OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

PHYSICS B (ADVANCING PHYSICS) G495

Field and Particle Pictures

Candidates answer on the question paper.

OCR supplied materials:
- Data, Formulae and Relationships Booklet
- Insert (inserted)

Other materials required:
- Electronic calculator
- Ruler (cm/mm)

Tuesday 21 June 2011
Morning

Duration: 2 hours

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The Insert will be found in the centre of this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. Additional paper may be used if necessary, but you must clearly show your candidate number, centre number and question number(s).
- Answer **all** the questions.
- Do **not** write in the bar codes.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- The total number of marks for this paper is **100**.
- You may use an electronic calculator.

  Where you see this icon you will be awarded marks for the quality of written communication in your answer.

  This means for example, you should:
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that the meaning is clear
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- You are advised to show all the steps in any calculations.
- This document consists of **24** pages. Any blank pages are indicated.
- The questions in Section C are based on the material in the Insert.

Answer **all** the questions.

Section A

1 Here is a list of some particles emitted in radioactive decays.

alpha particle **neutrino** **gamma ray** **positron** **beta particle**

Choose from the list

(a) the particle with negative charge

.... **[1]**

(b) the two particles with positive charge

.... **[1]**

(c) the three particles that are leptons.

.... **[1]**

2 Fig. 2.1 shows the variation of electrical potential *V* with distance *r* from a charged particle.

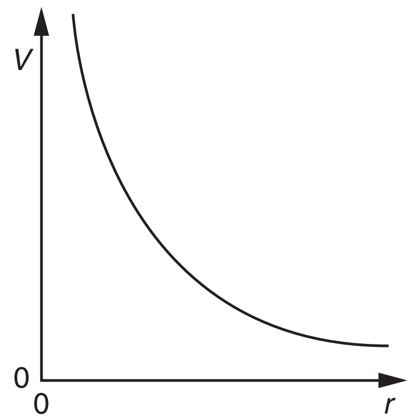


Fig. 2.1

(a) State what is represented by the gradient of the graph.

[1]

(b) State the feature of the graph that shows that the charge on the particle is **positive**.

[1]

3 A fast-moving electron enters a container of low pressure gas. There is a uniform magnetic field in the container. Fig. 3.1 shows the path of the electron. The region of the magnetic field is shown by the crosses on Fig. 3.1.

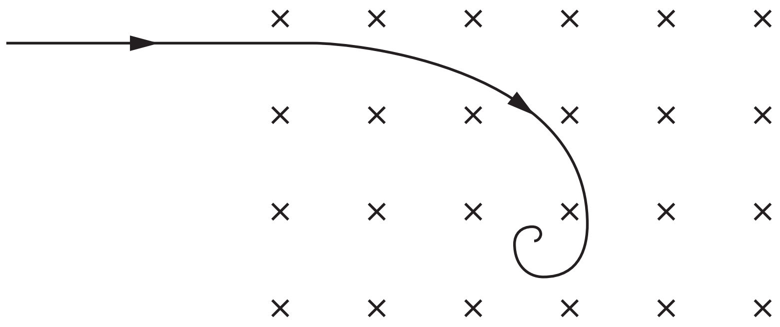


Fig. 3.1

(a) State why the electron path is curved.

[1]

(b) State why the path is a spiral.

[1]

4 Fig. 4.1 shows an electron and a proton separated by 5.0×10^{-11} m.

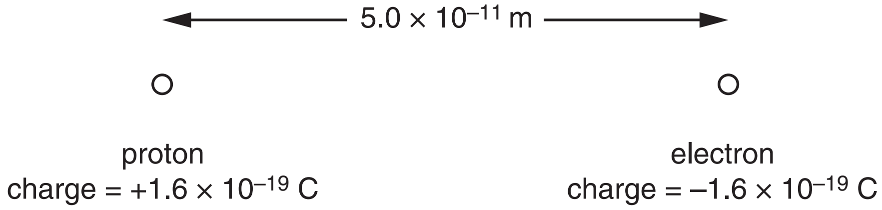


Fig. 4.1

Use information from Fig. 4.1 to calculate the electric force between the two particles.

electric force constant $k = 9.0 \times 10^{9}\,\mathrm{N\,m^2C^{-2}}$

force between particles = ... N **[2]**

5 In the second half of the twentieth century many people were given chest X-rays to look for early stages of tuberculosis, a serious disease.

(a) Use the data below to estimate the likely number of cancer cases expected from an X-ray programme over a 25 year period.

risk of developing cancer = 3% per Sv in a lifetime
number of people X-rayed per year = 290 000
equivalent dose of a chest X-ray = 20 μSv

number = ... **[1]**

(b) Suggest why the X-ray programme was stopped when the number of cases of tuberculosis fell.

[1]

6 Fig. 6.1 shows the three lowest energy levels of hydrogen.

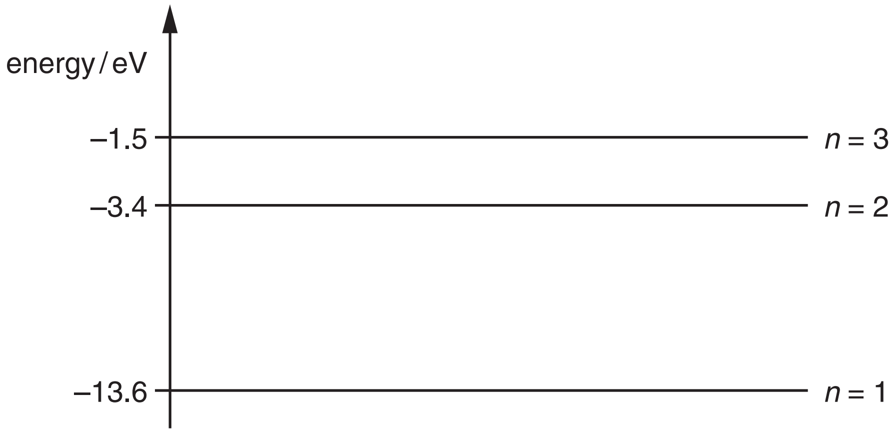


Fig. 6.1

(a) Explain why electron transitions between the energy levels shown can give three different frequencies of radiation. You may add to the diagram in your explanation.

[1]

(b) Show that the highest of these frequencies is about 3×10^{15} Hz.

$h = 6.6 \times 10^{-34}$ J s
$e = 1.6 \times 10^{-19}$ C

[2]

7 Fig. 7.1 shows a simple magnetic circuit and a simple electric circuit.

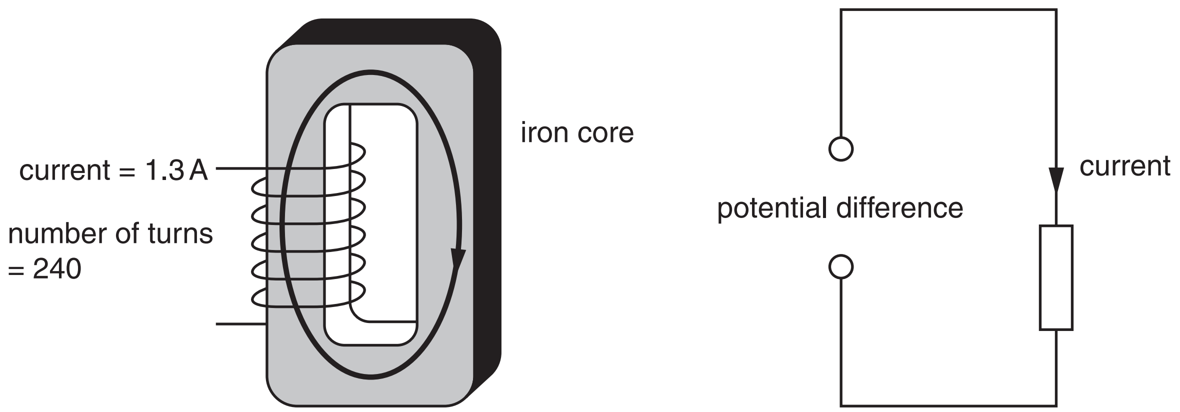


Fig. 7.1

In the magnetic circuit, current turns = 1.3 × 240 = 312 A turns.

The current produces a magnetic flux in the iron core, where flux = permeance × current turns.

(a) A magnetic circuit with greater permeance will produce a larger flux for the same current turns. Suggest **two** ways in which the permeance of the magnetic circuit could be increased.

[2]

(b) The magnetic circuit is analogous to the electric circuit. Complete the table below.

magnetic circuit	electric circuit
current turns	potential difference
flux	current
permeance of circuit	

[1]

8 Fig. 8.1 shows a simple transformer.

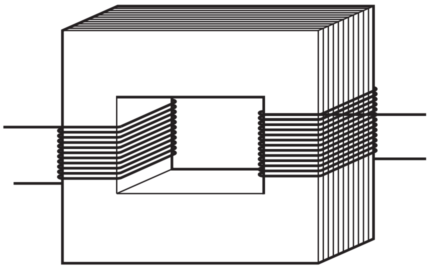


Fig. 8.1

Explain how an alternating current in the primary coil produces an alternating emf in the secondary coil.

Consider the behaviour of the flux in the core in your answer

[3]

[Section A Total: 20]

Section B

9 This question is about the force on an object in an electric field.

A small ball with a metallic coating is hung from an insulating spring between two metal plates as shown in Fig. 9.1. The ball is initially uncharged.

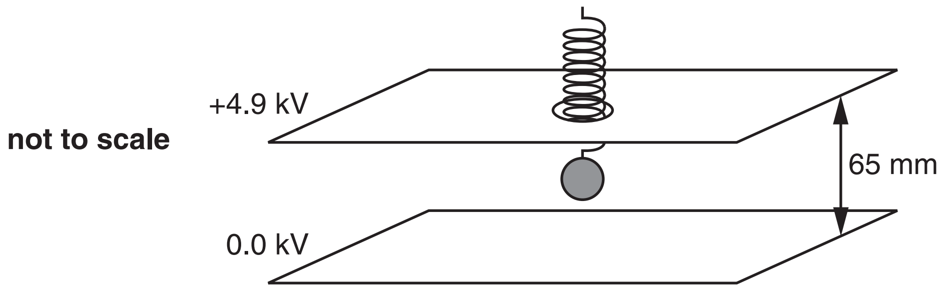


Fig. 9.1

The separation of the plates is 65 mm. There is a potential difference of 4.9 kV between the plates. This produces a uniform electric field.

(a) Show that the strength of the field is about $8 \times 10^4\,\mathrm{V\,m^{-1}}$.

[2]

(b) Show that the units $\mathrm{V\,m^{-1}}$ are equivalent to the units $\mathrm{N\,C^{-1}}$.

[2]

(c) The ball is now given a positive charge. The ball moves towards the lower plate, extending the spring by 2.5 mm.

(i) Show that the force on the ball due to the electric field is about 1μN.

stiffness constant of spring $k = 4.2 \times 10^{-4}\,\text{N m}^{-1}$

[2]

(ii) Use your answers to **(a)** and **(c)(i)** to estimate to one significant figure the number of electrons removed from the ball when it is given the positive charge.

$e = 1.6 \times 10^{-19}\,\text{C}$

number of electrons = ... **[3]**

(d) A radioactive beta source is placed near the apparatus as shown in Fig. 9.2. Nothing else is changed.

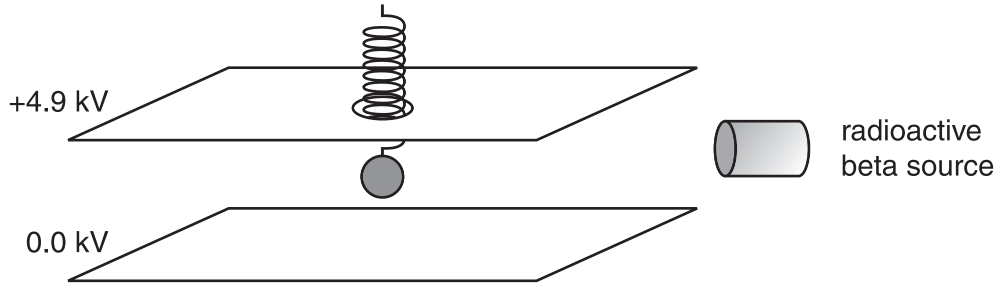


Fig. 9.2

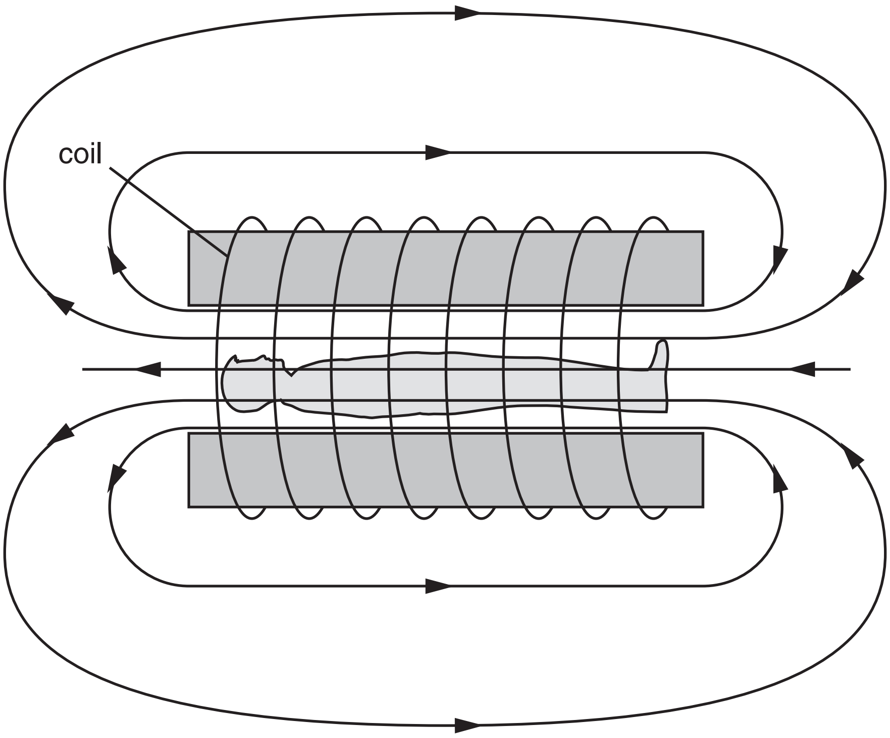
Suggest and explain how this might affect the position of the ball between the plates.

Your answer should use the correct terms in a logical order.

[4]

[Total: 13]

10 This question is about the magnetic field inside a magnetic resonance imaging (MRI) scanner.



not to scale

Fig. 10.1

Fig. 10.1 shows a simplified diagram of an MRI scanner. A direct current in the coil produces a uniform magnetic field inside the scanner.

(a) State how Fig. 10.1 shows that

(i) the field is uniform inside the scanner

(ii) the field is weaker outside the scanner than inside.

[2]

Patients with metal implants must inform the operator of the scanner. However, wearing a ring on the hand is acceptable.

(b) Fig. 10.2a shows a diagram of a ring in the magnetic field of the scanner. The plane of the ring is at right angles to the field.

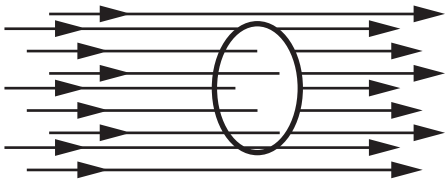


Fig. 10.2a

(i) Calculate the flux through the ring.

diameter of ring = 1.8×10^{-2} m
magnetic flux density $B = 0.70$ T

flux = ... Wb **[2]**

(ii) Explain why no emf is generated when the ring moves from left to right as shown in Fig. 10.2b.

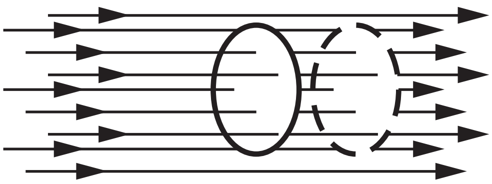


Fig. 10.2b

[2]

(c) The ring is turned through 90° in the field as shown in Fig. 10.3. The plane of the ring is now parallel to the field. This rotation takes 0.4 s.

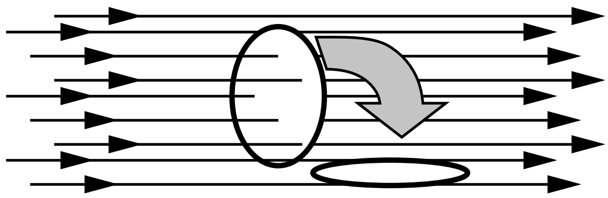


Fig. 10.3

Estimate the average emf generated during this rotation and explain why your calculation only gives an average value of emf.

emf = ... V **[3]**

[Total: 9]

11 This question is about the decay of strontium-90, a beta-emitter commonly used in schools.

A school source has an activity of 7.0×10^{4} Bq.

(a) (i) Show that the minimum number of strontium-90 nuclei in the source is about 9×10^{13}.

half-life of strontium = 9.2×10^{8} s

[2]

(ii) Suggest why this is a minimum figure.

[1]

Strontium-90 decays into yttrium-90 by releasing an electron and an anti-neutrino. Fig. 11.1 shows the energy spectrum of electrons released in this decay.

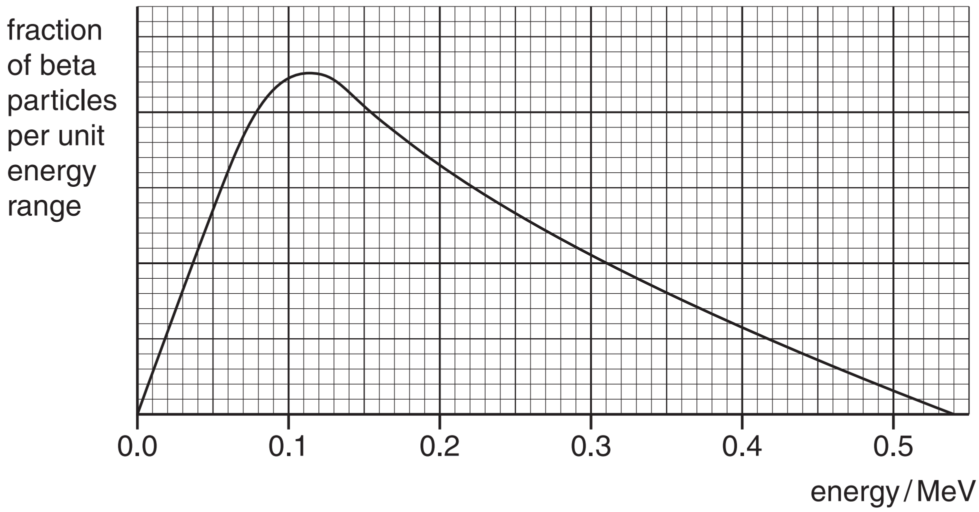


Fig. 11.1

(b) (i) Use the graph to estimate the most common energy of a beta particle released in the decay.

energy = ... MeV **[1]**

(ii) Each strontium-90 nucleus releases just over 0.5 MeV energy when it decays. Explain how the graph suggests that particles other than beta particles are also emitted in the decay.

[3]

(c) A beta particle released from strontium-90 has a kinetic energy of 0.45 MeV.

Calculate the relativistic factor γ for a beta particle with this kinetic energy and use this value to find the speed of a 0.45 MeV beta particle.

rest energy of electron = 0.511 MeV.
$c = 3.0 \times 10^8\,\mathrm{m\,s^{-1}}$

speed = ... $\mathrm{m\,s^{-1}}$ **[4]**

[Total: 11]

12 This question is about neutron-induced nuclear fission. This is the process that is the ultimate source of energy in nuclear power plants.

A uranium-235 (U-235) nucleus can 'capture' a neutron to form U-236. This nucleus is unstable.

(a) **(i)** Complete the decay equation below:

$$^{235}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \longrightarrow ^{236}_{92}\mathrm{U} \longrightarrow ^{90}_{\dots\dots\dots}\mathrm{Kr} + ^{144}_{56}\mathrm{Ba} + 2^{1}_{0}\mathrm{n}$$

[1]

(ii) Suggest why the rate of formation of krypton (Kr) and barium (Ba) may increase in an uncontrolled fission reaction of this type.

[1]

(b) Show that the energy released when a U-236 nucleus decays in the manner shown in **(a)** is about 3×10^{-11} J. Make each step in your calculation clear.

Data:

U-236 binding energy per nucleon = –7.6 MeV
Kr-90 binding energy per nucleon = –8.7 MeV
Ba-144 binding energy per nucleon = –8.3 MeV

$e = 1.6 \times 10^{-19}$ C

[3]

(c) In a typical fission reactor, energy is released at a rate of about 2.8×10^9 W.

Use the value of energy released in one fission event from **(b)** to calculate the mass of U-235 used in one year of operating the reactor.

1 atomic mass unit = 1.66×10^{-27} kg
1 year = 3.2×10^7 s

mass = ... kg **[3]**

[Total: 8]

[Section B Total: 41]

Section C

These questions are based on the Advance Notice.

13 (a) (i) Assuming that the Earth is a perfect sphere show that its circumference (the length of a meridian line) is about 40 000 km.

radius of Earth = 6 400 km

[1]

(ii) Using the value calculated in **(i)** for the length of a meridian show that a milliare (line 23 in the article) is about 2 km.

[1]

(b) (i) The article states (lines 28–29) that a pendulum of length 0.1 virga would "change direction 3959.2 times in exactly half an hour". Show that this is equivalent to a frequency of about 1.0 Hz.

[2]

(ii) The Earth is not a perfect sphere: its radius at the Equator is greater than at the poles.

Use the expression for gravitational field strength $g = -\frac{GM}{r^2}$ to calculate the ratio

$$\frac{g \text{ at the poles}}{g \text{ at the Equator}}.$$

Earth's radius at poles = 6 360 km
Earth's radius at Equator = 6 380 km

ratio = ... **[2]**

(iii) Use the expression $T = 2\pi \sqrt{\frac{l}{g}}$ to explain why pendulums constructed to have a frequency of 1.0 Hz would have to be longer at the Earth's poles than at the Equator.

[2]

(iv) Suggest advantages and disadvantages of using the pendulum in this way to define a standard length (lines 33–34 in the article).

[4]

[Total: 12]

14 (a) When producing a prototype standard metre bar, it is important to be very specific about its structure and the conditions under which it is kept. Suggest and explain what is likely to happen to the length of the supported bar with the following changes:

(i) too high a temperature

[1]

(ii) too high an atmospheric pressure

[1]

(iii) too great a distance between the cylindrical supports (Fig. 2 in the article).

[2]

(b) Suggest and explain an advantage of making the bar from platinum-iridium rather than from pure platinum.

[2]

(c) Describe how the definition of the metre was used to define the kilogramme (lines 45–48 in the article).

[2]

[Total: 8]

15 In the twentieth century, the wavelengths of certain specific colours of light were determined very accurately and used as the basis for a standard length.

(a) State **two** advantages of using the wavelength of light as a standard for length.

1.

2.

[2]

(b) In 1960, the metre was defined as the distance in a vacuum occupied by 1 650 763.73 wavelengths of the orange-red light emitted by krypton-86 (lines 81–87 in the article). Show that this implies that the wavelength of this light is about 600 nm.

[1]

(c) Using the value of the wavelength from **(b)**, calculate the energy difference between the electron levels in the krypton atom giving rise to the emitted orange-red light.

Planck constant, $h = 6.6 \times 10^{-34}$ J s
speed of light, $c = 3.0 \times 10^{8}$ m s^{-1}

energy difference = ... J **[3]**

[Total: 6]

16 The development of interferometers provided a new, accurate method of measuring the wavelength of light, allowing an improved way of defining the metre to be used. Fig. 16.1 is a diagram of a Michelson interferometer (Fig. 3 in the article).

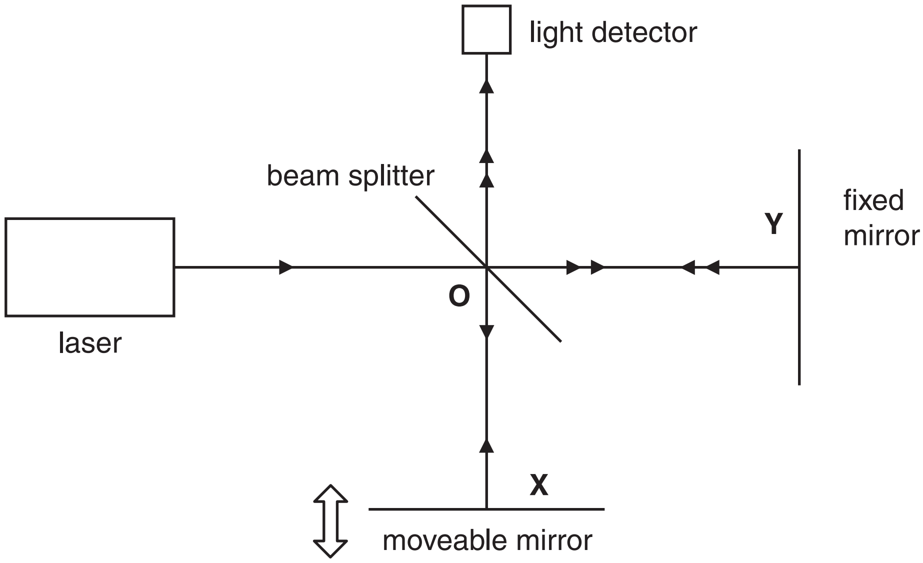


Fig. 16.1

(a) Draw a phasor representing photons taking the path **OXO** when the intensity of light at the detector is **zero**. The phasor for those photons travelling the path **OYO** has been drawn.

phasor via **OYO** phasor via **OXO**

[2]

(b) In a typical experiment, the moveable mirror is moved along the line **OX** a distance of 0.21 mm. During that movement the intensity of light at the detector falls to zero 800 times. Calculate the wavelength of the laser light.

wavelength = ... m **[3]**

(c) A glass tube is placed in the beam **OX** and the air is slowly pumped out of the tube. The refractive index of air is proportional to its density.
Describe what changes will occur to the two phasors as the air is removed. State how the detector signal will vary.

[3]

[Total: 8]

17 In 1983, the definition of the metre was changed to that which we use today (lines 99–100) along with three recommended methods of using it to measure distances.

(a) Explain why method 1 (line 103 in the article) is not used in practice except for very long distances.

[2]

(b) Describe how method 2 (line 104 in the article) can be used to make precise measurements of length.

Your explanation should be carefully ordered and clear.

[3]

[Total: 5]

[Section C Total: 39]

END OF QUESTION PAPER

PLEASE DO NOT WRITE ON THIS PAGE