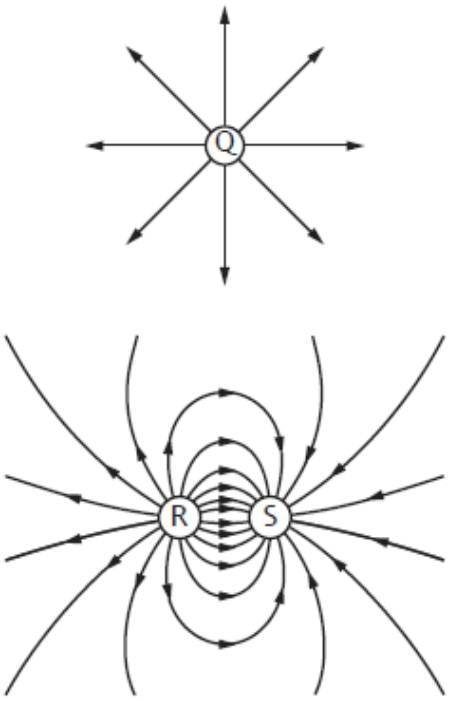
10. The electric field patterns around charged particles Q, R and S are shown.



Which row in the table shows the charges on particles Q, R and S?

	Charge on Q	*Charge on R*	*Charge on S*
A	positive	positive	negative
B	negative	negative	positive
C	negative	positive	negative
D	negative	negative	negative
E	positive	positive	positive

11. Which of the following statements describes a spontaneous nuclear fission reaction?

A $^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{144}_{56}\mathrm{Ba} + {}^{90}_{36}\mathrm{Kr} + 2{}^{1}_{0}\mathrm{n}$

B $^{7}_{3}\mathrm{Li} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{4}_{2}\mathrm{He}$

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

D $^{226}_{88}\mathrm{Ra} \rightarrow {}^{222}_{86}\mathrm{Rn} + {}^{4}_{2}\mathrm{He}$

E $^{216}_{84}\mathrm{Po} \rightarrow {}^{216}_{84}\mathrm{Po} + \gamma$

12. The following statement describes a fusion reaction.

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} + {}^{139}_{57}\mathrm{La} + {}^{95}_{42}\mathrm{Mo} + 2\,{}^{1}_{0}\mathrm{n} + 7\,{}^{0}_{-1}e$$

The total mass of the particles before the reaction is $391{\cdot}848 \times 10^{-27}$ kg.

The total mass of the particles after the reaction is $391{\cdot}478 \times 10^{-27}$ kg.

The energy released in the reaction is

A $3{\cdot}53 \times 10^{-8}$ J

B $3{\cdot}52 \times 10^{-8}$ J

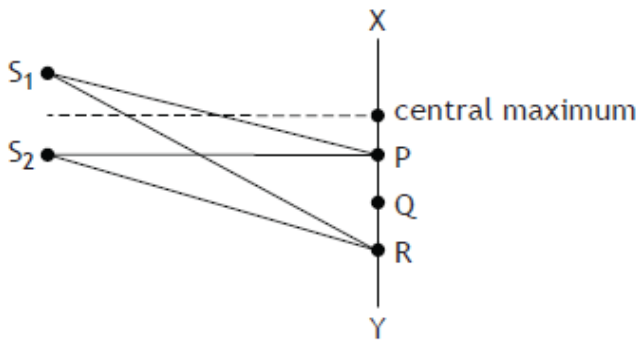
C $3{\cdot}33 \times 10^{-11}$ J

D $1{\cdot}67 \times 10^{-11}$ J

E $1{\cdot}11 \times 10^{-19}$ J.

13. S_1 and S_2 are sources of coherent waves.

An interference pattern is obtained between X and Y.



The first order maximum occurs at P, where $S_1P = 200$ mm and $S_2P = 180$ mm.

For the third order maximum, at R, the path difference ($S_1R - S_2R$) is

A 20 mm

B 30 mm

C 40 mm

D 50 mm

E 60 mm.

15. Which of the following lists the particles in order of size from smallest to largest?

A helium nucleus; electron; proton

B helium nucleus; proton; electron

C proton; helium nucleus, electron

D electron; helium nucleus, proton

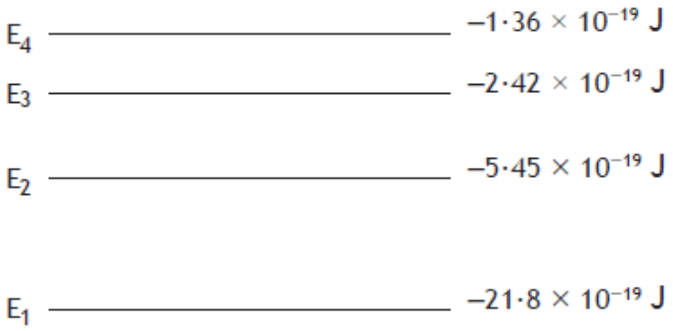
E electron; proton; helium nucleus

4. 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.

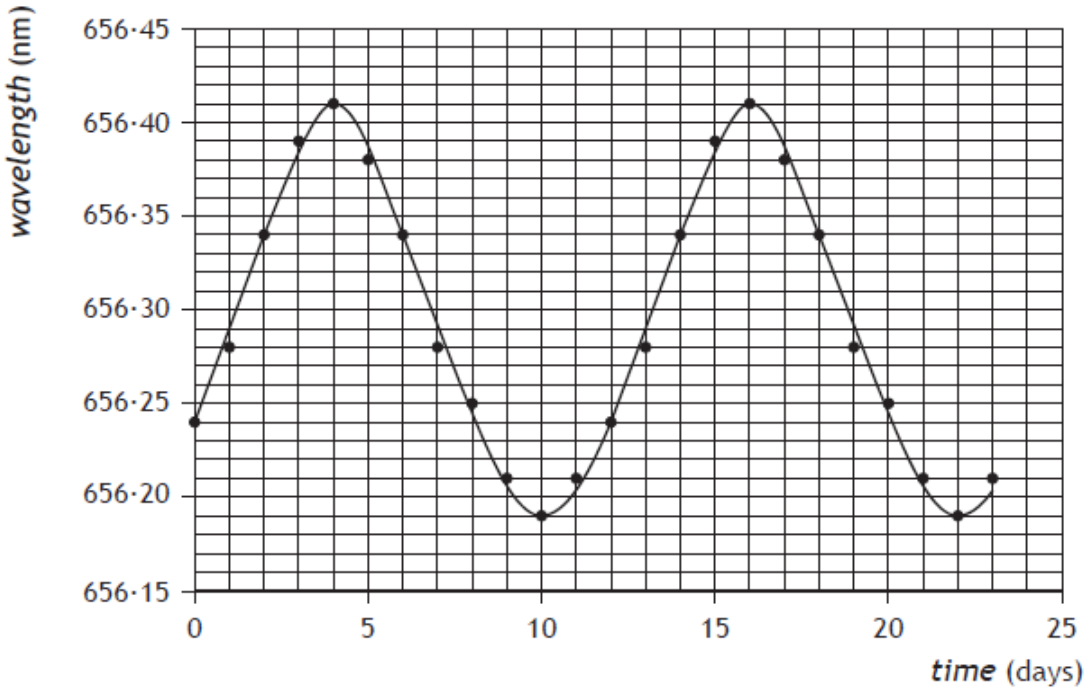


Radiation is emitted when electrons make transitions from higher to lower energy levels.

Identify the transition, between these energy levels, that produces the hydrogen alpha line.

Justify your answer by calculation. **5**

(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:

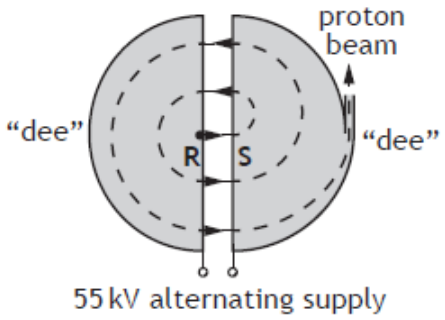
(i) determine the period of orbit of this star; **1**

(ii) calculate the maximum recessional velocity of the star; **5**

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

5. 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) Show that the work done on a proton as it accelerates from **R** to **S** is $8{\cdot}8 \times 10^{-15}$ J. **2**

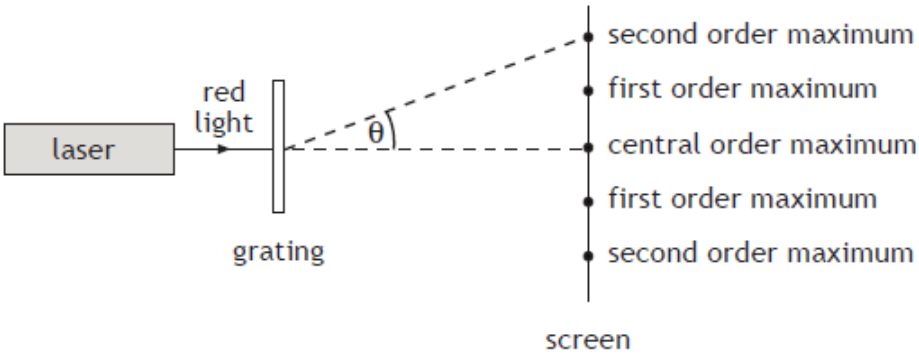
(b) Inside the "dees" a uniform magnetic field acts on the protons.

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

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

6. A laser produces a narrow beam of monochromatic light. **MARK**

(a) Red light from a laser passes through a grating as shown.



A series of maxima and minima is observed.

Explain in terms of waves how a **minimum** is produced. **1**

(b) The laser is now replaced by a second laser, which emits blue light.

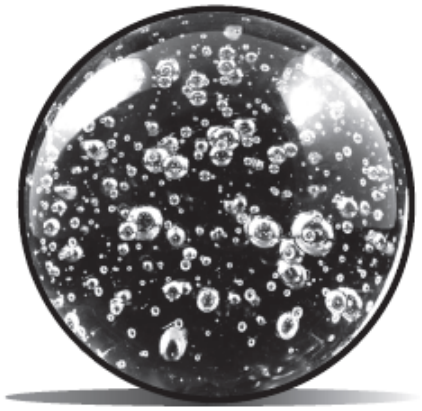
Explain why the observed maxima are now closer together. **2**

(c) The wavelength of the blue light from the second laser is $4{\cdot}73 \times 10^{-7}$ m.

The spacing between the lines on the grating is $2{\cdot}00 \times 10^{-6}$ m.

Calculate the angle between the central maximum and the second order maximum. **3**

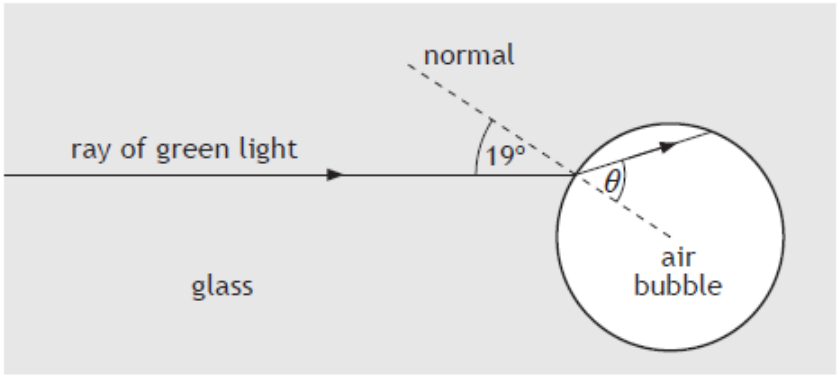
8. A student places a glass paperweight containing air bubbles on a sheet of white paper.



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. **3**

(b) Calculate the maximum angle of incidence at which a ray of green light can enter the air bubble. **3**

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

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

10. Physicists study subatomic particles using particle accelerators.

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.

(a) State whether a pion is classed as a baryon or a meson.

Justify your answer. **2**

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

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

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

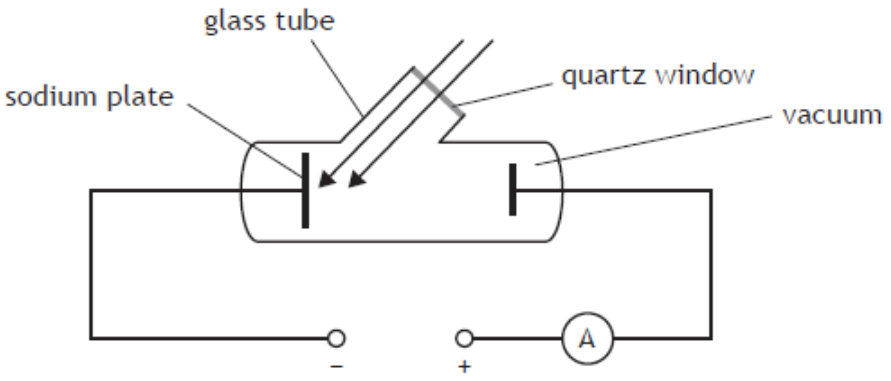
State the names of the quarks that make up an π^- particle. **1**

(d) 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 0·9c.

Calculate the mean lifetime of these π^+ particles relative to a stationary observer. **3**

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



constant voltage supply

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

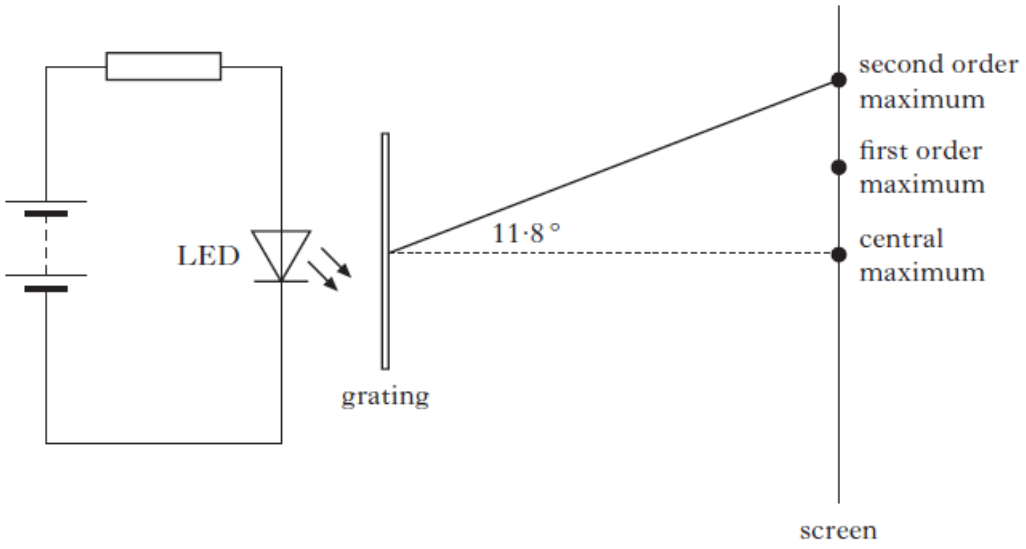
Light of frequency $6{\cdot}74 \times 10^{14}$ Hz is incident on the sodium plate and photoelectrons are emitted.

(a) Calculate the maximum kinetic energy of a photoelectron just as it is emitted from the sodium plate. **3**

(b) Calculate the maximum velocity of a photoelectron just as it is emitted from the sodium plate. **3**

29. (*a*) Monochromatic light from a light emitting diode (LED) is incident on a grating as shown.

The grating has 200 lines per mm.



(i) Calculate the wavelength of the light emitted by the LED. **3**

(ii) State the colour of the LED. **1**

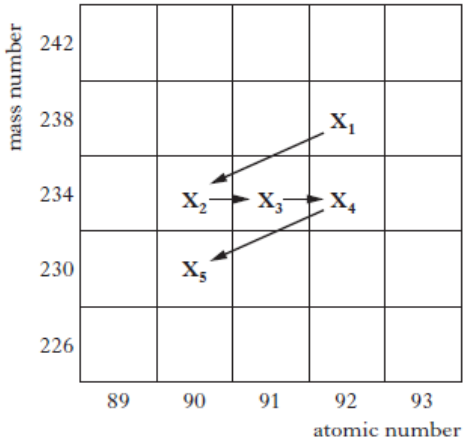
(*b*) The grating is now changed for one which has more lines per mm.

State the effect this has on the pattern observed on the screen. Justify your answer. **2**

(*c*) The grating is now used to view the spectrum produced by sunlight. A number of dark lines are observed on the spectrum.

Why does the spectrum of sunlight include these dark lines? **2**

12. Part of a radioactive decay series is shown in the diagram.
The symbols **X1** to **X5** represent nuclides in this series.



A student makes the following statements about the decay series.

I Nuclides **X2** and **X3** contain the same number of protons.

II Nuclide **X1** decays into nuclide **X2** by emitting an alpha particle.

III Nuclide **X3** decays into nuclide **X4** by emitting a beta particle.

Which of these statements is/are correct?

A I only

B II only

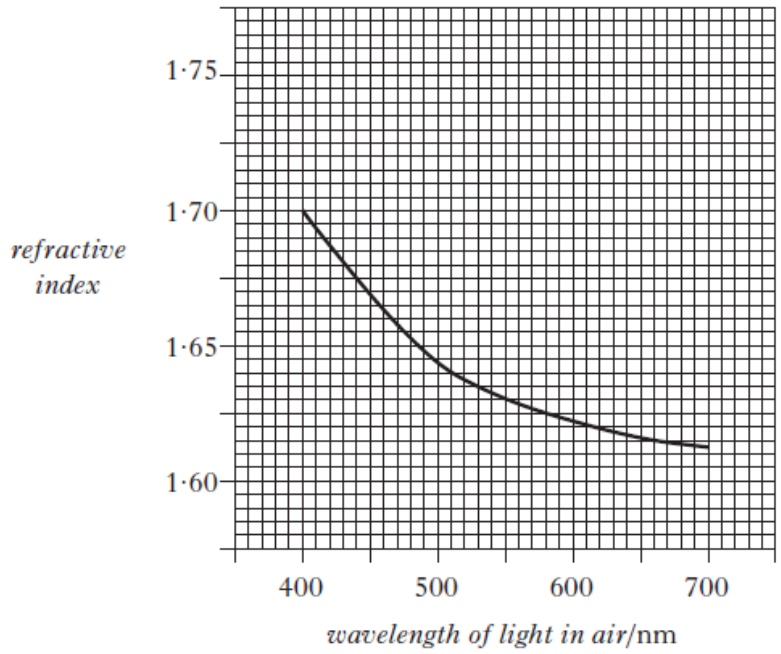
C III only

D II and III only

E I, II and III

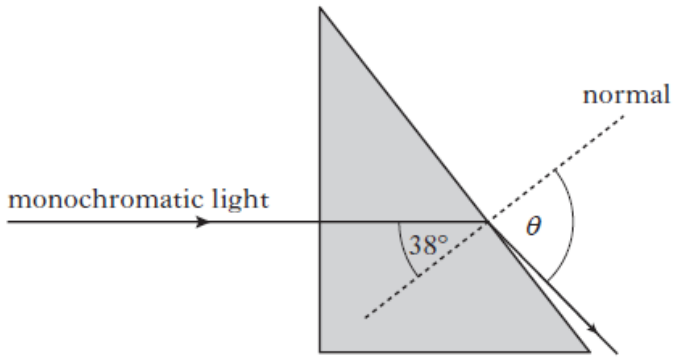
29. Monochromatic light is shone into a triangular prism of flint glass.

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.

not to scale



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

10. Three students each make a statement about antiparticles.

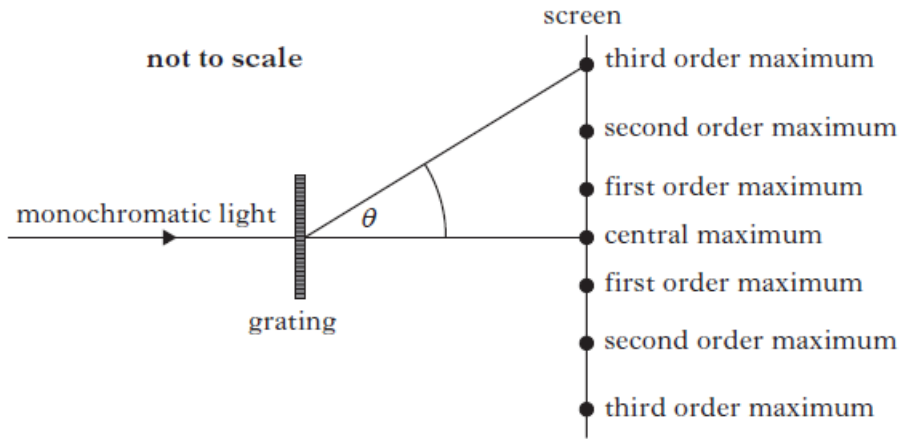
I An antiparticle has the same mass as its equivalent particle.
II An antiparticle has the same charge as its equivalent particle.
III Every elementary particle has a corresponding antiparticle.

Which of the statements is/are correct?

A I only
B II only
C I and III only
D II and III only
E I, II and III

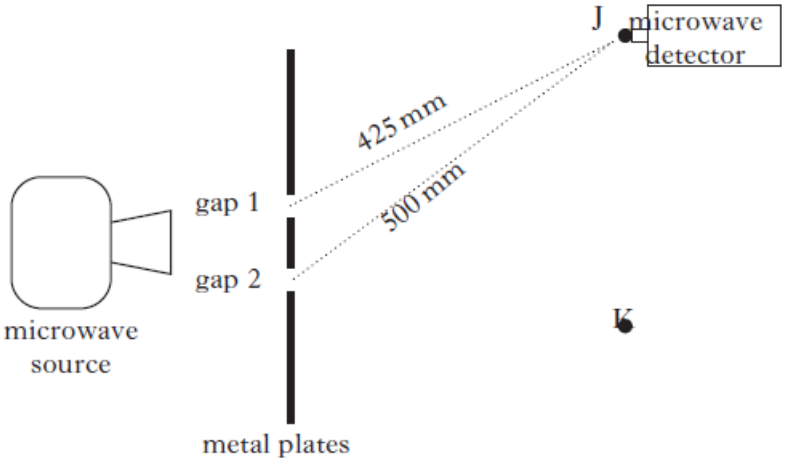
28. Two experiments are carried out to study the interference of waves.

(*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

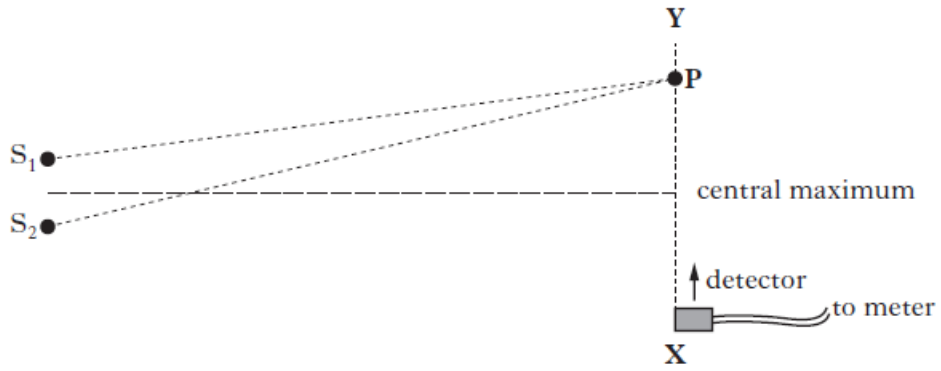
(ii) The microwave detector is now moved to K, which is a point of destructive interference.

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

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**

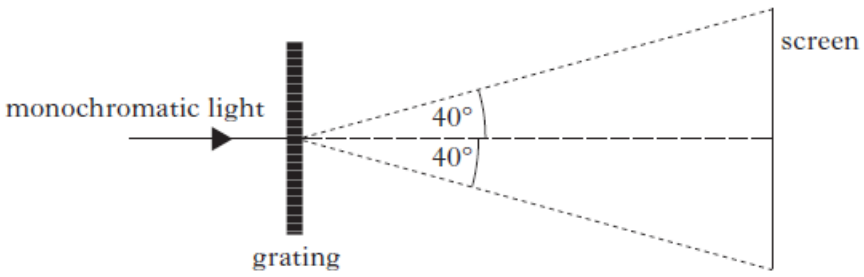
(ii) The **third** maximum from the central maximum is located at P.

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.

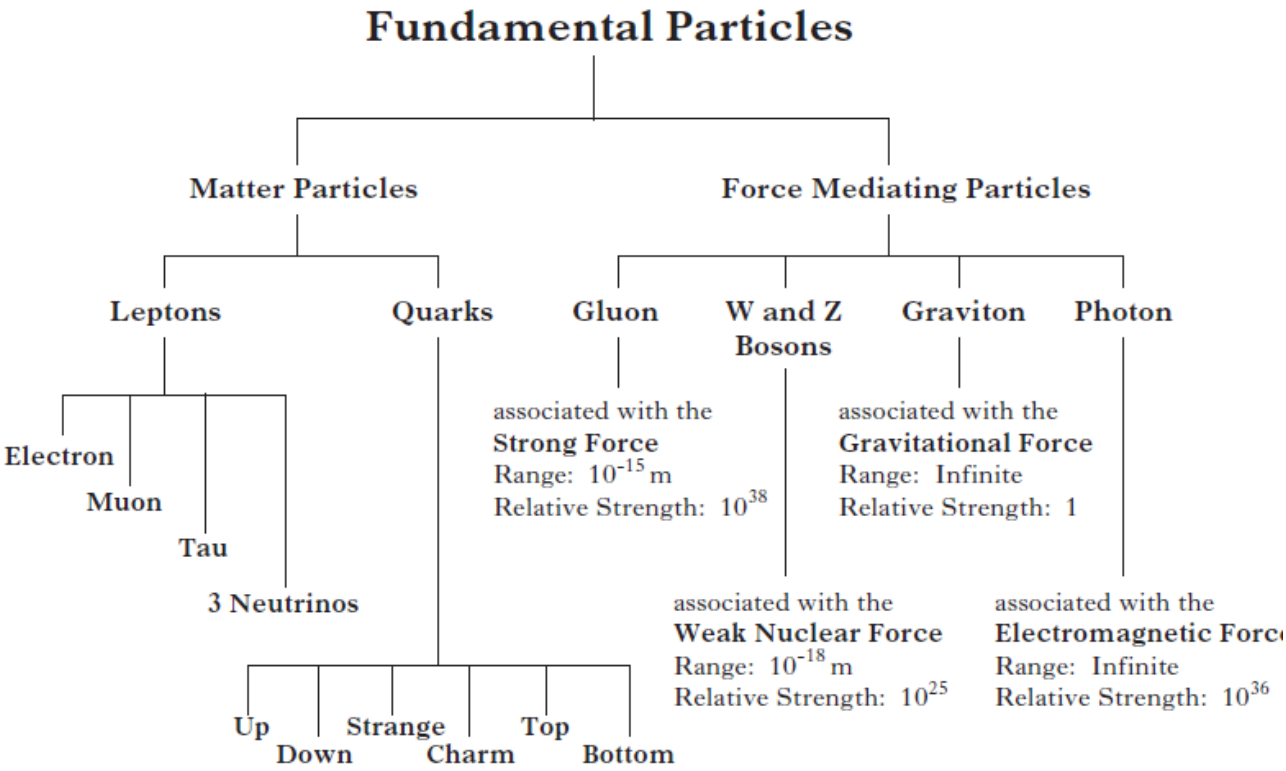
Determine the total number of maxima visible on the screen. **3**

(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**

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**

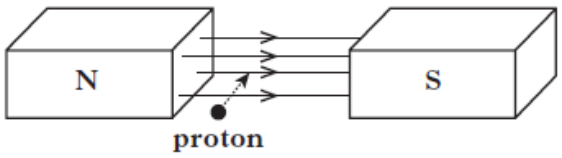
(*b*) A particle called the sigma plus (Σ^+) has a charge of +1. It contains two different types of quark. It has two up quarks each having a charge of $+^2/_3$ and one strange quark.

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.

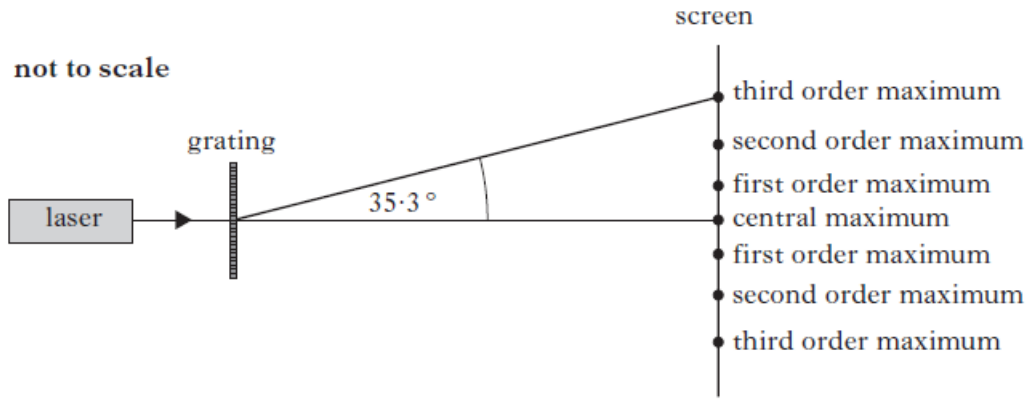


In which direction is this proton deflected? **1**

(ii) The neutron is classified as a hadron.

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

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 °.

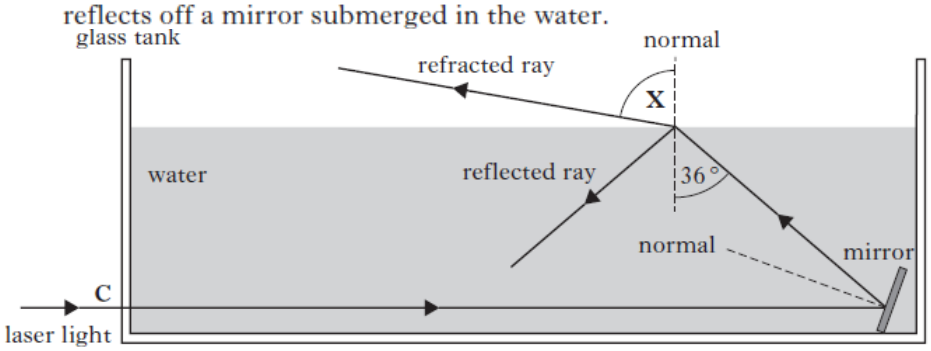
(*a*) Calculate the value she obtains for the slit separation for this grating. **2**

(*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**

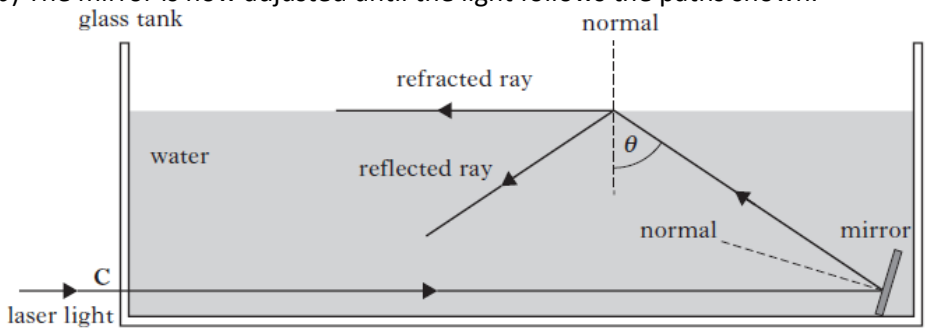
29. A technician investigates the path of laser light as it passes through a glass tan filled with water. The light enters the glass tank along the normal at **C** the reflects off a mirror submerged in the water.



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 q is equal to the critical angle for this laser light in water. 1

(ii) Calculate angle q. 2