Practice Question Set For A-Level
Subject : Physics
Paper-1 Topic: Waves

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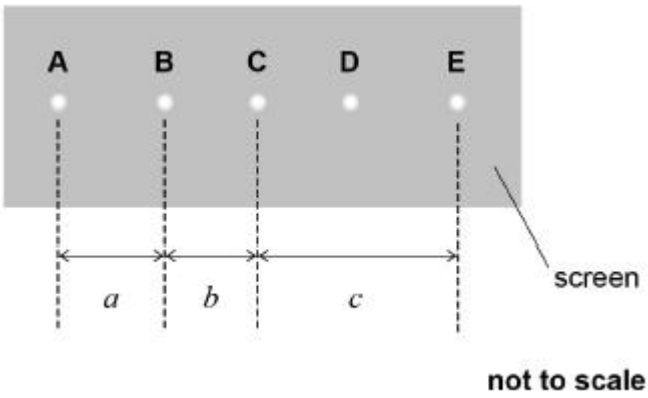
Name of the Student:_____
Max. Marks : 23 Marks **Time : 23 Minutes**

Q1.

This question is about the measurement of the wavelength of laser light.
The light is shone onto a diffraction grating at normal incidence.
The light transmitted by the diffraction grating produces five spots on a screen. These spots are labelled **A** to **E** in **Figure 1**.

Figure 1



A student uses a metre ruler with 1 mm divisions to take readings. He uses these readings to obtain measurements a, b and c, the distances between centres of the spots as shown in **Figure 1**.
Table 1 shows his measurements and his estimated uncertainties.

Table 1

Measurement	Distance / mm	Uncertainty / mm
a	289	2
b	255	2
c	544	2

(a) Explain why the student's estimated uncertainty in measurement a is greater than the smallest division on the metre ruler.
You should refer to the readings taken by the student in obtaining this measurement.

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(2)

(b) The distance between the centres of spots **A** and **C** and the distance between the centres of spots **C** and **E** are equal.
That is:

$$a + b = c$$

Calculate the percentage uncertainty in the sum of a and b.

percentage uncertainty = _____

(2)

(c) Discuss why the experimental measurements lead to a different percentage uncertainty in c compared to that in $a + b$.

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(2)

(d) Eye protection should be used to prevent eye damage when using a laser.

Describe **one** other safety measure to minimise the risk of eye damage when using a laser in the laboratory.

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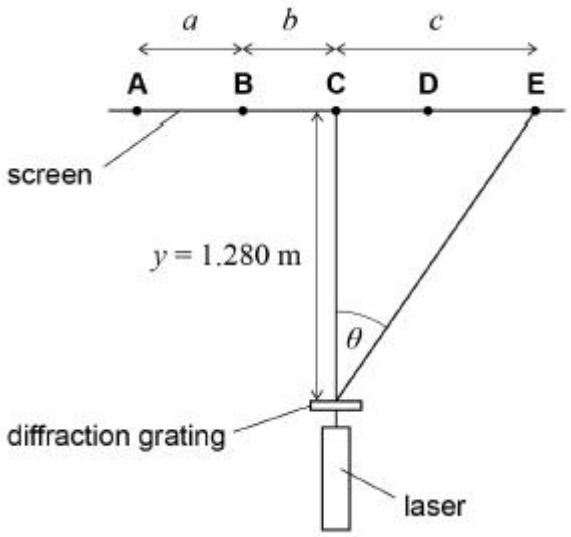
(1)

(e) **Figure 2** shows the experimental arrangement with y, the perpendicular distance between the diffraction grating and the screen, equal to 1.280 m.
Table 2 shows some of the data from **Table 1**.

Table 2

Measurement	Distance / mm
a	289
b	255
c	544

Figure 2



Calculate the angle θ shown on **Figure 2**.

θ = _____ degrees

(1)

(f) Spot **E** is the second-order maximum.
The diffraction grating has 3.00×10^5 lines per metre.

Calculate the wavelength of the laser light.

wavelength = _____ m

(1)

(g) The student plans to repeat the experiment using the same diffraction grating and laser.

State and explain **one** way the student can change the experimental arrangement to reduce the percentage uncertainty in the measurement of the wavelength.

Assume the percentage uncertainty in sin θ is the sum of the percentage uncertainties in y and c.

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(2)

(Total 12 marks)

Q2.

This question is about two applications of photon energy and momentum: positron emission tomography (PET) and a solar sail.

$$\text{The momentum of a photon is } \frac{\text{photon energy}}{\text{speed of light in a vacuum}}$$

(a) In preparing for a PET scan of a patient's brain, a small sample of a substance containing unstable nuclei is injected into the patient.
A positron is emitted when one of the unstable nuclei undergoes β^+decay.

Explain how the change in quark character in β^+decay affects the number of neutrons and the number of protons in the unstable nucleus.

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(2)

(b) The positron interacts with an electron, resulting in annihilation. As a result, gamma photons are produced.
The energy of each gamma photon is 0.52 MeV.

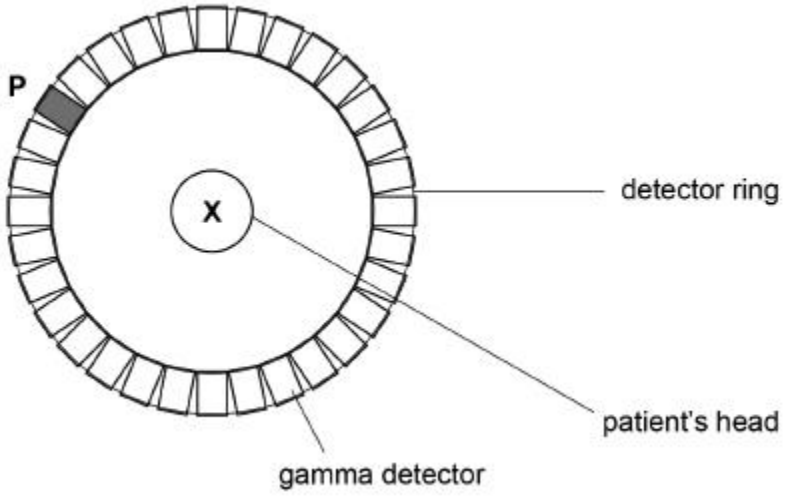
Calculate the momentum, in N s, of one of the gamma photons produced in this annihilation.

momentum = _____ N s

(2)

(c) **Figure 1** shows a cross-sectional view of the patient's head inside a ring of gamma detectors during the PET scan.

Figure 1



A positron and an electron meet and annihilate at position **X** shown in **Figure 1**.
Assume they have negligible kinetic energy when they meet.

Gamma photons are produced in this annihilation and are detected. The arrival of one gamma photon at detector **P** triggers a signal. Detector **P** has been shaded in **Figure 1**.

Identify by shading any other detectors that will be triggered by this annihilation.

(1)

(d) Explain your answer to question **(c)**.

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(2)

(e) **Figure 2** shows a stream of photons of light, emitted from the Sun, incident on a solar sail. A solar sail is an experimental spacecraft that uses photons of light to accelerate it.

Figure 2

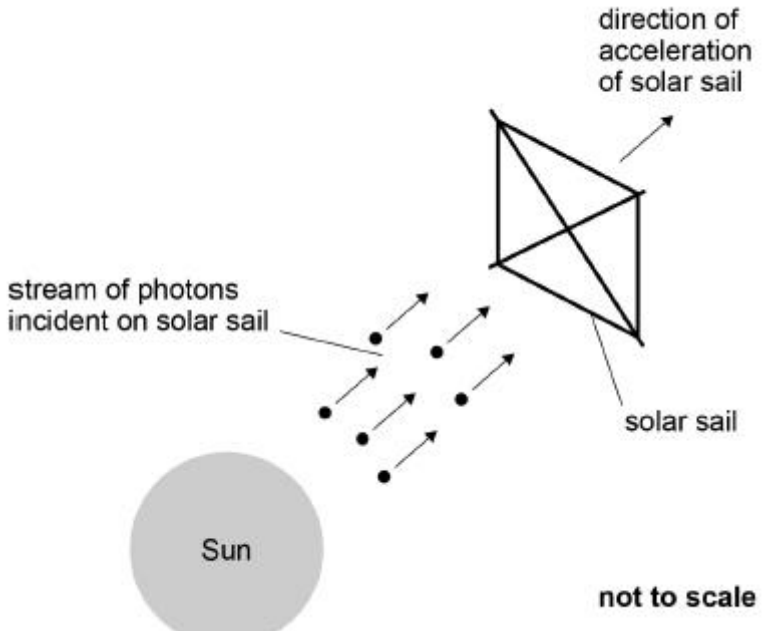
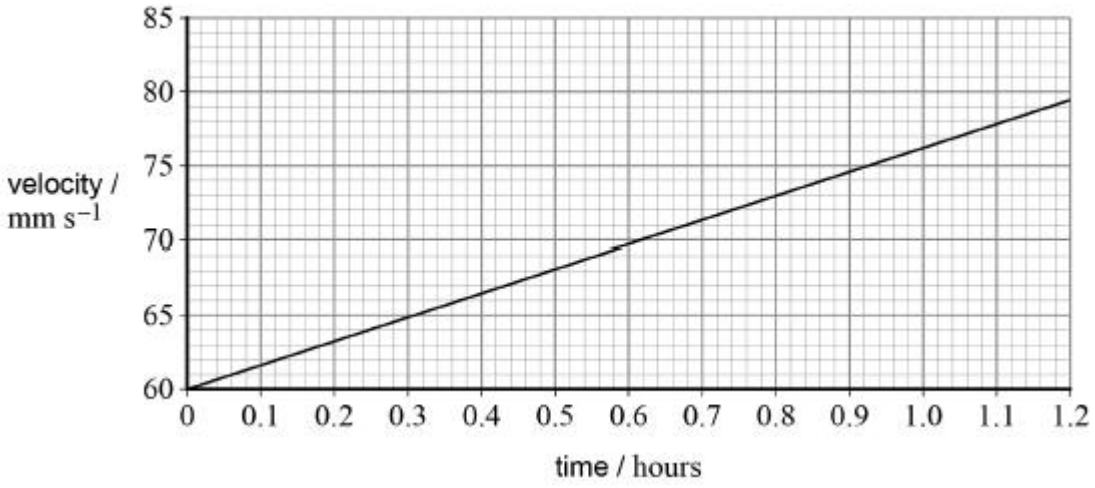


Figure 3 shows the velocity–time graph for the solar sail.

Figure 3



Calculate the acceleration, in m s^{-2}, of the solar sail.

acceleration = _____ m s^{-2}

(2)

(f) The reflectance of a surface is proportional to the percentage of incident photons that are reflected off the surface.

Explain the effect of increasing the reflectance of the solar sail on the acceleration. Assume gravity has negligible effect on the solar sail.

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(2)

(Total 11 marks)