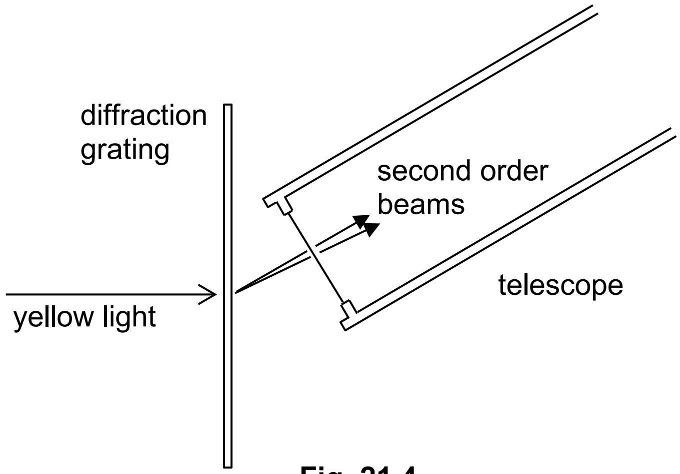


Fig. 21.4

Use the Rayleigh criterion to find the approximate value of D such that the two maxima are just resolved.

D = ... m [2]

22 Read the passage below and answer the questions that follow.

Solar energy has been widely used around the world as a greener form of energy. The following passages show how it is used in three different applications:

1. floating solar farm,
2. domestic usage of solar energy and
3. solar powered aircraft.

(a) In Singapore, the Republic took one big step towards environmental sustainability when its first large-scale floating solar photovoltaic (PV) system at Tengeh Reservoir - about the size of 45 football fields - was officially opened on 14 July 2021.

Fig. 22.1 shows part of the floating solar farm.

Fig. 22.1

The idea of building a floating solar farm came up a decade ago when Singapore was looking for ways to harness solar energy on a large scale. In 2016, national water agency PUB and the Economic Development Board launched a test bed at Tengeh Reservoir, which showed that a floating solar farm was feasible and did not affect surrounding wildlife or water quality. The energy generated goes into the national electricity grid, providing energy for the various sectors in the country. As dirt on the solar panels can reduce operational efficiency, they are tilted at a slight angle to allow rainwater to wash the dirt off.

PV cells are made of light-sensitive semiconductor materials. There are two broad categories of technology used for PV cells, namely crystalline silicon and thin film, which is a newer technology that is growing in popularity.

An important differentiator in solar PV performance, especially in hot climates, is the temperature coefficient of power. PV cell performance declines as cell temperature rises. For example, in bright sunlight, cell temperatures in Singapore can reach over 70 °C, whereas PV cells are rated at a cell temperature of 25 °C. The percentage loss in power output at 70 °C is therefore measured as $(70 - 25) \times$ temperature coefficient.

Most PV cells using thin film technologies have a lower negative temperature coefficient compared to those using crystalline silicon technologies. In other words, they tend to lose less of their rated capacity as temperature rises.

Fig. 22.2 shows the temperature coefficient of the two PV cell technologies.

Technology	**Temperature Coefficient (% / °C)**
Crystalline silicon	– 0.50
Thin film	– 0.25

Fig. 22.2

The output of a PV cell is measured relative to that of a cell at Standard Test Conditions (STC) at the temperature of 25 °C. Fig. 22.3 shows the variation with temperature of the relative output of a PV cell using crystalline silicon technology.

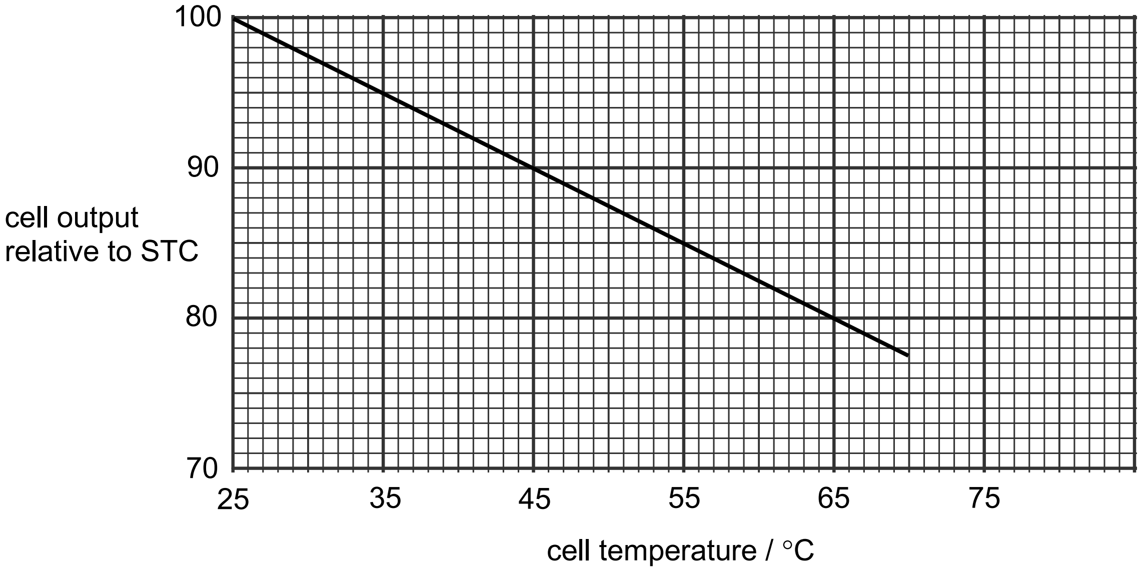


Fig. 22.3

(i) State why the solar panels are tilted at a slight angle.

....

.... [1]

(ii) Calculate the percentage power loss of the thin film PV cells when the cell temperature reaches 70 °C.

power loss = ... % [1]

(iii) Hence, sketch in Fig. 22.3, the graph to show the variation of the output of the thin film PV cells with temperature.

[1]

(b) In the United Kingdom (UK), domestic PV cell systems convert sunlight into electricity which can be used in the home.

Fig. 22.4 shows the power generated P from two identical PV cell systems over various hours of the day. The two systems are placed at an angle of 35° to the horizontal such that one system is East facing and the other is South facing.

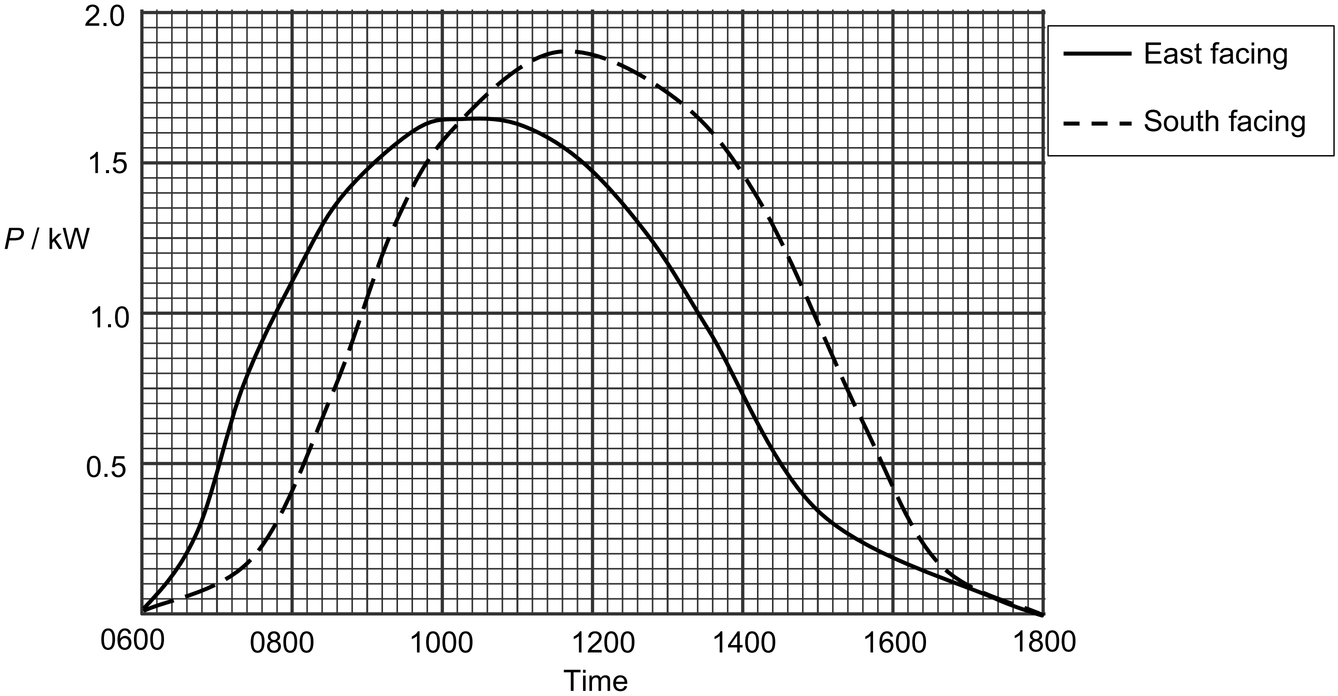


Fig. 22.4

(i) With reference to Fig. 22.4, estimate the amount of energy in joules generated in one day by the East facing solar system.

energy = ... J [3]

(ii) Sketch on Fig. 22.4, a curve to represent a West facing solar system. [1]

(iii) State and explain a factor that can affect the performance of a PV cell system on the roof of buildings in the UK.

....

.... [1]

(c) In Switzerland, a privately financed project, Solar Impulse (Fig. 22.5), led by a Swiss engineer aims to achieve the first circumnavigation of the Earth by a piloted fixed-wing aircraft using only solar power. Solar Impulse has a mass of 2300 kg. The cruising altitude (height above sea-level) of Solar Impulse is 8500 m, and it can attain a maximum altitude of 12000 m. At night-time, the altitude decreases to 1500 m to save energy.

Fig. 22.5

Gliding occurs when the engines of an aircraft are not in use. It is possible to find a *glide ratio* for airborne bodies. This is the ratio of the distance the body travels horizontally to its vertical drop when gliding. The glide ratio is also the lift to drag ratio (the ratio of the vertically upward force on the aircraft to the resistive force on the aircraft) for an aircraft in horizontal flight at constant speed. For the Solar Impulse, the value of the glide ratio is 40.

The electrical energy from the PV cells is stored in Lithium-ion batteries and the batteries supply power to the electric motors. The batteries have an energy density of 0.260 kWh kg^{-1}. The amount of energy the PV cells capture depends upon many variables including geographic location (angle of latitude), time of day, time of year, altitude and the weather.

(i) Use the concept of glide ratio to calculate the horizontal distance travelled by Solar Impulse when gliding from cruising altitude to night-time altitude.

distance = ... m [1]

(ii) Deduce the drag force acting on Solar Impulse whilst in horizontal flight at constant speed.

drag force = ... N [2]

(iii) Use the unit kWh kg^{-1} to deduce what is meant by the phrase *energy density*.

....

.... [1]

(iv) Fig. 22.6 represents the side view of Solar Impulse moving to the right.

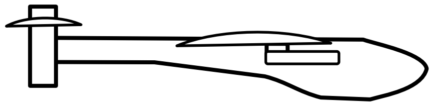


Fig. 22.6

On Fig. 22.6, draw and label arrows to show the forces acting on Solar Impulse when it is in horizontal flight at constant speed.

[2]

(v) Suggest why the energy collected by the PV cells depends on the altitude of the aircraft.

....

.... [1]