H

Exam Question Practice

Section 2 — Extended Answer Questions for UNIT 2 -ELECTRICTY

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Speed of light in vacuum	c	$3 \cdot 00 \times 10^{8}$ m s^{-1}	Planck's constant	h	$6 \cdot 63 \times 10^{-34}$ J s
Magnitude of the charge on an electron	e	$1 \cdot 60 \times 10^{-19}$ C	Mass of electron	m_e	$9 \cdot 11 \times 10^{-31}$ kg
Universal Constant of Gravitation	G	$6 \cdot 67 \times 10^{-11}$ m^3 kg^{-1} s^{-2}	Mass of neutron	m_n	$1 \cdot 675 \times 10^{-27}$ kg
Gravitational acceleration on Earth	g	$9 \cdot 8$ m s^{-2}	Mass of proton	m_p	$1 \cdot 673 \times 10^{-27}$ kg
Hubble's constant	H_0	$2 \cdot 3 \times 10^{-18}$ s^{-1}			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	*Refractive index*	*Substance*	*Refractive index*
Diamond	2·42	Water	1·33
Crown glass	1·50	Air	1·00

SPECTRAL LINES

Element	*Wavelength*/nm	*Colour*
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	*Wavelength*/nm	*Colour*
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

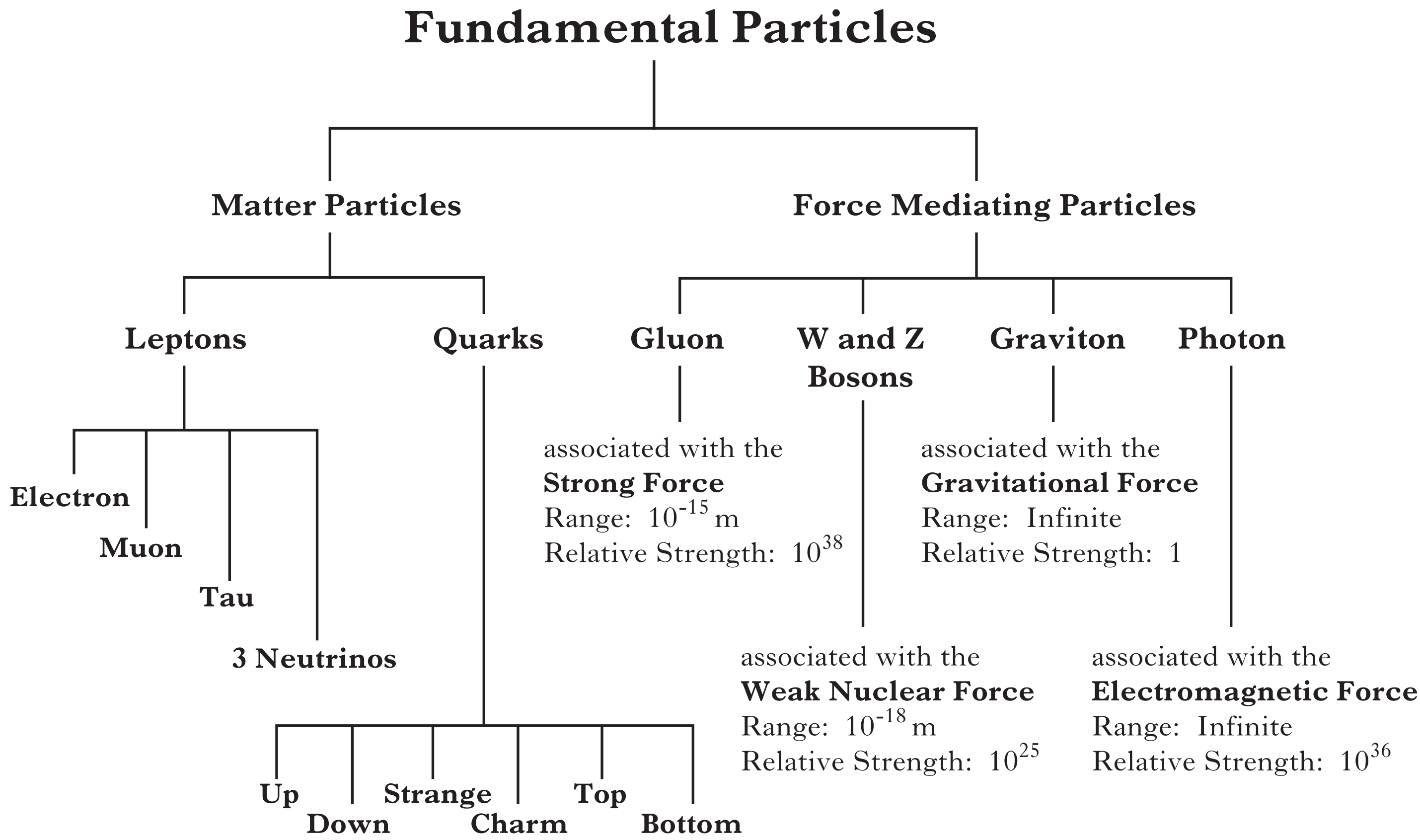
Element	*Wavelength*/nm	*Colour*
Carbon dioxide	9550, 10590	Infrared
Helium-neon	633	Red

PROPERTIES OF SELECTED MATERIALS

Substance	*Density*/kg m^{-3}	*Melting Point*/K	*Boiling Point*/K
Aluminium	$2 \cdot 70 \times 10^{3}$	933	2623
Copper	$8 \cdot 96 \times 10^{3}$	1357	2853
Ice	$9 \cdot 20 \times 10^{2}$	273	. . . .
Sea Water	$1 \cdot 02 \times 10^{3}$	264	377
Water	$1 \cdot 00 \times 10^{3}$	273	373
Air	1·29	. . . .	. . . .
Hydrogen	$9 \cdot 0 \times 10^{-2}$	14	20

The gas densities refer to a temperature of 273 K and a pressure of $1 \cdot 01 \times 10^{5}$ Pa.

26. The following diagram gives information on the Standard Model of Fundamental Particles and Interactions.



Marks

Use information from the diagram and your knowledge of physics to answer the following questions.

(*a*) Explain why particles such as leptons and quarks are known as *Fundamental Particles*. **1**

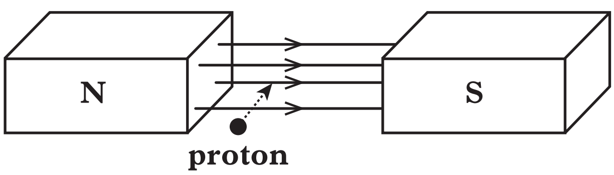
(*b*) A particle called the sigma plus (Σ^+) has a charge of +1. It contains two different types of quark. It has two up quarks each having a charge of $+^2/_3$ and one strange quark.

What is the charge on the strange quark? **1**

(*c*) Explain why the gluon cannot be the force mediating particle for the gravitational force. **1**

(*d*) In the Large Hadron Collider (LHC) beams of hadrons travel in opposite directions inside a circular accelerator and then collide. The accelerating particles are guided around the collider using strong magnetic fields.

(i) The diagram shows a proton entering a magnetic field.



In which direction is this proton deflected? **1**

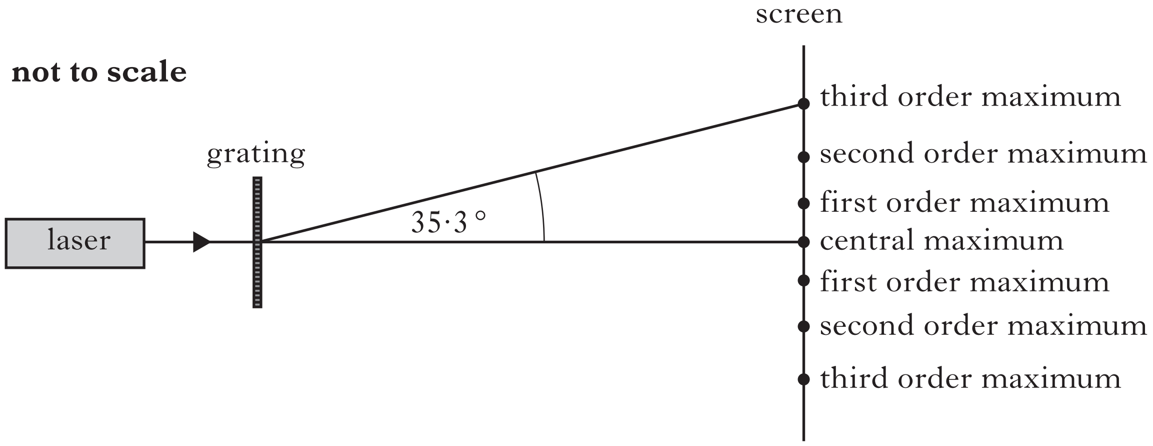
(ii) The neutron is classified as a hadron.

Explain why neutrons are **not** used for collision experiments in the LHC. **1**

(5)

Marks

27. A manufacturer claims that a grating consists of $3{\cdot}00 \times 10^5$ lines per metre and is accurate to $\pm$ 2·0%. A technician decides to test this claim. She directs laser light of wavelength 633 nm onto the grating.



She measures the angle between the central maximum and the third order maximum to be 35·3°.

(*a*) Calculate the value she obtains for the slit separation for this grating. **2**

(*b*) What value does she determine for the number of lines per metre for this grating? **1**

(*c*) Does the technician's value for the number of lines per metre agree with the manufacturer's claim of $3{\cdot}00 \times 10^5$ lines per metre $\pm$ 2·0%?

You must justify your answer by calculation. **2**

(5)

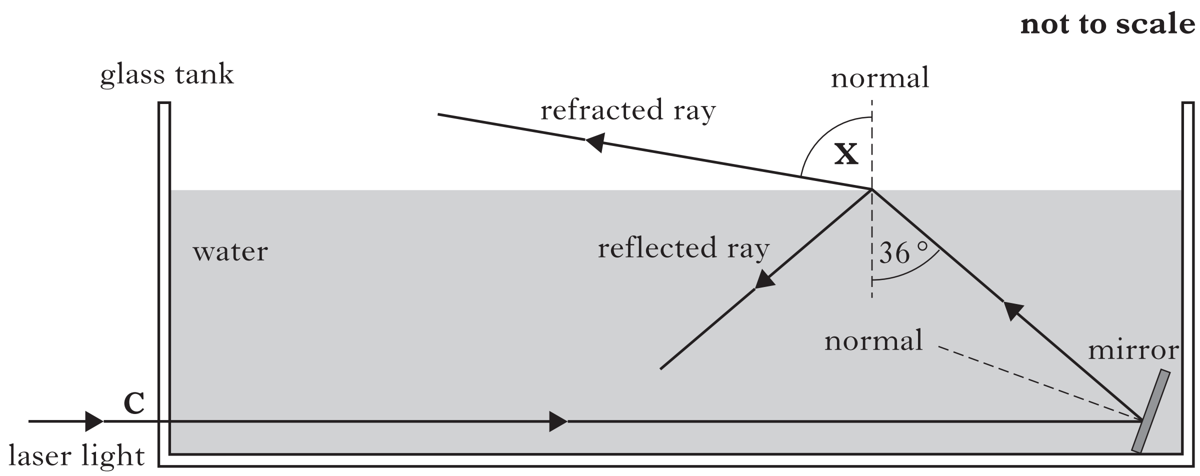
28. One of the most important debates in scientific history asked the question:

"Is light a wave or a particle?"

Use your knowledge of physics to comment on our understanding of this issue. **(3)**

Marks

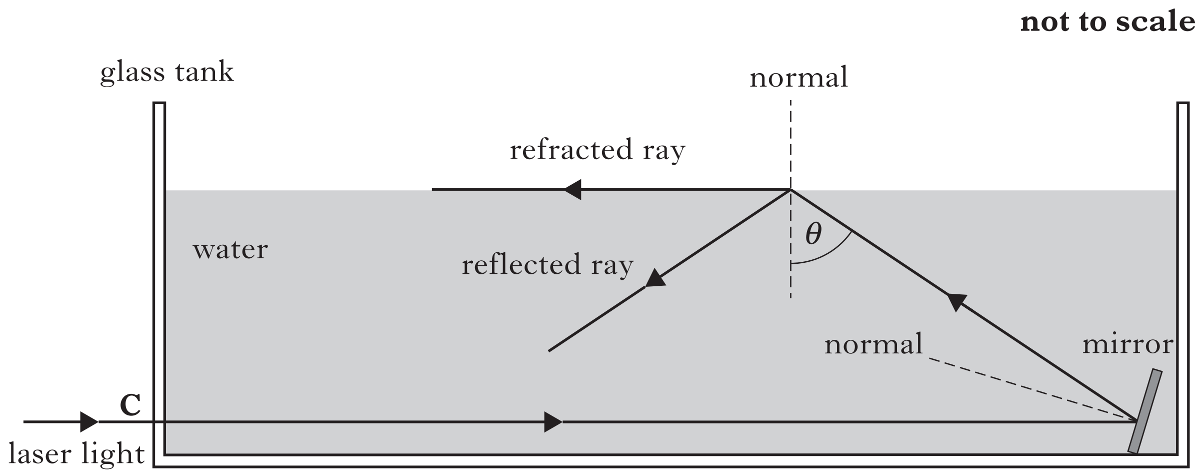
29. A technician investigates the path of laser light as it passes through a glass tank filled with water. The light enters the glass tank along the normal at **C** then reflects off a mirror submerged in the water.



The refractive index of water for this laser light is 1·33.

(*a*) Calculate angle **X**. **2**

(*b*) The mirror is now adjusted until the light follows the paths shown.



(i) State why the value of θ is equal to the critical angle for this laser light in water. **1**

(ii) Calculate angle θ. **2**

(*c*) The water is now replaced with a liquid which has a greater refractive index. The mirror is kept at the same angle as in part (*b*) and the incident ray again enters the tank along the normal at **C.**

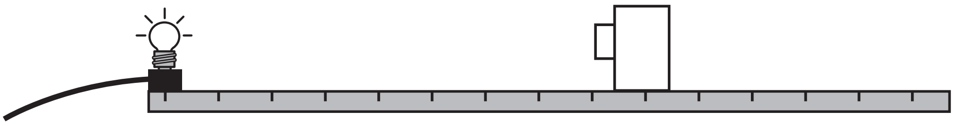
Draw a sketch which shows the path of the light ray after it has reflected off the mirror.

Your sketch should only show what happens at the surface of the liquid. **1**

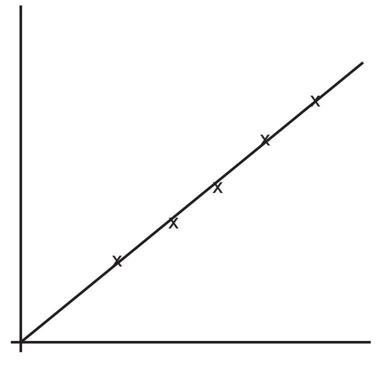
(6)

30. A student investigates how irradiance I varies with distance d from a small lamp.

The following apparatus is set up in a darkened laboratory.



The results are used to produce the following graph.



(*a*) Explain why this graph confirms the relationship $I = \dfrac{k}{d^2}$ **1**

(*b*) The irradiance of light from the lamp at a distance of 1·6 m is 4·0 W m^{-2}.

Calculate the irradiance of the light at a distance of 0·40 m from the lamp. **2**

(*c*) The experiment is repeated with the laboratory lights switched on.

Copy the graph shown and, on the same axes, draw another line to show the results of the second experiment. **1**

(4)

Marks

25. (*a*) Experimental work at CERN has been described as "*recreating the conditions that occurred just after the Big Bang*".

Describe what scientists mean by the *Big Bang theory* and give **one** piece of evidence which supports this theory. **2**

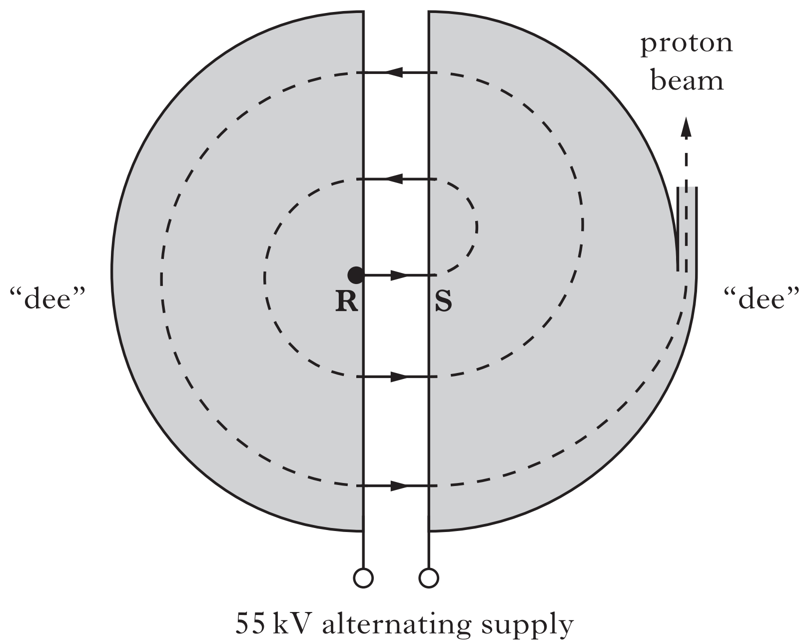
(*b*) During a television programme the presenter states, "*Looking through a telescope at the night sky is like looking back in time*".

Use physics principles to comment on this statement. **3**

(5)

26. A cyclotron is used in a hospital to accelerate protons that are then targeted to kill cancer cells.

The cyclotron consists of two D-shaped, hollow metal structures called "dees", placed in a vacuum. The diagram shows the cyclotron viewed from above.



Protons are released from rest at **R** and are accelerated across the gap between the "dees" by a voltage of 55 kV.

(*a*) (i) Show that the work done on a proton as it accelerates from **R** to **S** is $8 \cdot 8 \times 10^{-15}$ J. **1**

(ii) Calculate the speed of a proton as it reaches **S**. **2**

(*b*) Inside the "dees" a uniform magnetic field acts on the protons.

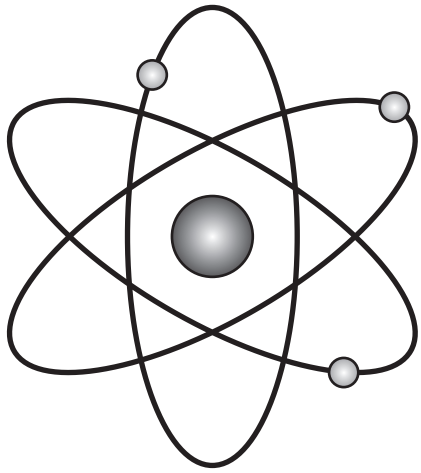
Determine the direction of this magnetic field. **1**

(*c*) Explain why an alternating voltage is used in the cyclotron. **2**

(6)

Marks

27. A science textbook contains the following diagram of an atom.

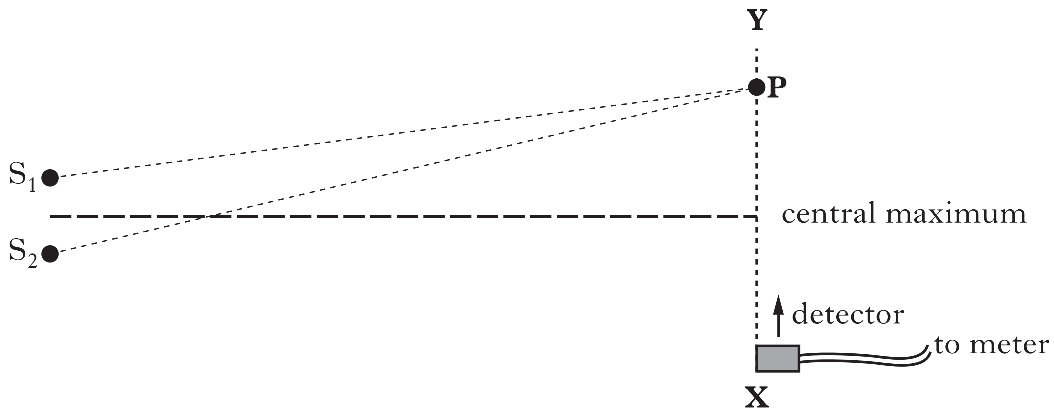


Use your knowledge of physics to comment on this diagram. **(3)**

Marks

28. A student is using different types of electromagnetic radiation to investigate interference.

(*a*) In the first experiment, two identical sources of microwaves, S_1 and S_2, are positioned a short distance apart as shown.



(i) The student moves a microwave detector from X towards Y. The reading on the meter increases and decreases regularly.

Explain, in terms of waves, what causes the minimum readings to occur. **1**

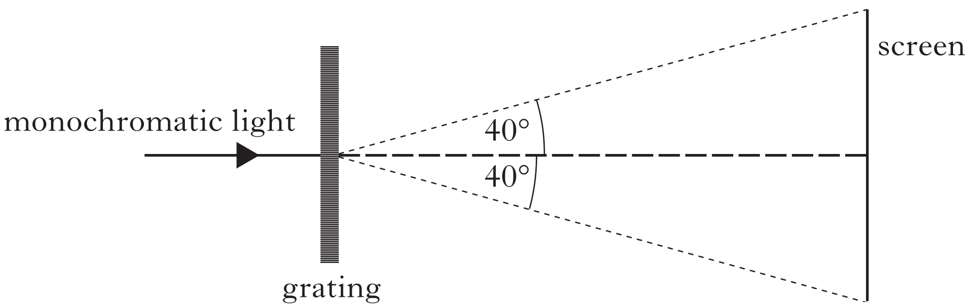
(ii) The **third** maximum from the central maximum is located at P.

The distance from S_1 to P is 620 mm.

The wavelength of the waves is 28 mm.

Calculate the distance from S_2 to P. **2**

(*b*) (i) In the second experiment, a beam of parallel, monochromatic light is incident on a grating. An interference pattern is produced on a screen. The edges of the screen are at an angle of 40° to the centre of the grating as shown.



The wavelength of the light is 420 nm and the separation of the slits on the grating is $3{\cdot}27 \times 10^{-6}$ m.

Determine the total number of maxima visible on the screen. **3**

(ii) The experiment is now repeated using a source of monochromatic red light.

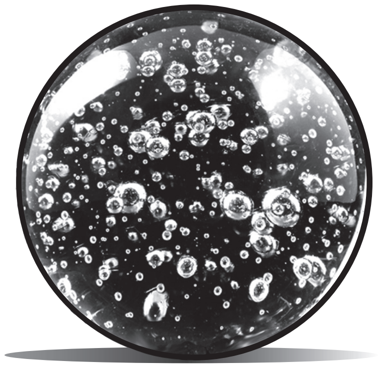
How does the total number of maxima visible on the screen compare to the answer to part (*b*)(i)?

Justify your answer. **2**

(8)

Marks

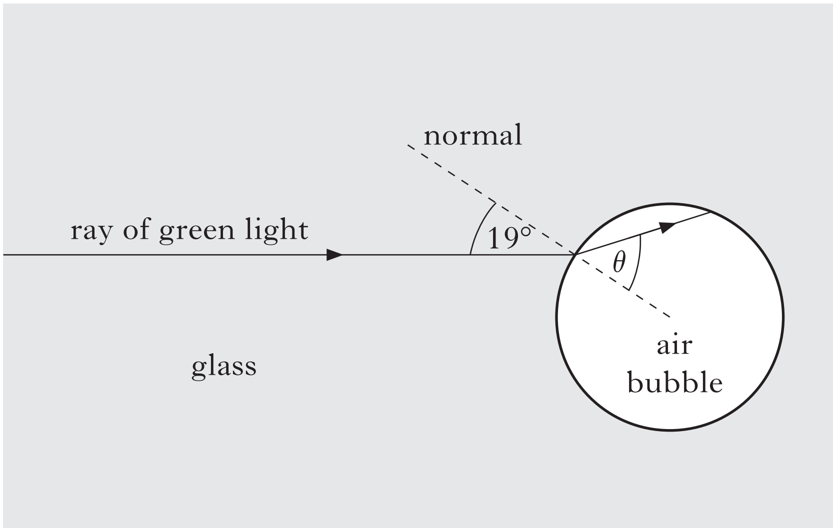
29. A student places a glass paperweight containing air bubbles on a sheet of white paper.



The student notices that when white light passes through the paperweight, a pattern of spectra is produced.

The student decides to study this effect in more detail by carrying out an experiment in the laboratory.

A ray of green light follows the path shown as it enters an air bubble inside glass.



not to scale

The refractive index of the glass for this light is 1·49.

(*a*) Calculate the angle of refraction, θ, inside the air bubble. **2**

(*b*) Calculate the maximum angle of incidence at which a ray of green light can enter the air bubble. **2**

(*c*) The student now replaces the ray of green light with a ray of white light.

Explain why a spectrum is produced. **1**

(5)

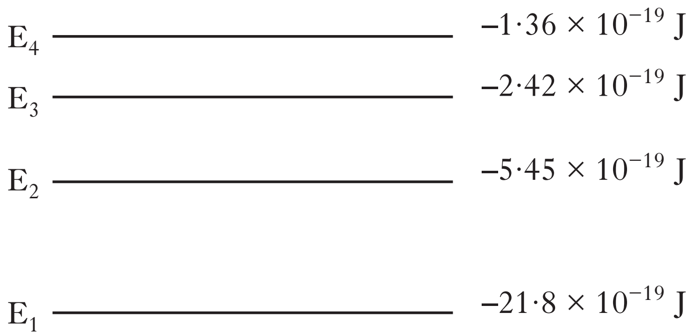
Marks

25. A binary star is a star system consisting of two stars orbiting around each other.

One of the techniques astronomers use to detect binary stars is to examine the spectrum of light emitted by the stars. In particular they look for the changes in wavelength of a specific spectral line, called the hydrogen alpha line, over a period of time.

Accurate measurements of the wavelength of the hydrogen alpha line on Earth have determined it to be 656·28 nm.

(*a*) The following diagram shows some of the energy levels for the hydrogen atom.



Radiation is emitted when electrons make transitions from higher to lower energy levels.

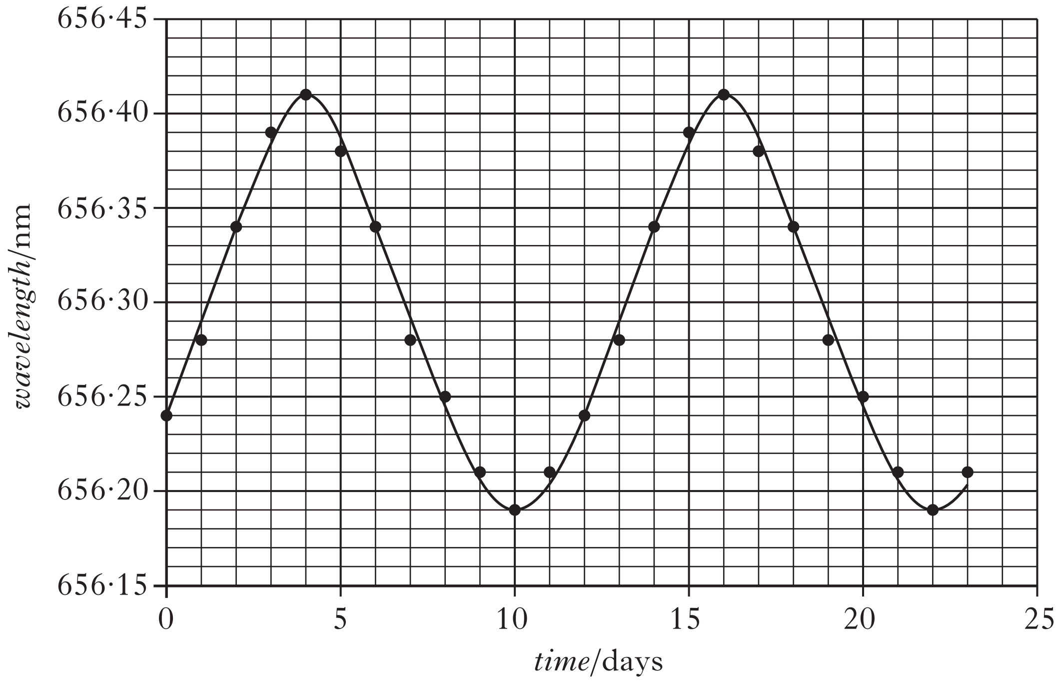
Which transition, between these energy levels, produces the hydrogen alpha line?

Justify your answer by calculation. **3**

Marks

25. (continued)

(*b*) The graph shows how the wavelength of the hydrogen alpha line for one of the stars in a binary pair varies with time, as observed on Earth.



Using information from the graph:

(i) determine the period of orbit of this star; **1**

(ii) calculate the maximum recessional velocity of the star; **3**

(iii) explain how the maximum approach velocity of the star compares to its maximum recessional velocity. **2**

(9)

Marks

26. Physicists study subatomic particles using particle accelerators.

(*a*) Pions are subatomic particles made up of two quarks.

There are three types of pion:

π^+ particles which have a charge of +1;
π^- particles which have a charge of −1;
and π^0 particles which have a zero charge.

The π^+ particle is made up of an up quark and an anti-down quark.

(i) Is a pion classed as a baryon or a meson?

Justify your answer. **1**

(ii) The charge on an up quark is $+\frac{2}{3}$.

Determine the charge on an anti-down quark. **1**

(iii) The π^- particle is the antiparticle of the π^+ particle.

State the names of the quarks that make up a π^- particle. **1**

(iv) π^+ particles have a mean lifetime of $2{\cdot}6 \times 10^{-8}$ s in their own frame of reference.

In an experiment in a particle accelerator, π^+ particles are accelerated to a velocity of $0{\cdot}9c$.

Calculate the mean lifetime of these π^+ particles relative to a stationary observer. **2**

(*b*) Explain how particle accelerators, such as the Large Hadron Collider at CERN, are able to:

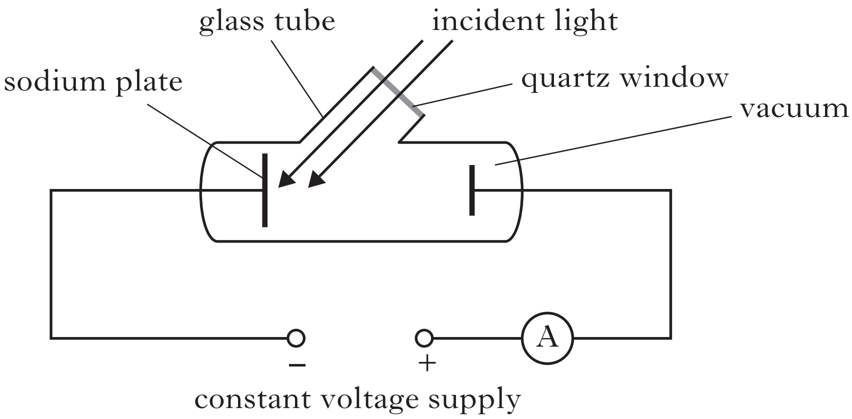
(i) accelerate charged particles; **1**

(ii) deflect charged particles. **1**

(7)

Marks

27. The following apparatus is set up in a physics laboratory to investigate the photoelectric effect.



The work function of sodium is $3{\cdot}78 \times 10^{-19}$ J.

Light of frequency $6{\cdot}74 \times 10^{14}$ Hz is incident on the sodium plate and photoelectrons are emitted.

(*a*) (i) Calculate the maximum kinetic energy of a photoelectron just as it is emitted from the sodium plate. **2**

(ii) Calculate the maximum velocity of a photoelectron just as it is emitted from the sodium plate. **2**

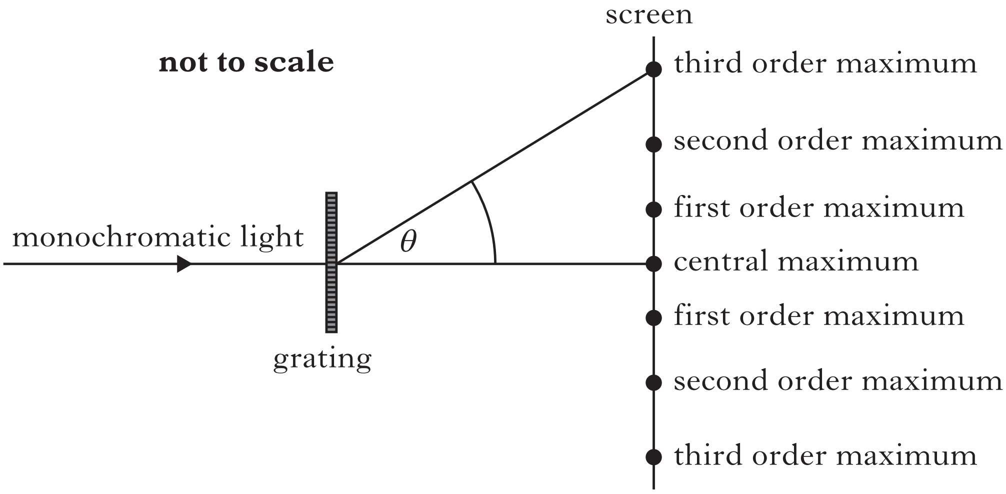
(*b*) The irradiance of this incident light is now decreased.

Explain how this affects the maximum velocity of a photoelectron just as it is emitted from the sodium plate. **2**

(6)

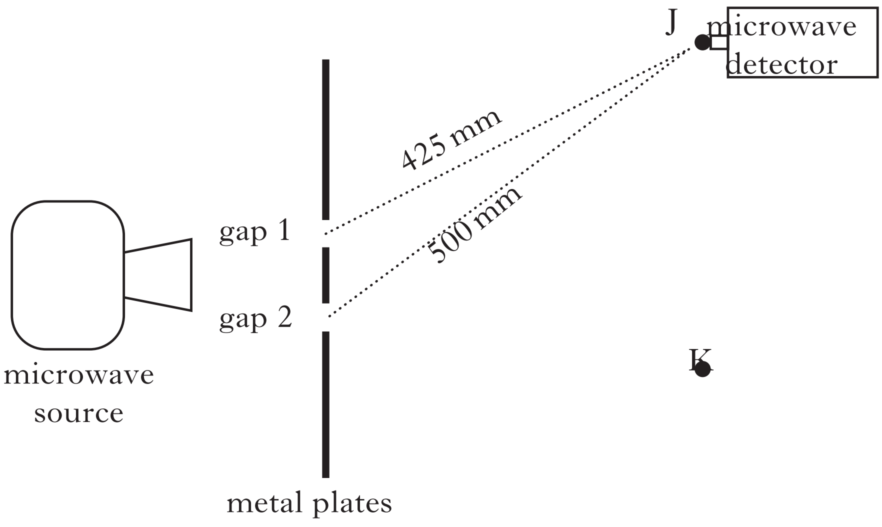
28. Two experiments are carried out to study the interference of waves.

(*a*) In the first experiment, monochromatic light of wavelength 589 nm passes through a grating. The distance between the slits on the grating is $5{\cdot}0 \times 10^{-6}$ m.



Calculate the angle θ between the central maximum and the third order maximum. **2**

(*b*) In the second experiment, microwaves of wavelength 30 mm pass through two gaps between metal plates as shown.



(i) The distances from each of the gaps to point J are shown in the diagram.

Use this information to determine whether J is a point of constructive or destructive interference.

You must justify your answer by calculation. **2**

(ii) The microwave detector is now moved to K, which is a point of destructive interference.

Gap 1 is then covered with a sheet of metal.

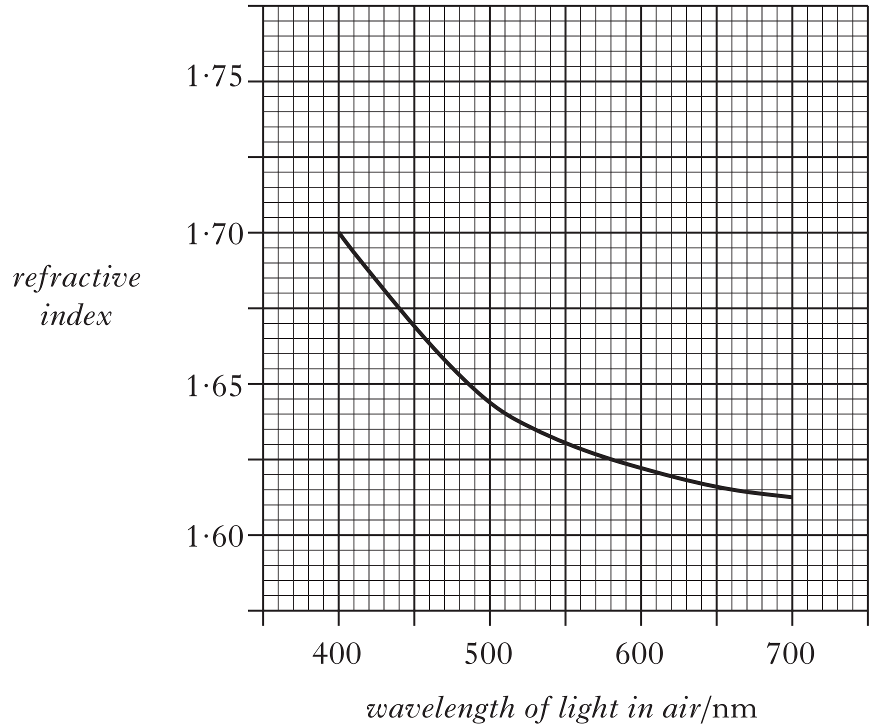
Does the strength of the signal detected at K increase, decrease or stay the same? You must justify your answer. **2**

(6)

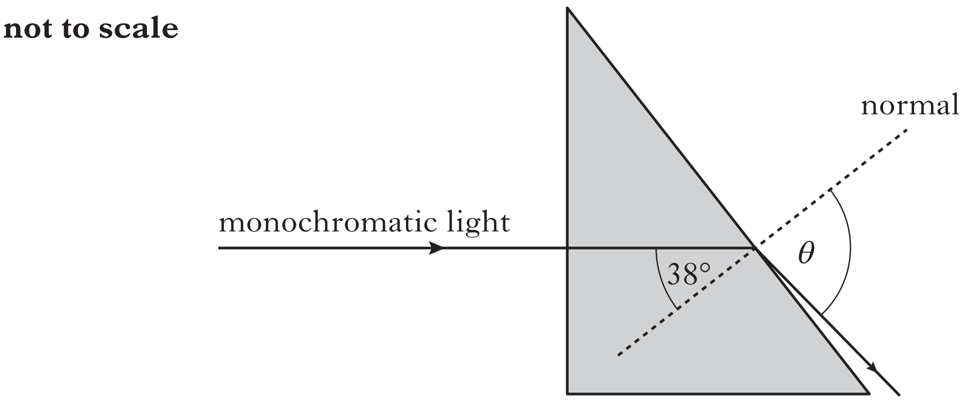
Marks

29. Monochromatic light is shone into a triangular prism of flint glass.

The graph shows how the refractive index of flint glass varies with the wavelength of light in air.



(*a*) A ray of monochromatic light of wavelength 660 nm in air passes through the prism as shown.



Calculate the angle of refraction θ. **2**

(*b*) The ray of light is now replaced with one of shorter wavelength.

Is the speed of this new ray in the prism less than, the same as or greater than the speed of the 660 nm ray in the prism?

Justify your answer. **2**

(4)

MARKS DO NOT WRITE IN THIS MARGIN

5. A quote from a well-known science fiction writer states:

"In the beginning there was nothing, which exploded."

Using your knowledge of physics, comment on the above statement. **3**

MARKS DO NOT WRITE IN THIS MARGIN

6\. (a) The Standard Model classifies *force mediating particles* as bosons. Name the boson associated with the electromagnetic force. **1**

(b) In July 2012 scientists at CERN announced that they had found a particle that behaved in the way that they expected the Higgs boson to behave. Within a year this particle was confirmed to be a Higgs boson.

This Higgs boson had a mass-energy equivalence of 126 GeV.
($1\ \text{eV} = 1{\cdot}6 \times 10^{-19}\ \text{J}$)

(i) Show that the mass of the Higgs boson is $2{\cdot}2 \times 10^{-25}$ kg. **3**

Space for working and answer

(ii) Compare the mass of the Higgs boson with the mass of a proton in terms of orders of magnitude. **2**

Space for working and answer

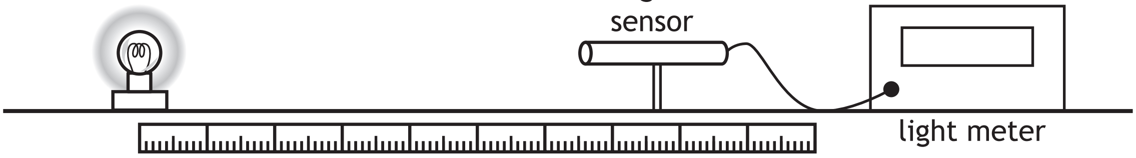
[Turn over

7. The use of analogies from everyday life can help better understanding of physics concepts. Throwing different balls at a coconut shy to dislodge a coconut is an analogy which can help understanding of the photoelectric effect.

Use your knowledge of physics to comment on this analogy. **3**

MARKS | DO NOT WRITE IN THIS MARGIN

8. A student investigates how irradiance I varies with distance d from a point source of light.



The distance between a small lamp and a light sensor is measured with a metre stick. The irradiance is measured with a light meter.

The apparatus is set up as shown in a darkened laboratory.

The following results are obtained.

d (m)	0·20	0·30	0·40	0·50
I ($W\,m^{-2}$)	134·0	60·5	33·6	21·8

(a) State what is meant by the term *irradiance*. **1**

(b) Use **all** the data to establish the relationship between irradiance I and distance d. **3**

MARKS | DO NOT WRITE IN THIS MARGIN

8. (continued)

(c) The lamp is now moved to a distance of 0·60 m from the light sensor.

Calculate the irradiance of light from the lamp at this distance. **3**

Space for working and answer

(d) Suggest one way in which the experiment could be improved.

You **must** justify your answer. **2**

(e) The student now replaces the lamp with a different small lamp.
The power output of this lamp is 24 W.

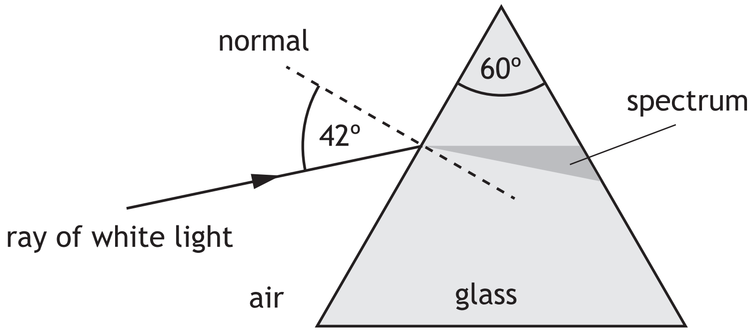
Calculate the irradiance of light from this lamp at a distance of 2·0 m. **4**

Space for working and answer

9. A student carries out two experiments to investigate the spectra produced from a ray of white light.

(a) In the first experiment, a ray of white light is incident on a glass prism as shown.

not to scale



(i) Explain why a spectrum is produced in the glass prism. **1**

(ii) The refractive index of the glass for red light is 1·54.

Calculate the speed of red light in the glass prism. **3**

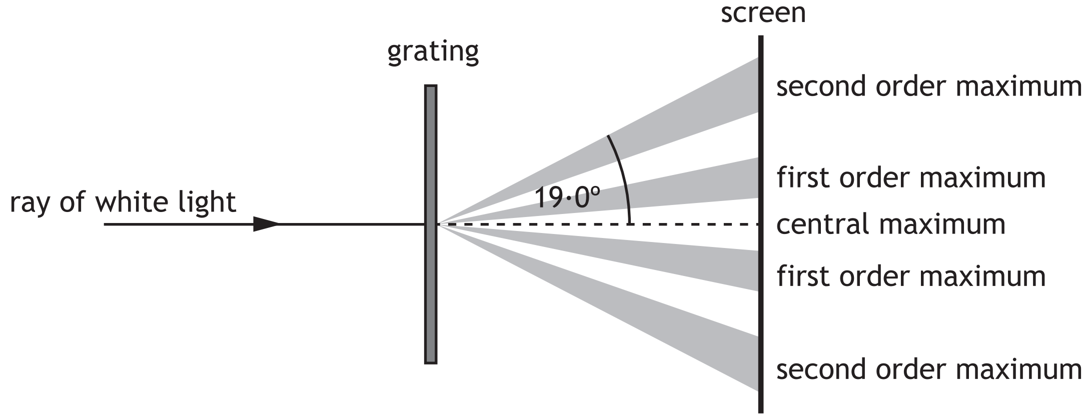
Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

9. (continued)

(b) In the second experiment, a ray of white light is incident on a grating.

not to scale



The angle between the central maximum and the second order maximum for red light is 19·0°.
The frequency of this red light is $4{\cdot}57 \times 10^{14}$ Hz.

(i) Calculate the distance between the slits on this grating. **5**

Space for working and answer

(ii) Explain why the angle to the second order maximum for blue light is different to that for red light. **3**

9. (continued)

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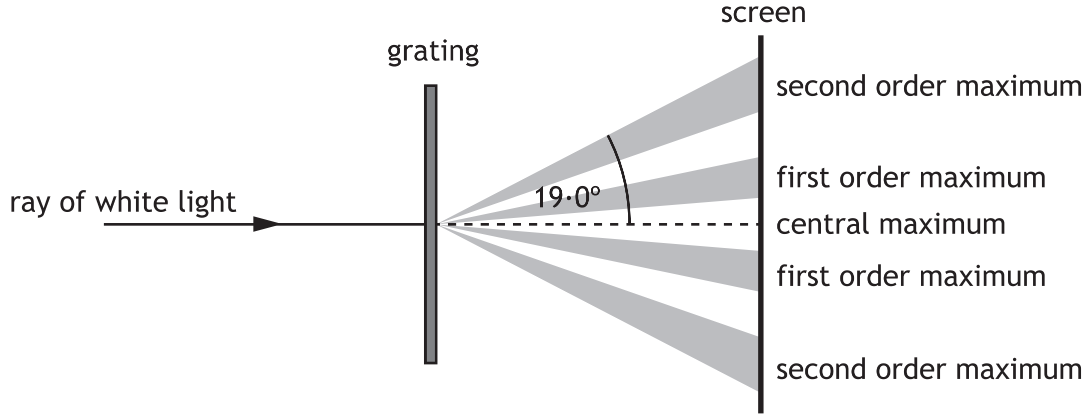
not to scale



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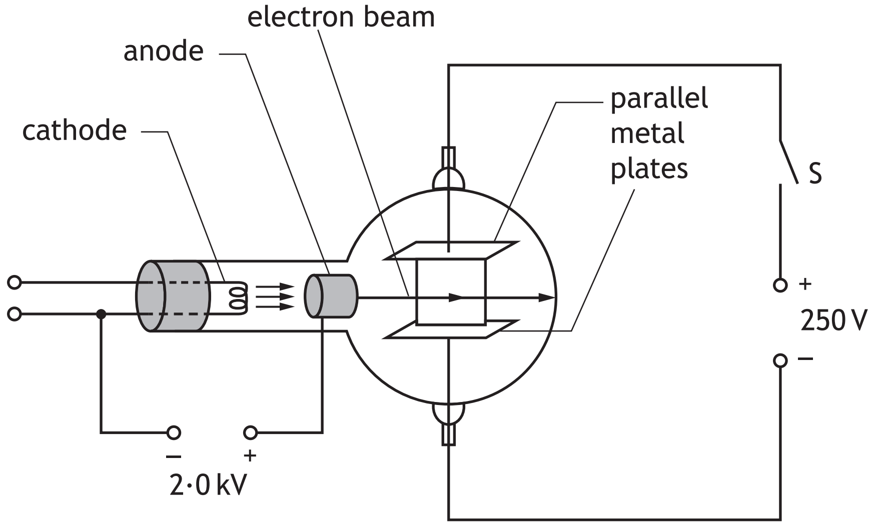
7. An experiment is set up to investigate the behaviour of electrons in electric fields.



(a) Electrons are accelerated from rest between the cathode and the anode by a potential difference of 2·0 kV.

Calculate the kinetic energy gained by each electron as it reaches the anode. **3**

Space for working and answer

(b) The electrons then pass between the two parallel metal plates.

The electron beam current is 8·0 mA.

Determine the number of electrons passing between the metal plates in one minute. **4**

Space for working and answer

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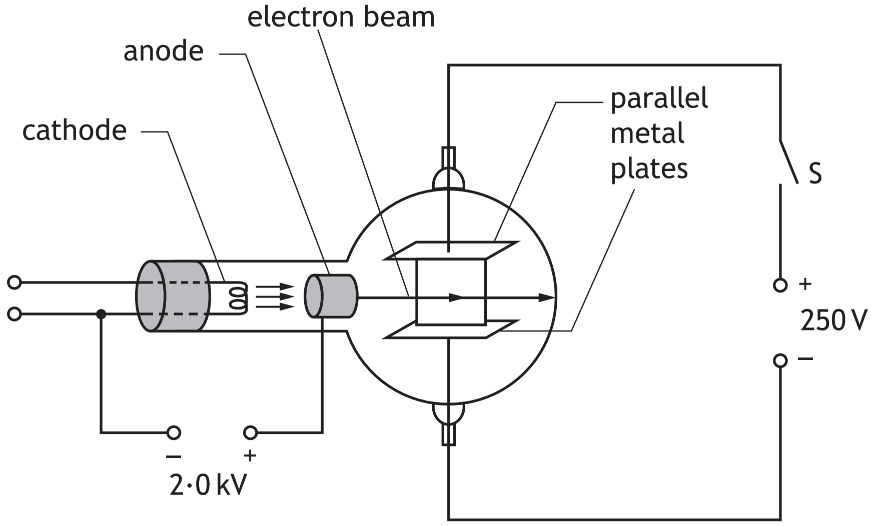

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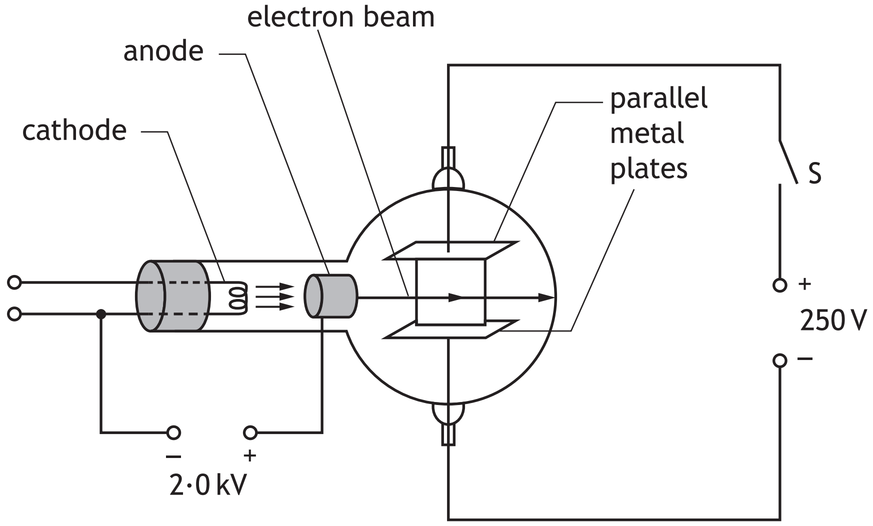

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Space for working and answer

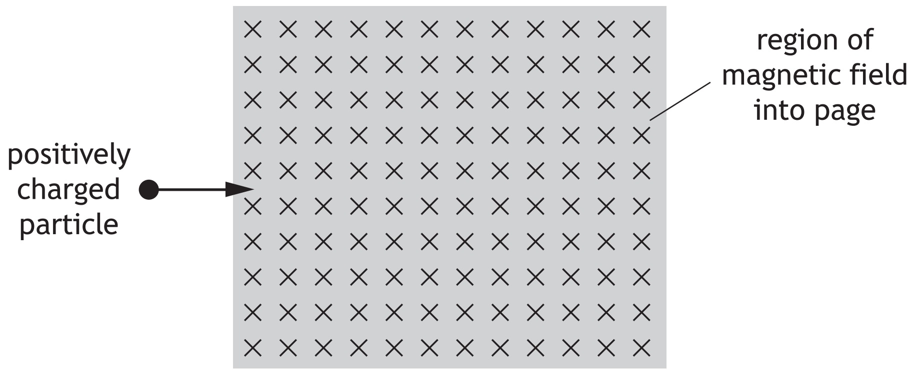
MARKS | DO NOT WRITE IN THIS MARGIN

8. continued)

(c) Magnetic fields are used to contain the plasma inside the fusion reactor.

Explain why it is necessary to use a magnetic field to contain the plasma. **1**

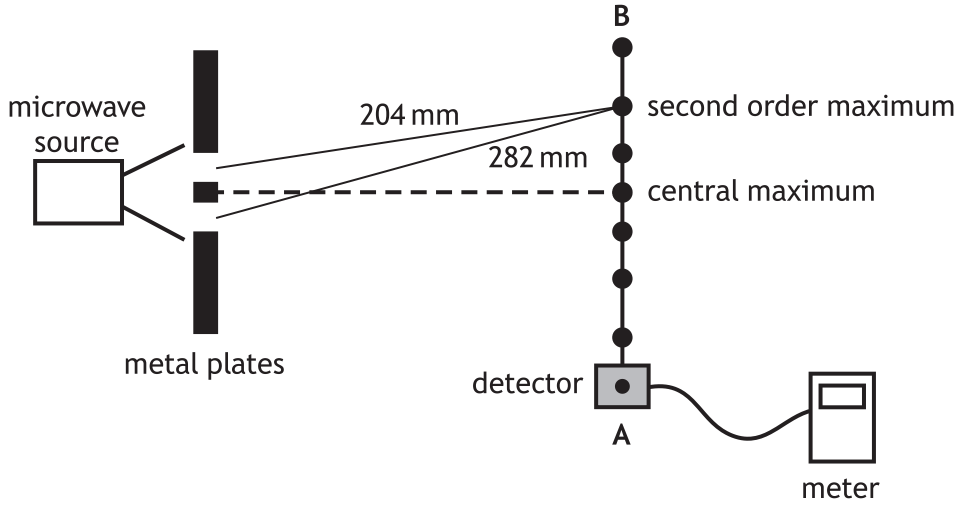
(d) The plasma consists of charged particles. A positively charged particle enters a region of the magnetic field as shown.



Determine the direction of the force exerted by the magnetic field on the positively charged particle as it enters the field. **1**

[Turn over

9. A student carries out an experiment to measure the wavelength of microwave radiation. Microwaves pass through two gaps between metal plates as shown.



As the detector is moved from A to B, a series of maxima and minima are detected.

(a) The microwaves passing through the gaps are coherent.

State what is meant by the term *coherent*. **1**

(b) Explain, in terms of waves, how a maximum is produced. **1**

(c) The measurements of the distance from each gap to the second order maximum are shown in the diagram above.

Calculate the wavelength of the microwaves. **3**

Space for working and answer

9. continued)

(d) The distance separating the two gaps is now increased.

State what happens to the path difference to the second order maximum.

Justify your answer. **2**

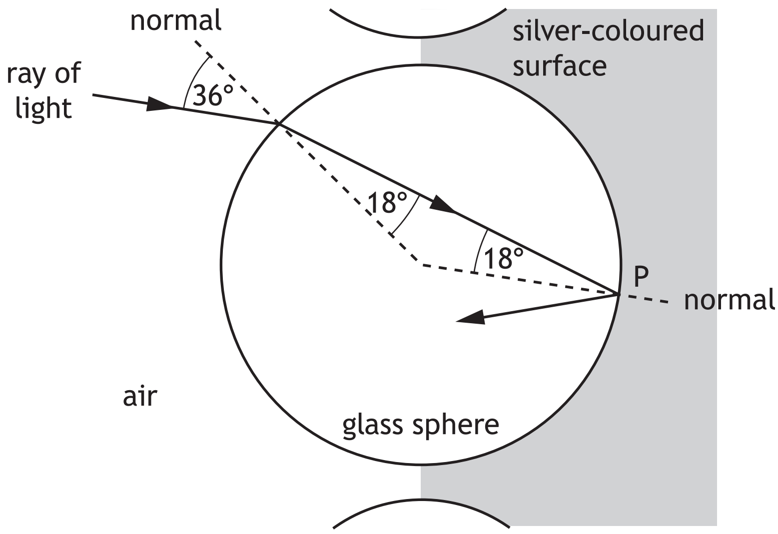
[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

10. Retroflective materials reflect light to enhance the visibility of clothing.

One type of retroflective material is made from small glass spheres partially embedded in a silver-coloured surface that reflects light.

A ray of monochromatic light follows the path shown as it enters one of the glass spheres.



(a) Calculate the refractive index of the glass for this light. **3**

Space for working and answer

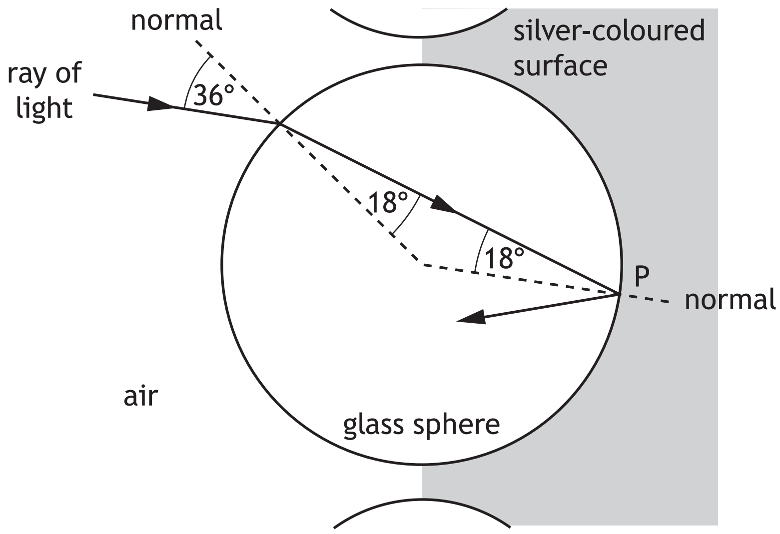
10. continued)

(b) Calculate the critical angle for this light in the glass. **3**

Space for working and answer

(c) The light is reflected at point P.

Complete the diagram below to show the path of the ray as it passes through the sphere and emerges into the air. **1**



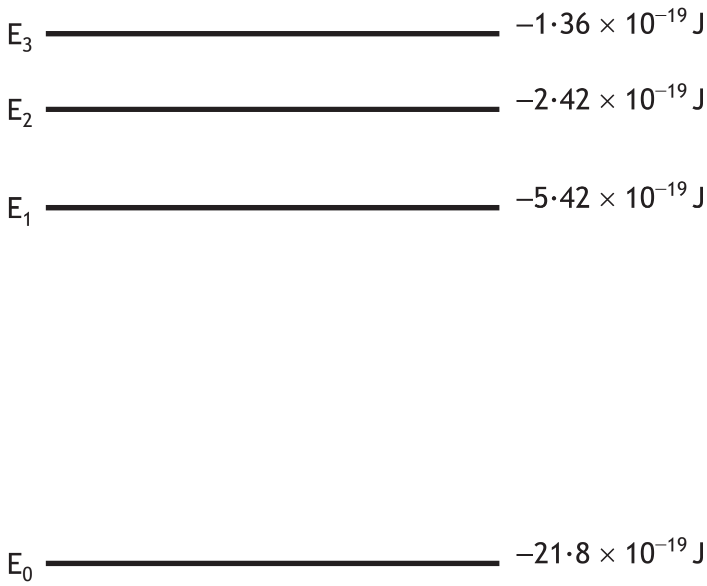
(An additional diagram, if required, can be found on *Page 38*.)

[Turn over

MARKS DO NOT WRITE IN THIS MARGIN

6. The visible spectrum of light emitted by a star is observed to contain a number of dark lines. The dark lines occur because certain wavelengths of light are absorbed when light passes through atoms in the star's outer atmosphere.

The diagram shows some of the energy levels for a hydrogen atom.



(a) For the energy levels shown in the diagram, identify the electron transition that would lead to the absorption of a photon with the highest frequency. **1**

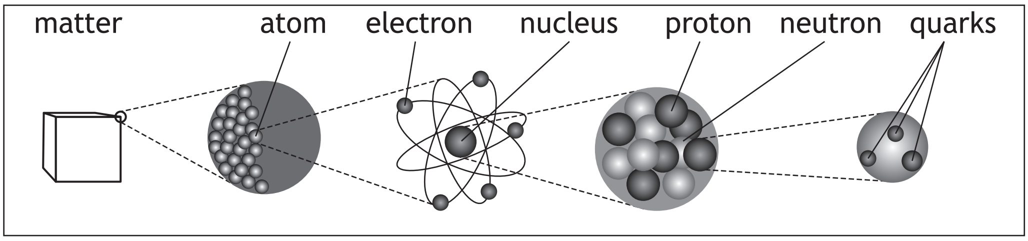
(b) An electron makes the transition from energy level E_1 to E_3.

Determine the frequency of the photon absorbed. **3**

Space for working and answer

MARKS DO NOT WRITE IN THIS MARGIN

7. The following diagram gives information on the Standard Model of fundamental particles.



(a) Explain why the proton and the neutron are **not** fundamental particles. 1

(b) An extract from a data book contains the following information about three types of sigma (Σ) particles. Sigma particles are made up of three quarks.

Particle	*Symbol*	*Quark Content*	*Charge*	*Mean lifetime* (s)
sigma plus	Σ^+	up up strange	$+1e$	$8{\cdot}0 \times 10^{-11}$
neutral sigma	Σ^0	up down strange	0	$7{\cdot}4 \times 10^{-20}$
sigma minus	Σ^-	down down strange	$-1e$	$1{\cdot}5 \times 10^{-10}$

(i) A student makes the following statement.

All baryons are hadrons, but not all hadrons are baryons.

Explain why this statement is correct. 2

(ii) The charge on an up quark is $+\frac{2}{3}e$.

Determine the charge on a strange quark. 1

Space for working and answer

7. (continued)

(c) (i) State the name of the force that holds the quarks together in the sigma (Σ) particle. **1**

(ii) State the name of the boson associated with this force. **1**

(d) Sigma minus (Σ^-) particles have a mean lifetime of $1{\cdot}5 \times 10^{-10}$ s in their frame of reference.

Σ^- are produced in a particle accelerator and travel at a speed of $0{\cdot}9c$ relative to a stationary observer.

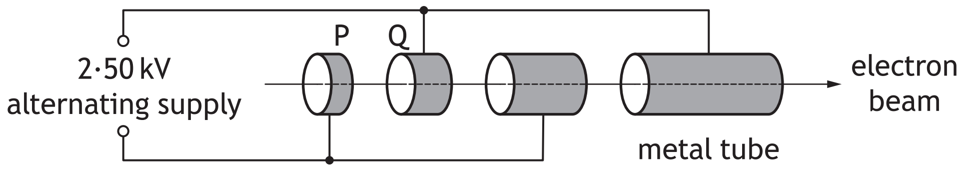
Calculate the mean lifetime of the Σ^- particle as measured by this observer. **3**

Space for working and answer

8. X-ray machines are used in hospitals.

An X-ray machine contains a linear accelerator that is used to accelerate electrons towards a metal target.

The linear accelerator consists of hollow metal tubes placed in a vacuum.



Electrons are accelerated across the gaps between the tubes by an alternating supply.

(a) (i) Calculate the work done on an electron as it accelerates from P to Q. **3**

Space for working and answer

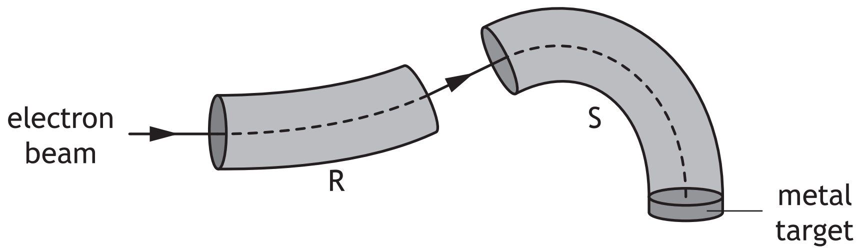
(ii) Explain why an alternating supply is used in the linear accelerator. **1**

8. (continued)

(b) The electron beam is then passed into a "slalom magnet" beam guide. The function of the beam guide is to direct the electrons towards a metal target.

Inside the beam guides R and S, two different magnetic fields act on the electrons.

Electrons strike the metal target to produce high energy photons of radiation.



(i) Determine the direction of the magnetic field inside beam guide R. **1**

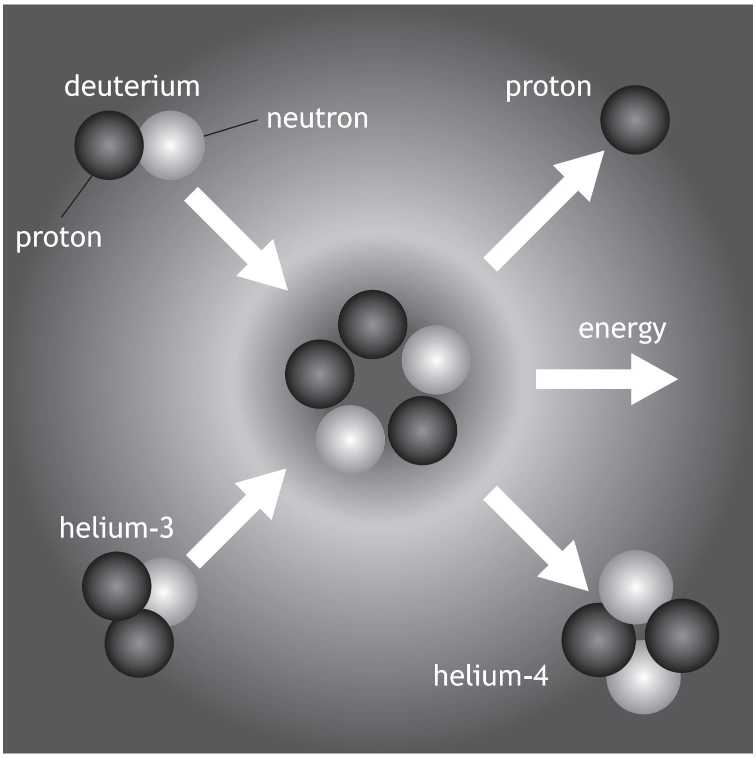
(ii) State **two** differences between the magnetic fields inside beam guides R and S. **2**

(c) Calculate the minimum speed of an electron that will produce a photon of energy $4{\cdot}16 \times 10^{-17}$ J. **3**

Space for working and answer

9. A diagram from a 'How Things Work' website contains information about a nuclear fusion reaction.

Reaction of helium-3 with deuterium



(a) State what is meant by the term *nuclear fusion*. **1**

9. (continued)

(b) The following statement represents this fusion reaction.

$$^{3}_{2}He + {}^{2}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{1}p$$

The mass of the particles involved in the reaction are shown in the table.

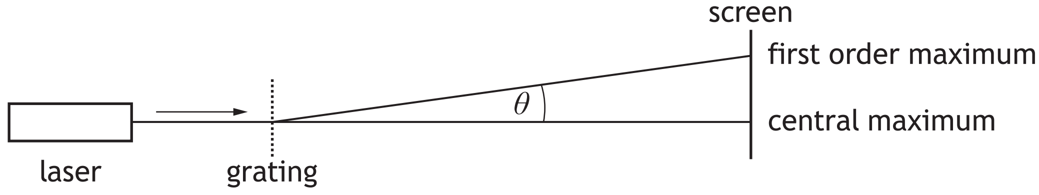
Particle	*Mass* (kg)
$^{3}_{2}He$	$5{\cdot}008 \times 10^{-27}$
$^{2}_{1}H$	$3{\cdot}344 \times 10^{-27}$
$^{4}_{2}He$	$6{\cdot}646 \times 10^{-27}$
$^{1}_{1}p$	$1{\cdot}673 \times 10^{-27}$

(i) Explain why energy is released in this reaction. **1**

(ii) Determine the energy released in this reaction. **4**

Space for working and answer

10. An experiment is carried out to determine the wavelength of light from a laser.



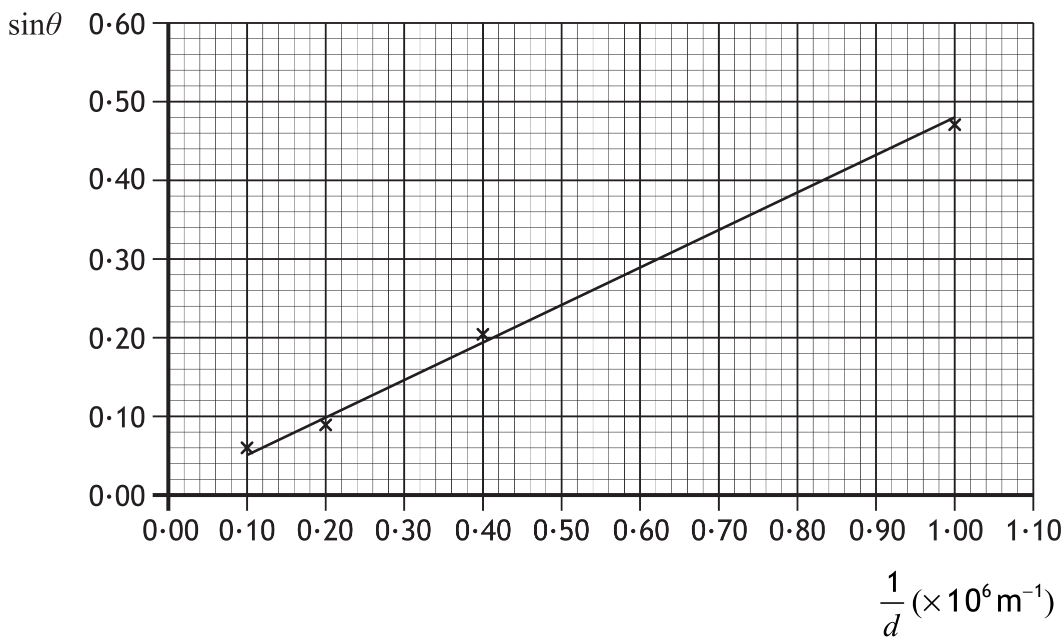
(a) Explain, in terms of waves, how a maximum is formed. **1**

(b) The experiment is carried out with four gratings.

The separation of the slits d is different for each grating.

The angle between the central maximum and the first order maximum θ, produced by each grating, is measured.

The results are used to produce a graph of $\sin\theta$ against $\frac{1}{d}$.



10. (b) (continued)

(i) Determine the wavelength of the light from the laser used in this experiment. **3**

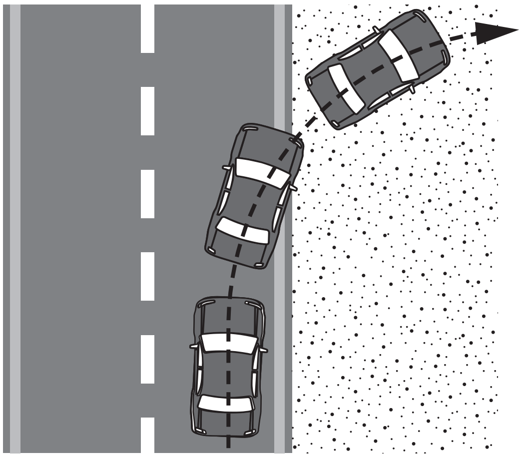
Space for working and answer

(ii) Determine the angle θ produced when a grating with a spacing d of $2{\cdot}0 \times 10^{-6}$ m is used with this laser. **3**

Space for working and answer

(c) Suggest **two** improvements that could be made to the experiment to improve reliability. **2**

11. The use of analogies from everyday life can help better understanding of physics concepts. A car moving from a smooth surface to a rough surface, eg from a road to sand, can be used as an analogy for the refraction of light.



Use your knowledge of physics to comment on this analogy. **3**