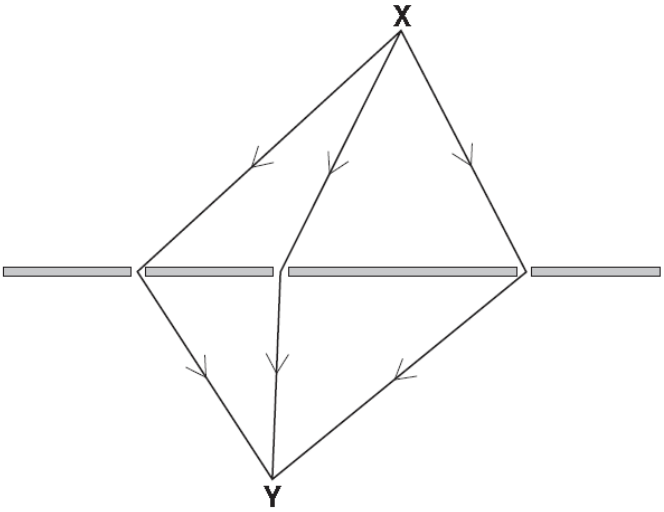
# Many Paths Current Specification Past Paper Questions

June 2009

A photon travels from **X** to **Y**. Three of the possible paths are shown below.




The phasors for these three paths are shown below. Each has the same amplitude *A*.

**(a)** Show, by drawing or otherwise, that the amplitude of the resultant phasor, $A_{res}$, is more than $2A$ and less than $3A$.

**[2]**

**(b)** The probability *P* of the photon arriving at **Y** depends on the amplitude of the resultant phasor, $A_{res}$.

State the relationship between the probability *P* and the amplitude $A_{res}$.

............................................................................................... **[1]**

Jan 2011

An electron is a quantum object.
An electron leaves a hot wire and arrives at a screen.
For all possible paths of this electron, the phasors are combined to give the total phasor amplitude *A* at any particular point on the screen.

Which of the following statements are correct for all points on the screen?
Put ticks (✓) in the **two** correct boxes.

| | |
|---|---|
| The phasors will all cancel out. | |
| The phasors are all in phase. | |
| Phasors are added as vectors. | |
| The electron always takes the shortest path. | |
| The probability of the electron reaching any point is proportional to $A$. | |
| The probability of the electron reaching any point is proportional to $A^2$. | |

**[2]**

In a simple wave model to explain the diffraction of waves at a gap, the gap of width *b* is divided into three equal parts as shown in Fig. 10.1.
The centre of each part is treated as a source of waves.

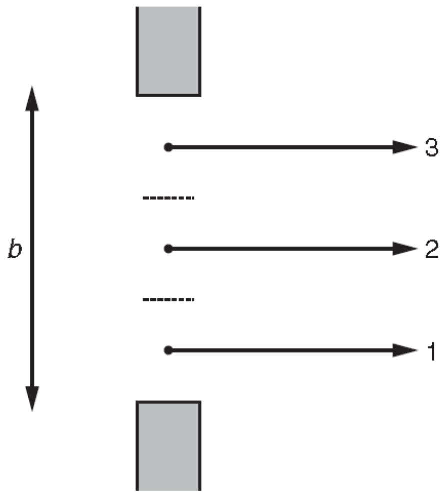



**Fig. 10.1**

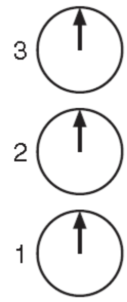



**Fig. 10.2**

**(a)** The phasors for the waves from each of the three parts of the gap reaching a distant screen in the straight-on direction are shown in Fig. 10.2.

**(i)** The paths taken by the waves in Fig. 10.1 are all equal in length. Explain how the phasors in Fig. 10.2 confirm this.

**[1]**

**(ii)** Each phasor has an amplitude *A*. Write down the amplitude of the resultant phasor at the distant screen.

amplitude = ........................................................ **[1]**

**(b)** At an angle $\theta$ to the straight-on direction, the path difference between neighbouring paths is $\Delta x$, as shown in Fig. 10.3. For one particular value of $\theta$, the resultant intensity is **zero**.

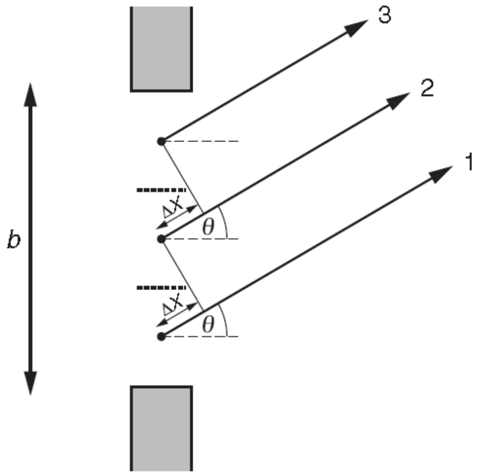



**Fig. 10.3**

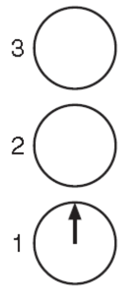



**Fig. 10.4**

**(i)** Explain why the phasor for path 1 has rotated 120° more than the phasor for path 2, when $\Delta x = \frac{1}{3}\lambda$, where $\lambda$ is the wavelength of the waves.

**[2]**

**(ii)** Draw arrows on Fig. 10.4 above to represent the phasors for waves 2 and 3.
Explain, using a diagram, why the three phasors have a zero resultant.
Label your phasors in the diagram 1, 2 and 3.

**[2]**

**(iii)** Use Fig. 10.3 and the fact that $\Delta x = \frac{1}{3}\lambda$ to show that $\lambda = b \sin \theta$ where $b$ is the total width of the gap. Show your working clearly in this space.

**[2]**

**(c)** Use the equation $\lambda = b \sin \theta$ to calculate the angle $\theta$ at which a minimum signal occurs when microwaves of wavelength 2.4 cm are incident on a gap of width 6.0 cm.

$\theta$ = ....................................................... ° **[2]**

June 2011

Fig. 3.1 shows three different paths for a photon travelling from a source **S** to a point **P** on a distant screen.

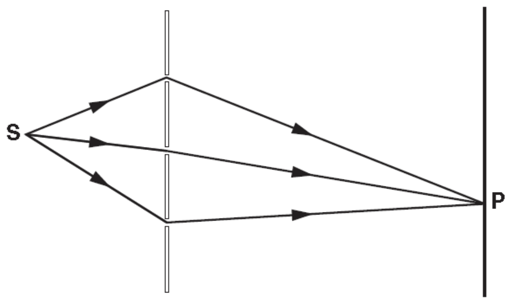



**Fig. 3.1**

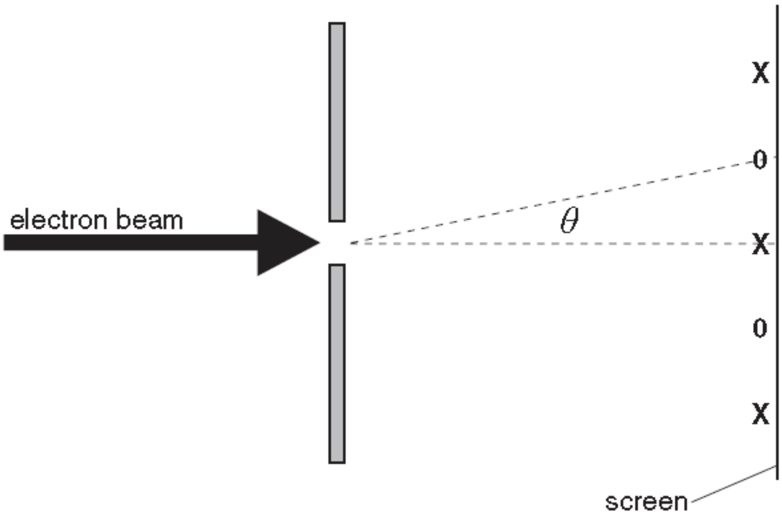
At **P**, the phasor for each path has the same amplitude as shown by this arrow:

Draw a diagram to show a combination of the three phasors which would give zero light intensity at **P**.

**[2]**

Jan 2012

This question is about electron diffraction.
When a parallel beam of electrons is incident on a narrow slit, a diffraction pattern can be observed on a screen.




**0** = place with a low probability of detecting an electron
**X** = place with a high probability of detecting an electron

**Fig. 10.1**

**(a)** To observe a diffraction pattern on the screen, the slit needs to be very small indeed.
The equation for single-slit diffraction is

$$\lambda = b \sin\theta$$

where $\lambda$ is the wavelength, $b$ the width of the narrow slit and $\theta$ the angle of the first minimum, shown above.

Calculate the width $b$ of the slit needed to give an angle $\theta$ of 1° for a wavelength of $7.0 \times 10^{-11}$ m.

$b$ = ........................................................ m **[1]**

**(b)** The wavelength associated with the electrons depends on their energy.
For low energy electrons of mass $m$ and speed $v$, the wavelength is given by:

$$\lambda = \frac{h}{mv}$$

**(i)** Calculate the speed of electrons with wavelength $\lambda = 7.0 \times 10^{-11}$ m.
$h = 6.6 \times 10^{-34}$ Js
$m = 9.1 \times 10^{-31}$ kg

speed = ................................................ $\text{m s}^{-1}$ **[2]**

**(ii)** Suggest and explain what will happen to the pattern seen in Fig. 10.1 when the energy of the electron beam is increased.

*In your answer, you should make the steps in your reasoning clear.*

**[3]**

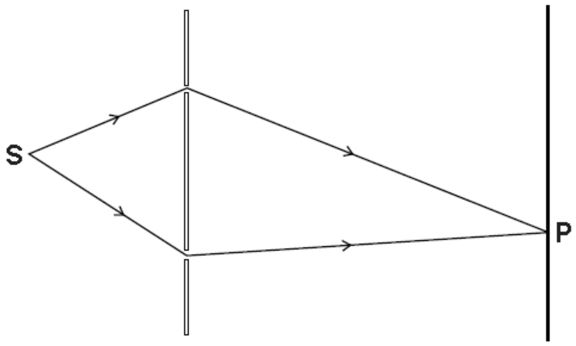
**(c)** The pattern is seen on the screen even when the beam of electrons is so weak that only one electron at a time passes through the apparatus.
Explain, in terms of the phasors for each possible path, why an electron reaching the slit has a very low probability of reaching the points marked **0** in Fig. 10.1.

**[2]**

**(d)** Electron diffraction is used to study the arrangement of atoms in the surface layers of solids.
Explain why the diffraction of electrons is better than the diffraction of light of wavelength 600 nm for studying the arrangement of atoms of spacing about 0.1 nm.

**[2]**

The diagram shows two different paths for a photon travelling from a source **S** through a screen containing two slits to a point **P** on a distant screen.




At the distant screen, the phasor for each path has the same amplitude **A** represented by the arrow below.

**(a)** Draw phasor diagrams to show how the resultant amplitude of the two phasors at **P** may be **(i)** 2**A**, **(ii)** $\sqrt{2}$**A**.

| **(i)** | **(ii)** |
|---|---|
| | |

**[2]**

**(b)** When the resultant amplitude is $\sqrt{2}$**A**, the probability of detecting a photon at **P** is half the probability compared with when the resultant amplitude is 2**A**.

Explain what this shows about the relationship between probability and amplitude.

**[2]**

Jan 2013

Fig. 6.1 shows two paths of light leaving a source, passing through two slits and reaching a point on a screen.

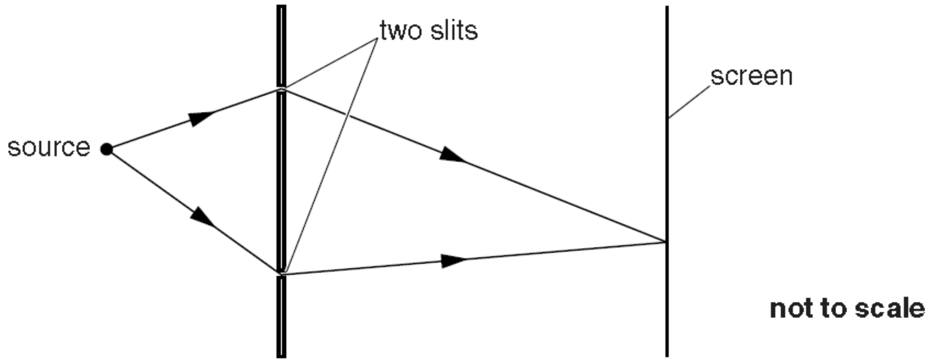



**Fig. 6.1**

Which of the following statements about photons arriving at a point on the screen are true?

Put a tick (✓) in the box next to **each** correct statement.

| Statement | |
|---|---|
| Visible light photons travel faster than infrared photons. | ☐ |
| The energy of a photon increases with the frequency of the radiation. | ☐ |
| The probability of a photon reaching the point can be found by considering the phasors for all photon paths. | ☐ |
| More than one photon must reach the point at once if there is to be destructive interference at that point. | ☐ |

**[2]**