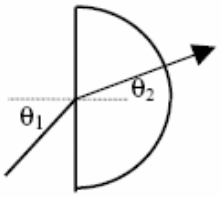
RADIATION AND MATTER

22. Two students are studying the refraction of monochromatic light. A ray of monochromatic light enters a semicircular glass block at the midpoint of its straight side, as shown in the diagram below.



The students use a protractor to measure a range of values for θ_1 and θ_2.
The measurements are given in the table below.

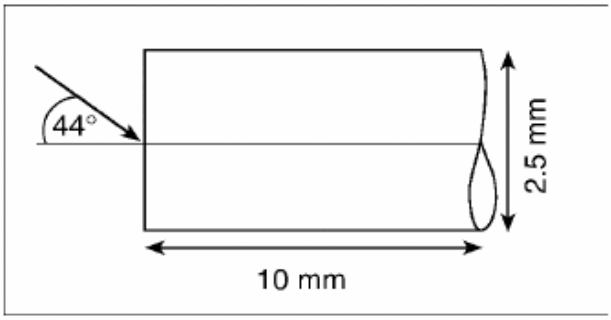
θ_1 / degrees	30	40	50	60	70
θ_2 / degrees	19	24	30	34	37

(a) Use **all** the measurements to obtain a mean value for the refractive index n of the glass. Express your answer in the form: n = value ± uncertainty. You must show how you obtained the uncertainty. 5

(b) State one way in which this experiment could be improved to obtain a more accurate estimate of the refractive index. 1

(6)

23. A green ray of light of frequency 600 THz enters an optical fibre at an angle of 44° to the axis of the fibre as shown below.
The refractive index of the optical fibre for green light is 1.4.



(a) Calculate the angle that the refracted ray makes with the axis of the fibre. 2

(b) Calculate the speed of the light in the fibre. 2

(c) Calculate the wavelength of the light in the fibre. 2

(d) Calculate the critical angle of the light in the fibre. 2

(e) Make a scale diagram of the optical fibre (scale 1 mm to 1 cm).
Use the scale diagram to show accurately how the ray of light travels along this 10 mm section of fibre. 2

(10)

24. Monochromatic light of wavelength 500 nm is shone on a grating with 2000 lines/cm. The light diffracts to give a maximum intensity at an angle θ to the normal from the grating.

(a) What colour of light is being used? 1

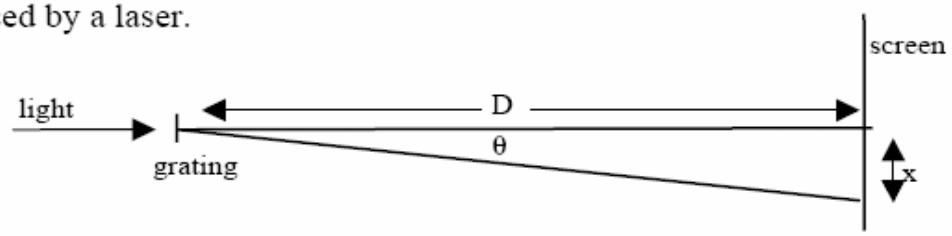
(b) What is the distance between the lines on the grating? 1

(c) Calculate the angle θ for the second maximum of interference produced. 2

(d) What effect would each of the following have on the angle θ ?
(i) decreasing the frequency of the light.
(ii) using light of a shorter wavelength
(iii) increasing the brightness of the light
(iv) widening the grating spacing. 4

(8)

25. A grating is used in an experiment to measure the wavelength of the light produced by a laser.



The grating used has 2500 lines per cm with a manufacturer's claim of an uncertainty of ±0.5%.
The distance D from the grating to the screen is measured as (2.37 ± 0.01) m.
The distance x from the central spot to the first maximum of intensity is measured to be (38 ± 1) cm.

(a) Calculate the grating spacing d. 1

(b) Tabulate measurements of d, x and D together with their percentage uncertainties. 2

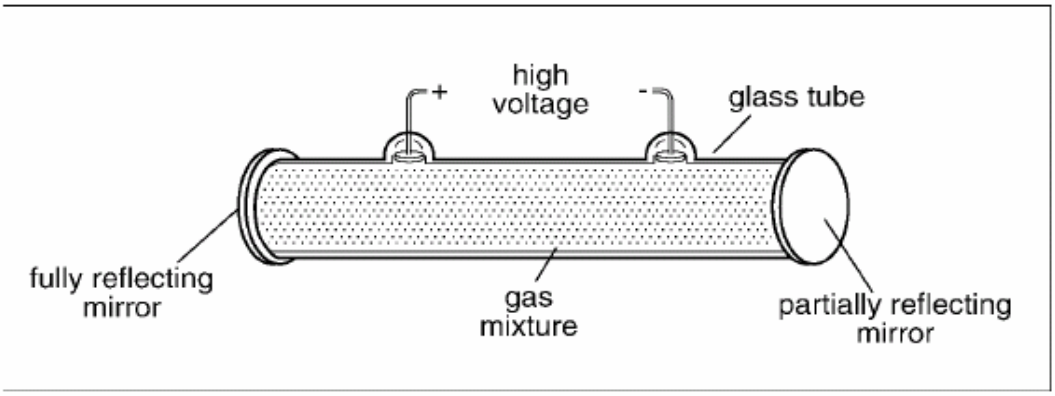
(c) Calculate a value for the angle θ. 1

(d) Determine a value in metres for the wavelength λ of the laser light used. Express your answer as λ = value ± uncertainty. 3

(e) State one way of improving the accuracy of the experiment. You must explain how this improvement affects the uncertainty in the measured value for λ. 2

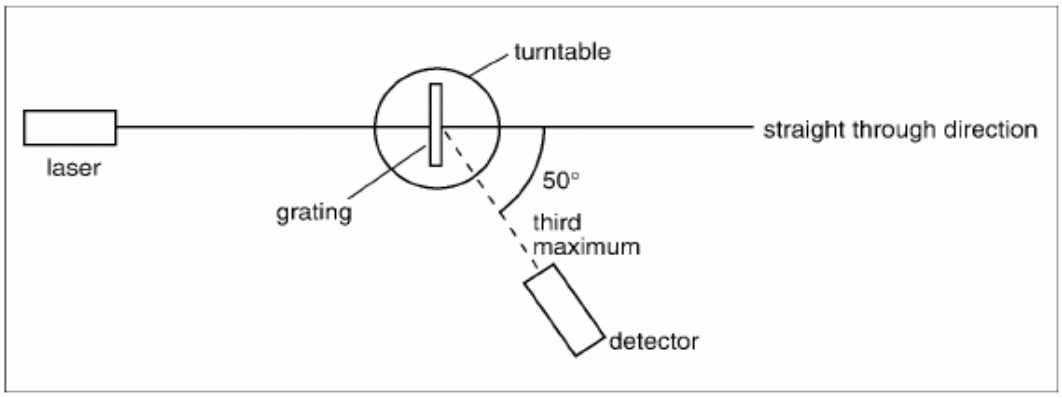
(9)

26. (a) The diagram below shows a simplified view of a laser tube that is used in a gas laser.



(i) Explain the purpose of each mirror in the laser tube.
(ii) The beam of light from the laser tube is very intense. Give **two** reasons for this. 4

(b) Light from a laser is directed at a grating as shown below.



The grating has 400 000 lines per metre.
The third maximum is detected at an angle of 50° as shown.
Calculate the wavelength of the laser light. 3
(7)

27. Sodium has a threshold frequency of 440 THz. A 2 cm x 4 cm surface of clean sodium is illuminated with radiation of frequency 600 THz. 6×10^8 photons are incident every second on the sodium surface.

(a) Calculate the energy of each incident photon of radiation. 2

(b) Determine the power provided by the radiation at the sodium surface. 2

(c) Calculate the intensity of the radiation at the surface of the sodium. 2

(d) Calculate the maximum kinetic energy of an electron released from the sodium surface. 2
(8)

28. (a) In describing photoelectric emission the following terms *photoelectron* and *work function* are used. Explain the meaning of the terms *photoelectron* and *work function*. 2

(b) A source of monochromatic radiation has a power of 30 W. The source emits radiation of frequency 6.0×10^{14} Hz.

(i) Calculate the energy of one photon of the radiation emitted by the source.

(ii) How many photons are emitted by the source in one second? 4

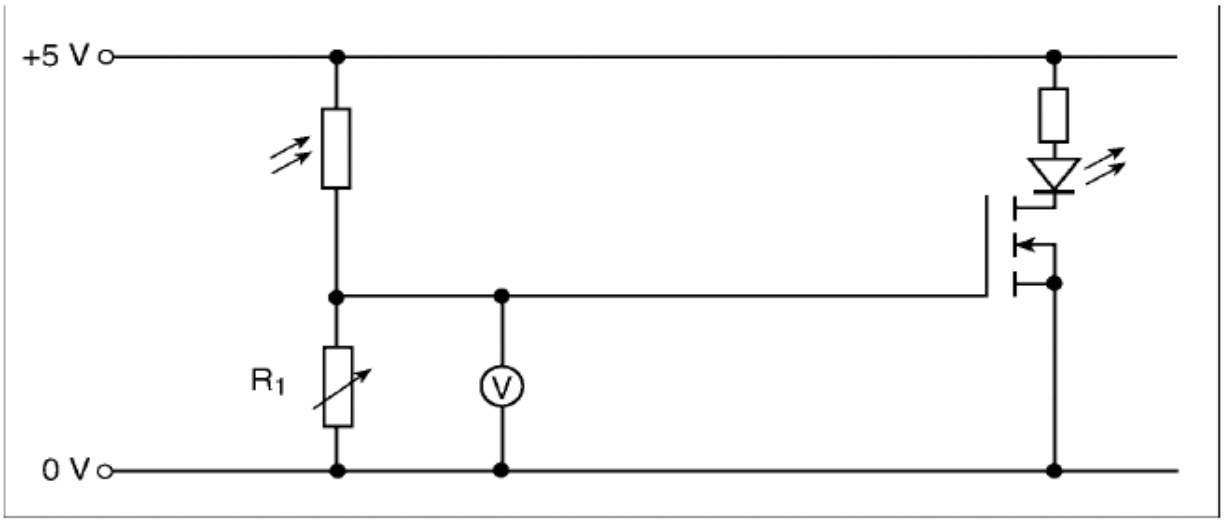
(c) The power of the source is reduced to 10 W.

(i) Explain the effect that this will have on the energy of an emitted photon.

(ii) What effect does reducing the power have on the number of photons emitted in one second. 2

(8)

29. A student designs the circuit shown below so that the LED will come on when the light intensity at the LDR rises to a certain value.



(a) (i) When the LDR is in darkness R_1 is set to a value of 10 kΩ and the reading on the voltmeter is 0.40 V.
Calculate the resistance of the LDR in darkness.

(ii) As the light intensity increases the reading on the voltmeter increases. When the light intensity reaches a certain value the LED comes on. Explain how the action of the n-channel enhancement MOSFET enables the LED to produce light. 4

(b) When the LED is lit it emits light of wavelength 510 nm.

(i) What is the colour of the light emitted by the LED?

(ii) Calculate the energy of one photon of radiation emitted by the LED. 4

(8)

30. Nuclear reactions can involve the release of energy.

(a) When plutonium $^{239}_{94}\text{Pu}$ captures a fast neutron, tellurium $^{137}_{x}\text{Te}$ and molybdenum $^{y}_{42}\text{Mo}$ and 3 neutrons are produced. Energy is released. The following statement represents this reaction.

$$^{239}_{94}\text{Pu} + {}^{1}_{0}\text{n} \rightarrow {}^{137}_{x}\text{Te} + {}^{y}_{42}\text{Mo} + 3 \text{ neutrons} + \text{energy}$$

(i) Determine the values of x and y in the above statement.

(ii) What is the name given to this type of nuclear reaction ?

(iii) Explain how energy is produced in this nuclear reaction. 4

(b) A nuclear reaction which occurs in the Sun produces helium $^{4}_{2}\text{He}$. The reaction is represented by the statement below.

$$^{3}_{1}\text{H} + {}^{2}_{1}\text{H} \rightarrow {}^{4}_{2}\text{He} + {}^{1}_{0}\text{n}$$

(i) What is the name given to this type of nuclear reaction?

(ii) The symbols $^{3}_{1}\text{H}$ and $^{2}_{1}\text{H}$ both represent hydrogen nuclei. What is the name given to two such nuclei which have the same atomic number?

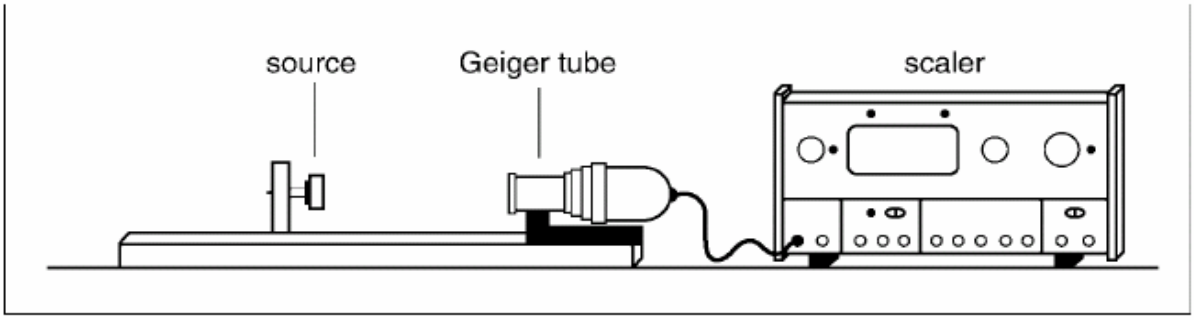
(iii) The masses of the nuclei involved in the nuclear reaction are given below.

nuclei	$^{3}_{1}\text{H}$	$^{2}_{1}\text{H}$	$^{4}_{2}\text{He}$	$^{1}_{0}\text{n}$
mass of nuclei / kg	5.004×10^{-27}	3.342×10^{-27}	6.642×10^{-27}	1.675×10^{-27}

Calculate the energy released when one nucleus of helium $^{4}_{2}\text{He}$ is formed. 5

(9)

31. A Geiger-Müller tube is connected to a scaler in order to measure the background count rate. This is measured to be 31 counts per minute (cpm). The Geiger-Müller tube is placed at different distances from a small source of gamma radiation as shown below.



The following results are obtained for the total count rate at various distances from the gamma ray source.

Distance from source / cm	5	10	15	20
Total count rate / cpm	1671	443	213	134
Corrected count rate / cpm				

(a) (i) Copy the above table. Complete the table, giving the corrected count rate at each distance from the source.

(ii) Use **all** the data from your completed table to establish the relationship between the corrected count rate and distance from the gamma ray source. 4

(b) The gamma ray source is to be used in an experiment to study the movement of mud in a model of a river estuary. A physicist involved in the experiment handles the source with very long tongs. In addition the experiment is completed as quickly as possible after removing the source from its container. The physicist does this to minimise the dose equivalent received from the gamma source.

(i) State **two** factors that affect the risk of biological harm from an exposure to radiation.

(ii) Explain how the action taken by the physicist causes the dose equivalent received to be as small as possible. 4

(8)