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.

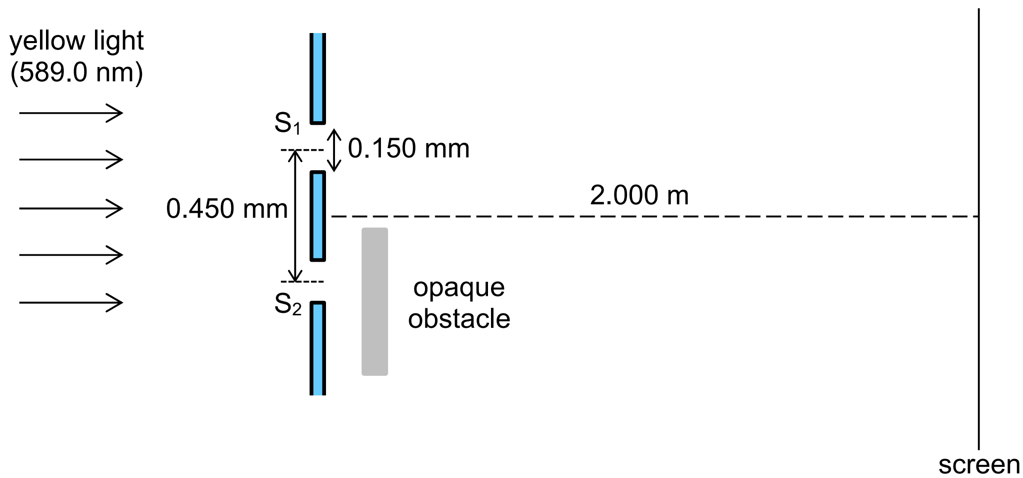

Fig. 21.1 (not to scale)

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.

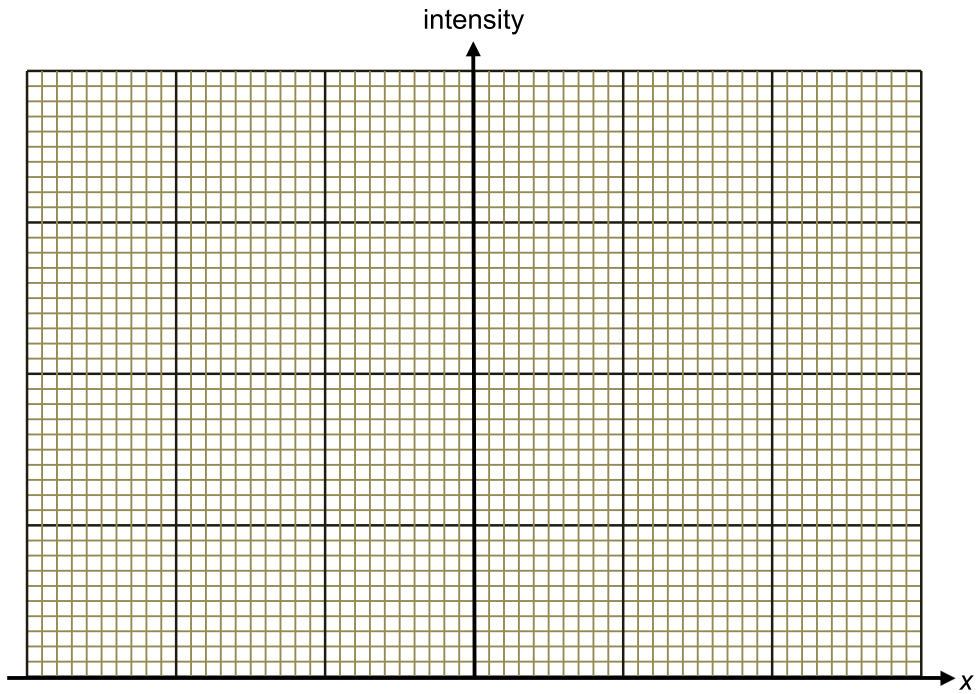

Fig. 21.2 [2]

(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.

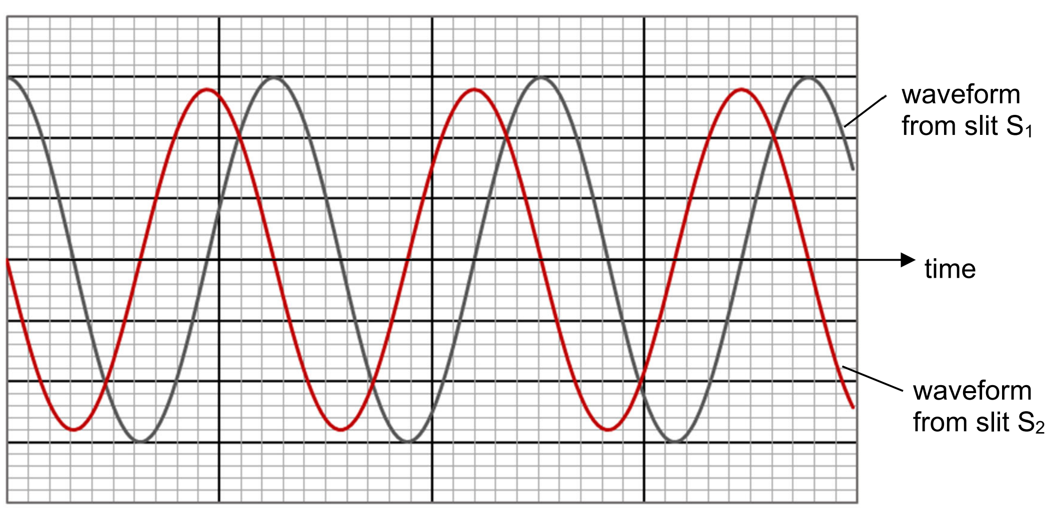

Fig. 21.3

(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.

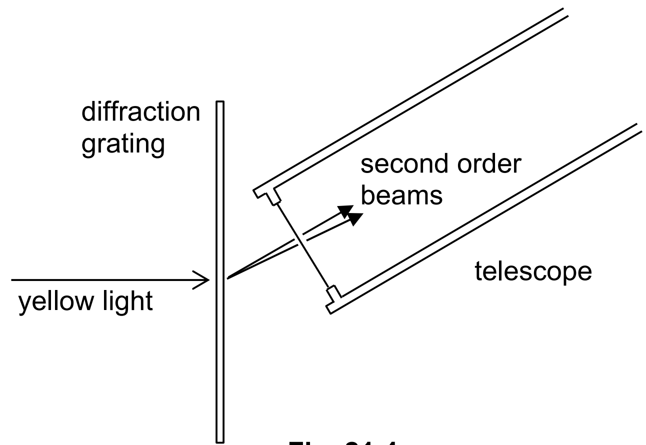

Fig. 21.4

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.

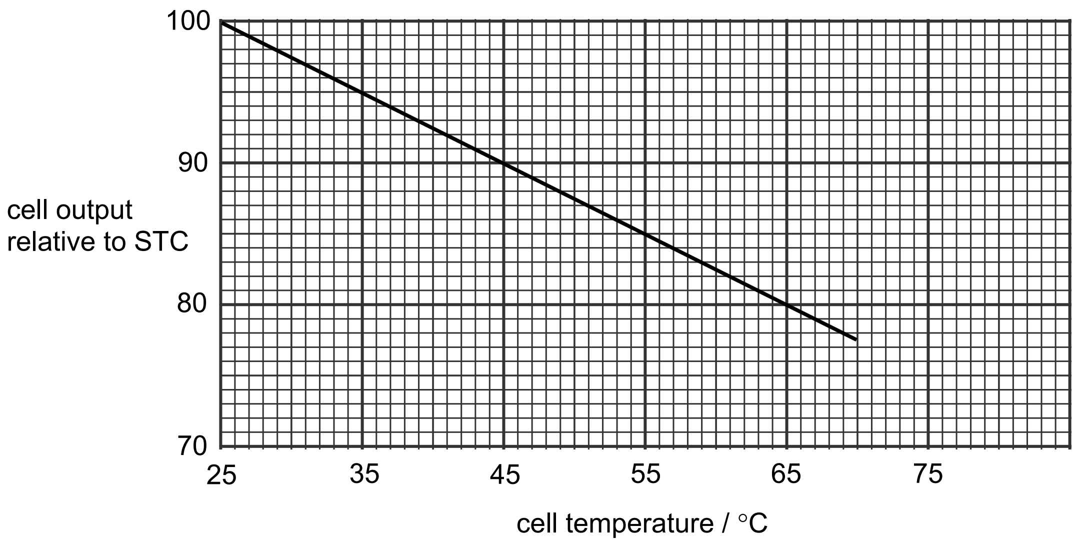

Fig. 22.3

(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.

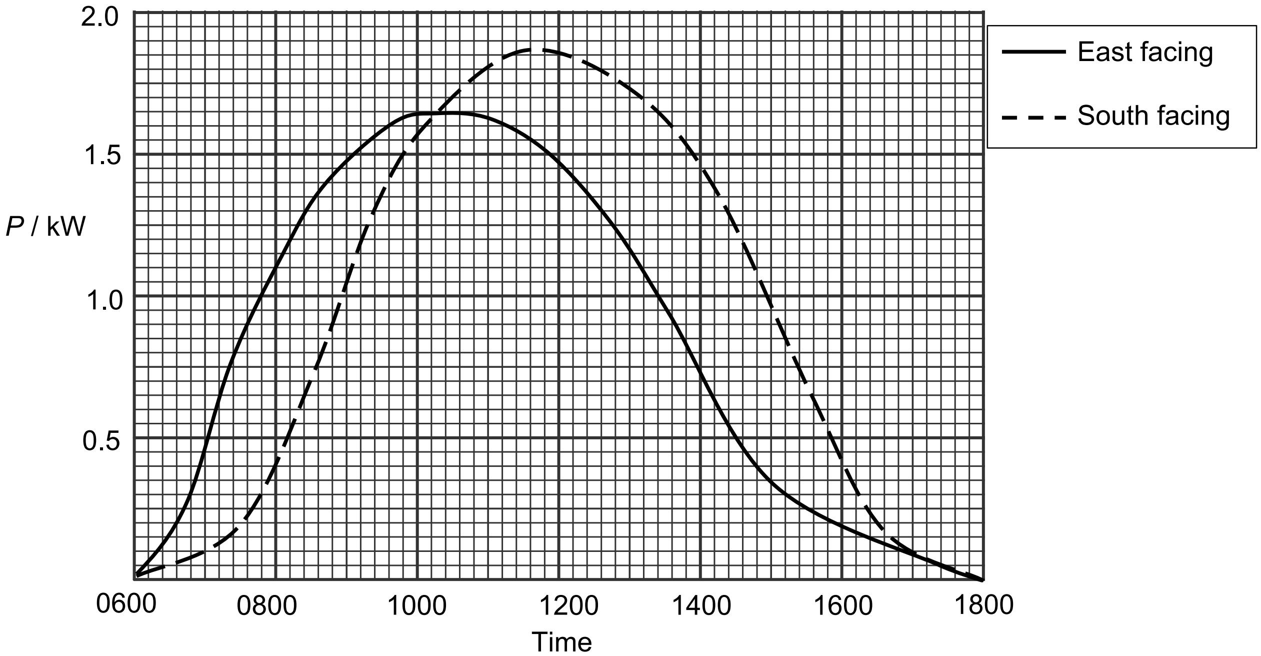

Fig. 22.4

(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.

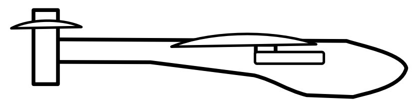

Fig. 22.6

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]