AS Level Physics

Chapter 4 – Waves

4.3.2 Superposition

Worked Examples

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Superposition

Exam Style Question 1

Fig. 5.1 shows two loudspeakers S and T connected to a signal generator, emitting sound of a single frequency but with different amplitudes. A person walks in the direction from O to Q. The line OQ is at a distance D from the loudspeakers.

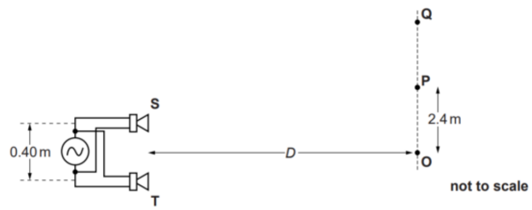


Fig. 5.1

The sound waves emitted individually by S and T have displacements x_S and x_T at the point P. Fig. 5.2 shows the variation with time t of each of these displacements. Note that the amplitude of the wave from T is twice that of the wave from S.

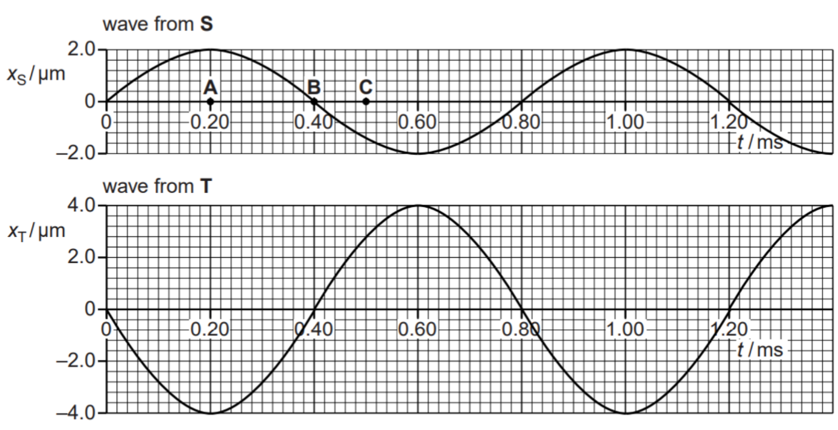


Fig. 5.2

Superposition

Exam Style Question 1

(a) Explain whether or not the two waves are coherent.

(b) Explain why the sound heard at P will be of minimum but not zero intensity.

(c) State the phase difference between the oscillation at time A, labelled on the t–axis of the x_S against t curve in Fig. 5.2, and the oscillation

(i) at time B

(ii) at time C

(d) (i) Calculate the wavelength λ of the sound waves emitted from the loudspeakers. speed of sound in air = $340\ m\ s^{-1}$

(ii) Maximum intensity of sound is heard at point O. The loudspeakers are $0.40\ m$ apart and the distance OP is $2.4\ m$. P is the position of the first minimum. Calculate the distance D from the loudspeakers to the line OQ. Assume that the equation used for the interference of light from a double-slit also applies for the sound from these two loudspeakers.

(e) (i) Explain the term intensity.

(ii) The intensity of the sound at point P, the minimum, is $4.0 \times 10^{-6}\ W\ m^{-2}$. Use data from Fig. 5.2 to calculate the maximum intensity of sound, at point O.

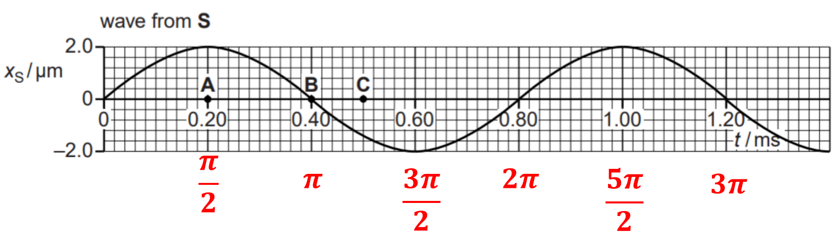
Superposition

Exam Style Question 1

(a) Explain whether or not the two waves are coherent.
The two waves are coherent because they are generated by the same source and have a constant phase difference at which both waves intersect the x-axis at 180°.

(b) Explain why the sound heard at P will be of minimum but not zero intensity.
For a minimum the **two** oscillations are $\pi\ rad$ out of phase however the wave from T has twice the amplitude compared to the wave from S, this means the resultant amplitude is 2.0 μm so a sound will still be heard.

(c) State the phase difference between the oscillation at time A, labelled on the t–axis of the x_S against t curve in Fig. 5.2, and the oscillation
(i) at time B
(ii) at time C
Step 1: To answer this question label the x-axis of the graph first in rads (this will make calculating the phase difference easier):



Step 2: Calculate the phase difference for A, B and C from the origin (0):

$$A = \frac{\pi}{2}$$
$$B = \pi$$

C is half way between π and $\frac{3\pi}{2}$ therefore:

$$C = \pi + \frac{\pi}{4} = \frac{5\pi}{4}$$

Superposition

Exam Style Question 1

Step 3: Calculate the phase difference between A and B:

$$phase\ difference = BO - AO = \pi - \frac{\pi}{2} = \frac{\pi}{2}$$

Step 4: Calculate the phase difference between A and C:

$$phase\ difference = CO - AO = \frac{5\pi}{4} - \frac{\pi}{2} = \frac{3\pi}{4}$$

Therefore:
(i) At time B phase difference compared to A is $\frac{\pi}{2}$.
(ii) At time C phase difference compared to A is $\frac{3\pi}{4}$.

(d) (i) Calculate the wavelength λ of the sound waves emitted from the loudspeakers. speed of sound in air = $340\ m\ s^{-1}$.
Use $v = f\lambda$
To get f we know the time period to be $T = 0.80 \times 10^{-3}\ s$ and use $f = \frac{1}{T}$

$$f = \frac{1}{0.80 \times 10^{-3}\ s} = 1250\ Hz$$

Now use $f = v\lambda$ and rearrange for λ:

$$\lambda = \frac{v}{f} = \frac{340\ m\ s^{-1}}{1250\ Hz} = 0.27\ m$$

(d) (ii) Calculate the distance D from the loudspeakers to the line OQ.
Use $\lambda = \frac{ax}{D}$ and rearrange for D

$$D = \frac{ax}{\lambda} = \frac{0.4\ m \times 4.8\ m}{0.27\ m} = 7.1\ m$$

x = 4.8m as the distance between O and P (2.4m) falls between minimum and maximum values. Thus, the next maximum occurs at 4.8m, the distance between two consecutive maxima.

(e) (i) Explain the term intensity.
Energy per unit time perpendicular to the direction of energy transfer.

Superposition

Exam Style Question 1

(ii) The intensity of the sound at point P, the minimum, is $\mathbf{4.0 \times 10^{-6}\ W\ m^{-2}}$. Use data from Fig. 5.2 to calculate the maximum intensity of sound, at point $\boldsymbol{O}$.

At P (the minimum) the amplitude is $2.0\ \mu m$ and at O (the maximum) the amplitude is $6.0\ \mu m$.
Therefore the ratio of amplitudes is $= 3$

We know that intensity is proportional to $(amplitude)^2$.
Therefore the ratio of intensities $= 9$.
So intensity at $O = 4.0 \times 10^{-6}\ W\ m^{-2} \times 9 = \mathbf{3.6 \times 10^{-5}\ W\ m^{-2}}$

Superposition

Exam Style Question 2

Fig. 5.1 shows two microwave transmitters A and B $0.20\ m$ apart. The transmitters emit microwaves of frequency $10\ GHz$, of equal amplitude and in phase. A microwave detector is placed at O a distance of $4.0\ m$ from AB.

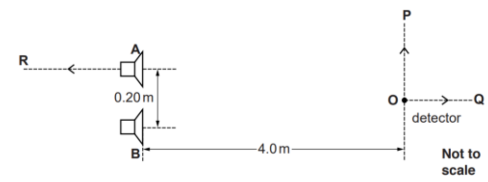


Fig. 5.1

(a) Interference of the waves from the two transmitters is detected only when the transmitters are coherent. Explain the meaning of

(i) Interference

(ii) Coherent

(b) The length of the detector aerial is half a wavelength. Calculate the length of the aerial. Show your working.

(c) (i) 1) Explain why the amplitude of the detected signal changes when the detector is moved in the direction OP.

2) Calculate the distance between adjacent maximum and minimum signals.

Superposition

Exam Style Question 2

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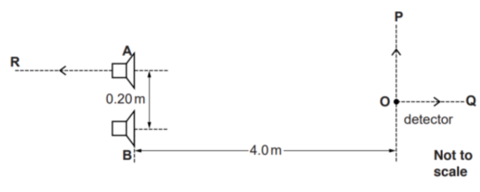

Fig. 5.1

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2) Calculate the distance between adjacent maximum and minimum signals.

Superposition

Exam Style Question 2

(a) Interference of the waves from the two transmitters is detected only when the transmitters are coherent. Explain the meaning of

(i) Interference

When two or more waves meet (or superpose) at a point there is a change in overall displacement.

(ii) Coherent

Constant phase difference between the waves.

(b) The length of the detector aerial is half a wavelength. Calculate the length of the aerial. Show your working.

Use $\lambda = \frac{c}{f}$ (c is $3.0 \times 10^8\ m\ s^{-1}$ because a microwave is an EM wave so it travels at the speed of light).

$$\lambda = \frac{3.0 \times 10^8\ m\ s^{-1}}{10 \times 10^9\ Hz} = 0.03\ m$$

Because the aerial is half a wavelength therefore:

$$aerial\ length = \frac{0.03\ m}{2} = 0.015\ m$$

(c) (i) 1) Explain why the amplitude of the detected signal changes when the detector is moved in the direction OP.

The path difference between the signals from the two transmitter changes along OP causing the detected signal to vary between maximum and minimum values.

(c) (i) 2) Calculate the distance between adjacent maximum and minimum signals.

Use $x = \frac{\lambda D}{a}$

$$x = \frac{(0.03\ m)(4.0\ m)}{0.20\ m} = 0.60\ m$$

Remember x is the distance the maximum to maximum signal so we have to divide it by 2 to get the distance between adjacent maximum and minimum signals:

$$distance = \frac{0.60\ m}{2} = 0.30\ m$$

Exam Style Question 3

Fig. 4.1 shows the variation with time t of the displacement y of the air at a point P in front of a loudspeaker emitting a sound wave of a single frequency.

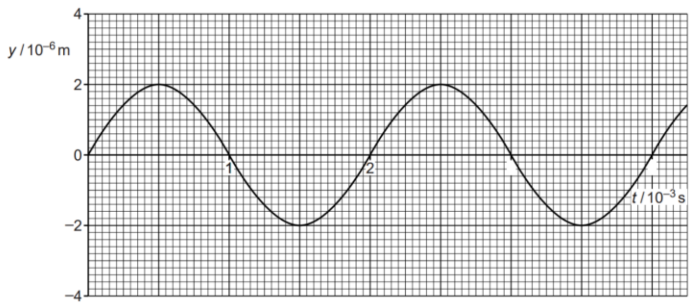

Fig. 4.1

(a) Calculate

(i) the frequency f of oscillation of the air at P,

(ii) the wavelength λ of the wave which is travelling at $340\ m\ s^{-1}$.

(b) Draw on Fig. 4.1 the variation with time of the displacement of the air at a point Q a distance of one quarter of a wavelength $\lambda/4$ beyond P. Label this curve Q.

(c) Explain the meaning of the term phase difference. Illustrate your answer by stating the phase difference between the displacements of the air at the points P and Q.

(d) The amplitude of vibration of the loudspeaker is increased to produce a wave at the original frequency, but of twice the intensity. Sketch on Fig. 4.1 the new displacement against time graph, for $t = 0$ to $t = 2\ \times 10^{-3}\ s$, at point P. Label this curve P. Explain your reasoning.

Superposition

Exam Style Question 3

(a) Calculate

(i) the frequency f of oscillation of the air at P,

Use $f = \frac{1}{T}$

$$f = \frac{1}{2 \times 10^{-3}\ s} = 500\ Hz$$

(ii) the wavelength λ of the wave which is travelling at $340\ m\ s^{-1}$.

Use $v = f\lambda$ and rearrange for λ

$$\lambda = \frac{v}{f} = \frac{340\ m\ s^{-1}}{500\ Hz} = 0.68\ m$$

(b) Draw on Fig. 4.1 the variation with time of the displacement of the air at a point Q a distance of one quarter of a wavelength $\lambda/4$ beyond P. Label this curve Q.

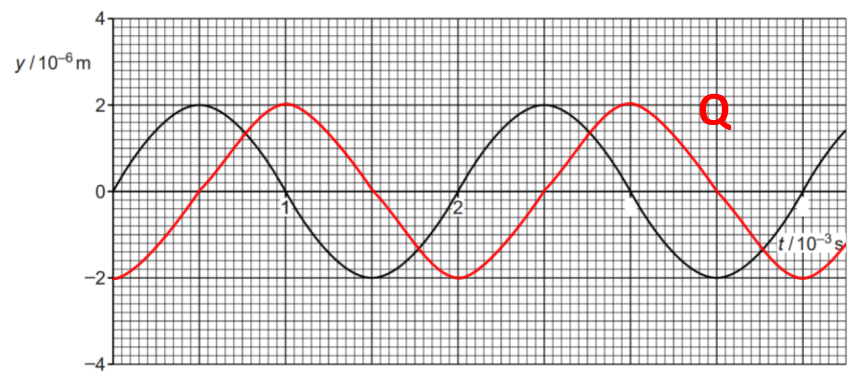

Fig. 4.1

Superposition

Exam Style Question 3

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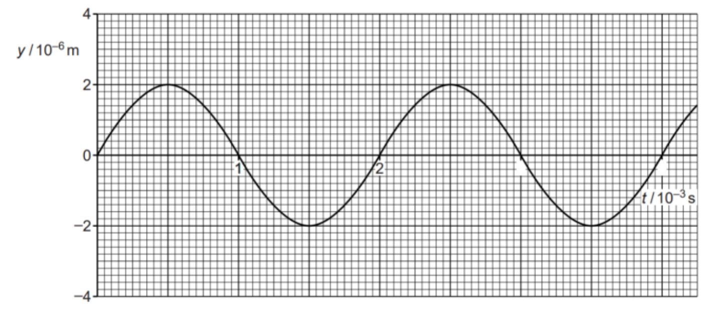

Fig. 4.1

(a) Calculate

(i) the frequency f of oscillation of the air at P,

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(b) Draw on Fig. 4.1 the variation with time of the displacement of the air at a point Q a distance of one quarter of a wavelength $\lambda/4$ beyond P. Label this curve Q.

(c) Explain the meaning of the term phase difference. Illustrate your answer by stating the phase difference between the displacements of the air at the points P and Q.

(d) The amplitude of vibration of the loudspeaker is increased to produce a wave at the original frequency, but of twice the intensity. Sketch on Fig. 4.1 the new displacement against time graph, for $t = 0$ to $t = 2 \times 10^{-3}\ s$, at point P. Label this curve P. Explain your reasoning.

Superposition

Exam Style Question 3

(c) Explain the meaning of the term phase difference. Illustrate your answer by stating the phase difference between the displacements of the air at the points P and Q.

Phase difference relates to the oscillation of two points on a wave and how far 'out of step' one oscillation is from the other. In this case Q is $\frac{\lambda}{4}$ out of phase to P giving it a phase difference of 90° or $\frac{\pi}{2} rads$.

(d) The amplitude of vibration of the loudspeaker is increased to produce a wave at the original frequency, but of twice the intensity. Sketch on Fig. 4.1 the new displacement against time graph, for $t = 0$ to $t = 2 \times 10^{-3}\ s$, at point P. Label this curve P. Explain your reasoning.

Intensity is proportional to $(amplitude)^2$

$$I \propto A^2$$

If intensity increases by 2 then amplitude increases by $\sqrt{2}$.

Therefore the amplitude increase is:

$$amplitude = (2.0 \times 10^{-6})(\sqrt{2}) = 2.8 \times 10^{-6}\ m$$

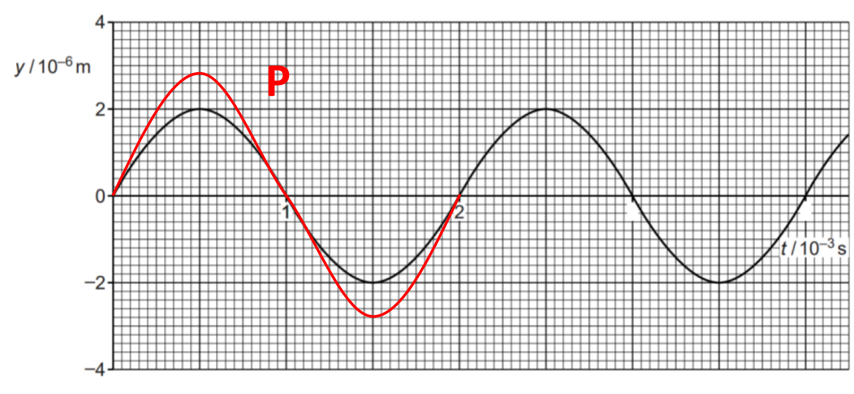


Fig. 4.1

Double-Slit

Exam Style Question 4

The diagram below shows the arrangement for viewing a visible interference pattern on a screen.

In a darkened room, a double slit (S_1 S_2) is placed in front of a narrow single slit situated in front of a monochromatic (one frequency only) light source.

(i) In order to produce a clear interference pattern on the screen, the wave sources must be coherent. State what is meant by coherent.

(ii) Explain how the arrangement shown ensures that the slits S_1 and S_2 act as coherent light sources.

(iii) The point O on the screen is directly opposite the centre of the double slit. State and explain the nature of the interference that occurs at O.

(iv) The distance between slits S_1 and S_2 is $0.6\ mm$. When the screen is placed $1.8\ m$ from the slits, the distance between neighbouring minima in the interference pattern formed on the screen is $2.0\ mm$. Calculate the wavelength of the light.

(v) State and explain how the interference pattern changes when light of a shorter wavelength is used in the experiment.

Double-Slit

Exam Style Question 4

(i) State what is meant by coherent.
Wave sources with a constant phase difference.

(ii) Explain how the arrangement shown ensures that the slits S_1 and S_2 act as coherent light sources.
The monochromatic (single wavelength) light source is shone on a narrow single slit. Diffraction at the single slit causes a diverging beam of light to shine on the two narrow slits S_1 and S_2. Since they are derived from a single source from the single slit the two slits share the same light, and therefore they act as coherent light sources.

(iii) State and explain the nature of the interference that occurs at O.
Constructive interference occurs at O and the waves meet in phase.

(iv) Calculate the wavelength of the light.
Use $\lambda = \frac{ax}{D}$,

$$\lambda = \frac{(0.6 \times 10^{-3}\ m)(2 \times 10^{-3}\ m)}{1.8\ m}$$

$$\lambda = 6.7 \times 10^{-7}\ m$$

(v) State and explain how the interference pattern changes when light of a shorter wavelength is used in the experiment.
Fringe separation would decrease because λ proportional x.

Double-Slit

Exam Style Question 5

This question is about the Young double slit experiment. See Fig. 7.1. The fringe pattern seen on the screen is shown to the right.

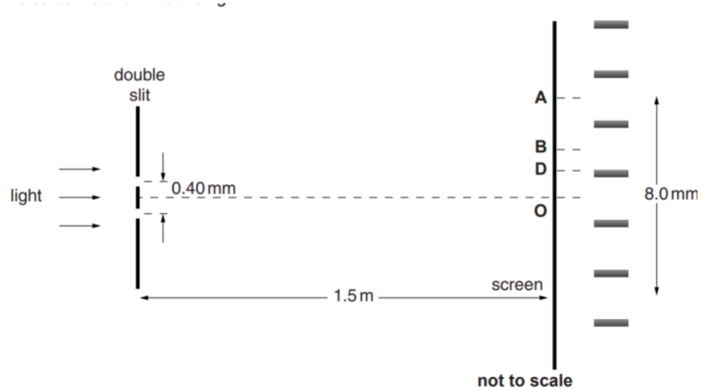


Fig. 7.1

Two parallel clear lines are scratched on a darkened glass slide $0.40\ mm$ apart. When a beam of monochromatic visible light is shone through these slits, interference fringes are observed on a screen placed $1.5\ m$ from the slide. The fringe at point B is bright and the fringe at point D is dark.

(a) Explain why this arrangement with two slits is used to produce visible fringes on the screen rather than two separate identical light sources.

(b) State the phase difference between the light waves from the two slits that meet on the screen in Fig. 7.1 at point

D ....

B ....

(c) (i) Use Fig. 7.1 to calculate the separation of adjacent bright fringes, the distance between O and B.

(ii) Show that the wavelength λ of the monochromatic light is about $5 \times 10^{-7}\ m$.

d) Calculate the path difference, in nanometres, between the light waves from the two slits that meet on the screen in Fig. 7.1 at point A.

Double-Slit

Exam Style Question 5

(a)Explain why this arrangement with two slits is used to produce visible fringes on the screen rather than two separate identical light sources.
Light from the two separate identical light sources need to be coherent and this is only possible if they both have a constant phase difference. It is only possible to produce this constant phase difference using a single source.

(b) State the phase difference between the light waves from the two slits that meet on the screen in Fig. 7.1 at:
Point D: Point D produces a dark fringe, this means that destructive interference takes place. Therefore the waves arrive in antiphase (or are out of phase). So, we know points with a phase difference of odd-number multiples of 180º ($\pi\ rads$) are exactly out of phase.

As point D is the next fringe after the Origin (O) this means the phase difference at point D is $180°$.

Point B: Point B is a light fringe again, and this means a constructive interference takes place and this also means the waves are in phase**.** We know when two points with a phase difference of zero or a multiple of 360º are in phase.

As point B is the very next fringe after D the phase difference is $360°$.

To summarise the phase difference at:

- Point O: $0°$
- Point D: $180°$
- Point B: $360°$

Double-Slit

Exam Style Question 5

This question is about the Young double slit experiment. See Fig. 7.1. The fringe pattern seen on the screen is shown to the right.

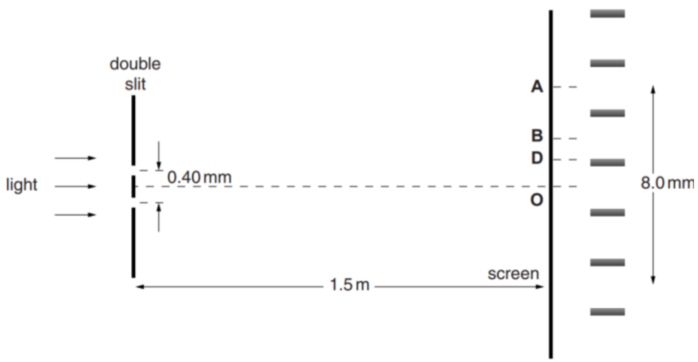


Fig. 7.1

Two parallel clear lines are scratched on a darkened glass slide 0.40 mm apart. When a beam of monochromatic visible light is shone through these slits, interference fringes are observed on a screen placed 1.5 m from the slide. The fringe at point B is bright and the fringe at point D is dark.

(a) Explain why this arrangement with two slits is used to produce visible fringes on the screen rather than two separate identical light sources.

(b) State the phase difference between the light waves from the two slits that meet on the screen in Fig. 7.1 at point

D ....

B ....

(c) (i) Use Fig. 7.1 to calculate the separation of adjacent bright fringes, the distance between O and B.

(ii) Show that the wavelength λ of the monochromatic light is about $5 \times 10^{-7}\ m$.

d) Calculate the path difference, in nanometres, between the light waves from the two slits that meet on the screen in Fig. 7.1 at point A.

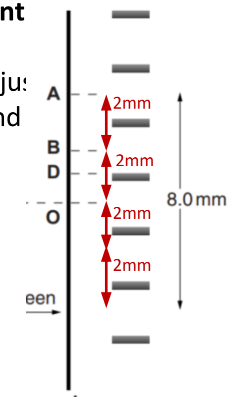
Double-Slit

Exam Style Question 5

(c) (i) Use Fig. 7.1 to calculate the separation of adjacent the distance between O and B.

If you look at the picture opposite you can see that it is jus problem. So the separation of adjacent bright fringes and between O and B is:

$$fringe\ separation = 2mm = 2 \times 10^{-3}\ m$$



(c) (ii) Show that the wavelength λ of the monochromatic light is about $5 \times 10^{-7}\ m$.

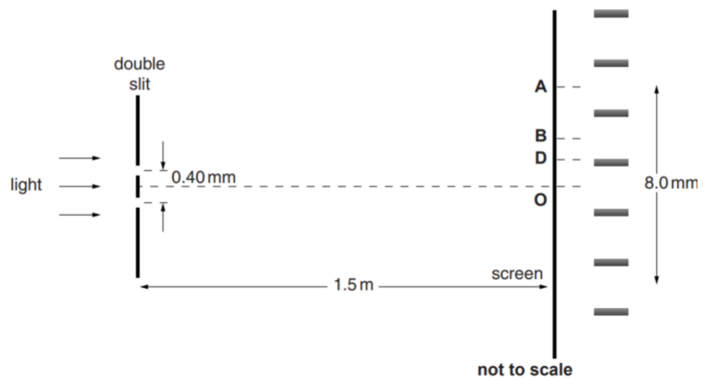
Use $\lambda = \frac{ax}{D}$

$$\lambda = \frac{(0.4 \times 10^{-3}\ m)(2 \times 10^{-3}\ m)}{1.5\ m}$$

$$\lambda = 5.33 \times 10^{-7}\ m$$

Exam Style Question 5

This question is about the Young double slit experiment. See Fig. 7.1. The fringe pattern seen on the screen is shown to the right.



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Two parallel clear lines are scratched on a darkened glass slide $0.40\ mm$ apart. When a beam of monochromatic visible light is shone through these slits, interference fringes are observed on a screen placed $1.5\ m$ from the slide. The fringe at point B is bright and the fringe at point D is dark.

(a) Explain why this arrangement with two slits is used to produce visible fringes on the screen rather than two separate identical light sources.

(b) State the phase difference between the light waves from the two slits that meet on the screen in Fig. 7.1 at point

D ....

B ....

(c) (i) Use Fig. 7.1 to calculate the separation of adjacent bright fringes, the distance between O and B.

(ii) Show that the wavelength λ of the monochromatic light is about $5 \times 10^{-7}\ m$.

d) Calculate the path difference, in nanometres, between the light waves from the two slits that meet on the screen in Fig. 7.1 at point A.

Double-Slit

Exam Style Question 5

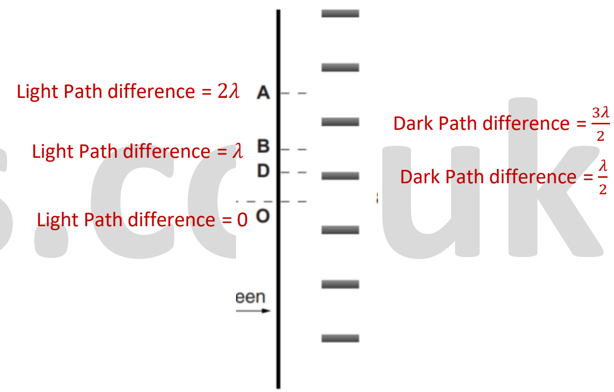
d) Calculate the path difference, in nanometres, between the light waves from the two slits that meet on the screen in Fig. 7.1 at point A.

So looking at the path difference for A is 2λ and we know $\lambda = 5.33 \times 10^{-7}\ m$.

Therefore the path difference between the light waves from the two slits that meet on the screen at point A is:

$$Path\ difference = 2\lambda = 2(5.33 \times 10^{-7}\ m)$$

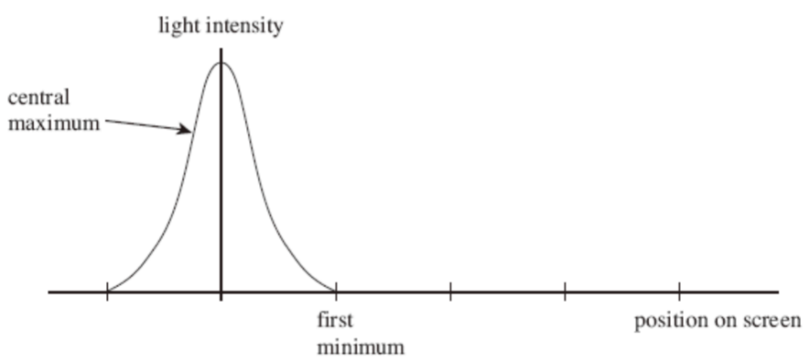
$$Path\ difference = 1.066 \times 10^{-6}\ m = 1060\ nm$$



Superposition (AQA Only)

Exam Style Question 6

A single slit diffraction pattern is produced on a screen using a laser. The intensity of the central maximum is plotted on the axes in the figure below.



(a) On the figure above, sketch how the intensity varies across the screen to the right of the central maximum.

(b) A laser is a source of monochromatic, coherent light. State what is meant by monochromatic light and coherent light.

(c) Describe how the pattern would change if light of a longer wavelength was used.

(d) State two ways in which the appearance of the fringes would change if the slit was made narrower.

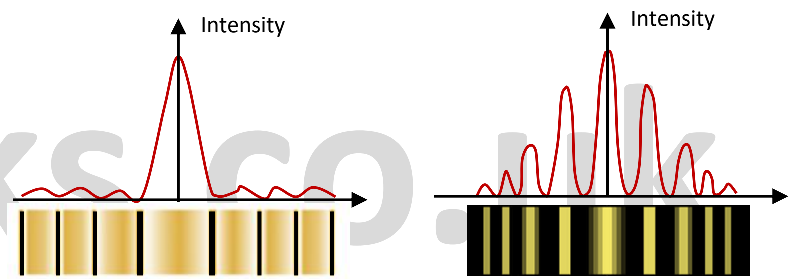
(e) The laser is replaced with a lamp that produces a narrow beam of white light. Sketch and label the appearance of the fringes as you would see them on a screen.

Superposition (AQA Only)

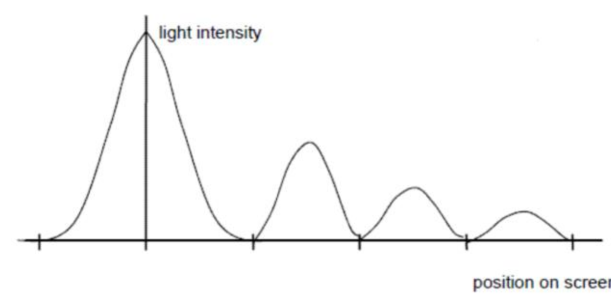
Exam Style Question 6

(a) On the figure above, sketch how the intensity varies across the screen to the right of the central maximum.

The diffraction pattern produced by light passing through a single slit differs from that of a double slit. The below diagram shows the patterns for both cases. For a single slit, there is a larger central maximum and a rapid decrease in intensity on either side. In contrast, a double slit pattern has fringes of nearly equal size and a slower intensity decrease.



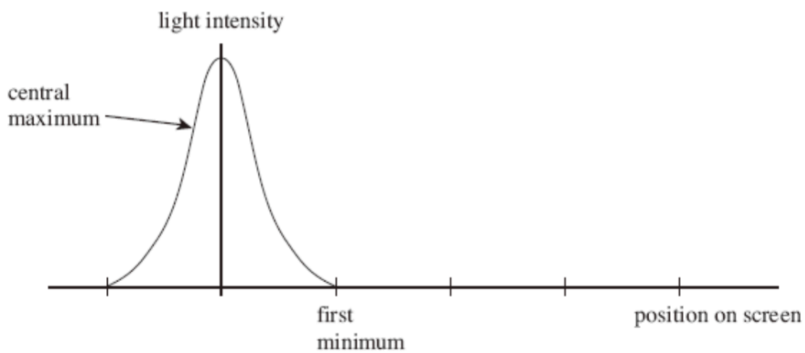
So the graph looks like the one below:



Superposition (AQA Only)

Exam Style Question 6

A single slit diffraction pattern is produced on a screen using a laser. The intensity of the central maximum is plotted on the axes in the figure below.



(a) On the figure above, sketch how the intensity varies across the screen to the right of the central maximum.

(b) A laser is a source of monochromatic, coherent light. State what is meant by monochromatic light and coherent light.

(c) Describe how the pattern would change if light of a longer wavelength was used.

(d) State two ways in which the appearance of the fringes would change if the slit was made narrower.

(e) The laser is replaced with a lamp that produces a narrow beam of white light. Sketch and label the appearance of the fringes as you would see them on a screen.

Superposition (AQA Only)

Exam Style Question 6

(b) A laser is a source of monochromatic, coherent light. State what is meant by monochromatic light and coherent light.
Monochromatic light: is light of a single wavelength (and frequency).
Coherent light: constant phase difference.

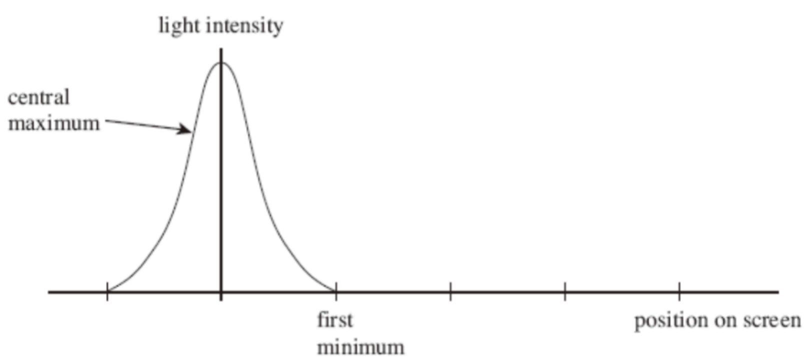
(c) Describe how the pattern would change if light of a longer wavelength was used.
Increasing the wavelength increase the amount of diffraction. This means the central maximum is wider, maxima are further apart, and the intensity of the central maximum is lower.

(d) State two ways in which the appearance of the fringes would change if the slit was made narrower.
Decreasing the slit width increases the amount of diffraction. This means the central maximum is wider, and the intensity of the central maximum is lower.
(A wider slit lets more light through, which adds to the increase in intensity and a narrower slit lets less light through).

Superposition (AQA Only)

Exam Style Question 6

A single slit diffraction pattern is produced on a screen using a laser. The intensity of the central maximum is plotted on the axes in the figure below.



(a) On the figure above, sketch how the intensity varies across the screen to the right of the central maximum.

(b) A laser is a source of monochromatic, coherent light. State what is meant by monochromatic light and coherent light.

(c) Describe how the pattern would change if light of a longer wavelength was used.

(d) State two ways in which the appearance of the fringes would change if the slit was made narrower.

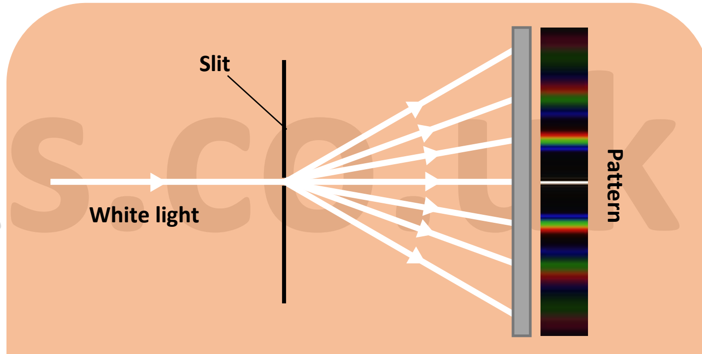
(e) The laser is replaced with a lamp that produces a narrow beam of white light. Sketch and label the appearance of the fringes as you would see them on a screen.

Superposition (AQA Only)

Exam Style Question 6

(e) The laser is replaced with a lamp that produces a narrow beam of white light. Sketch and label the appearance of the fringes as you would see them on a screen.

White light is actually a mixture of different colours, each with different wavelengths. When white light is shone through a single narrow slit, all of the different wavelengths are diffracted by different amounts. This means that instead of getting clear fringes (as you would with a monochromatic light source) you get spectra of colours, as shown below:



- Colours are present within each subsidiary maxima.
- Blue/violet on the inner edge and red on the outer edge.
- Middle of the pattern is a central maximum which is white

Diffraction Grating

Exam Style Question 7

This question is about the light from low energy compact fluorescent lamps which are replacing filament lamps in the home.

The light from a compact fluorescent lamp is analysed by passing it through a diffraction grating. Fig. 6.1 shows the angular positions of the three major lines in the first order spectrum and the bright central beam.

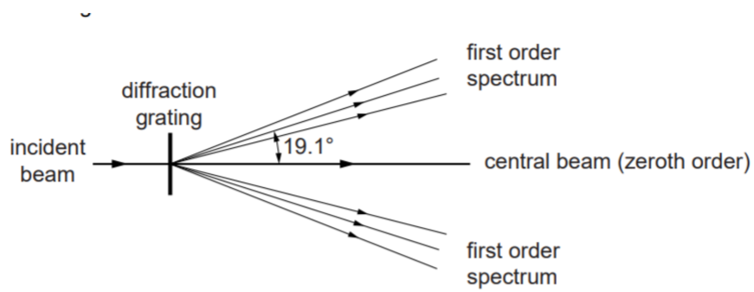


Fig. 6.1

(i) On Fig. 6.1 label one set of the lines in the first order spectrum R, G and V to indicate which is red, green and violet.

(ii) Explain why the bright central beam appears white.

(iii) The line separation d on the grating is $1.67 \times 10^{-6}\ m$.

Calculate the wavelength λ of the light producing the first order line at an angle of 19.1° to the central bright beam.

Diffraction Grating

Exam Style Question 7

(i) On Fig. 6.1 label one set of the lines in the first order spectrum R, G and V to indicate which is red, green and violet.

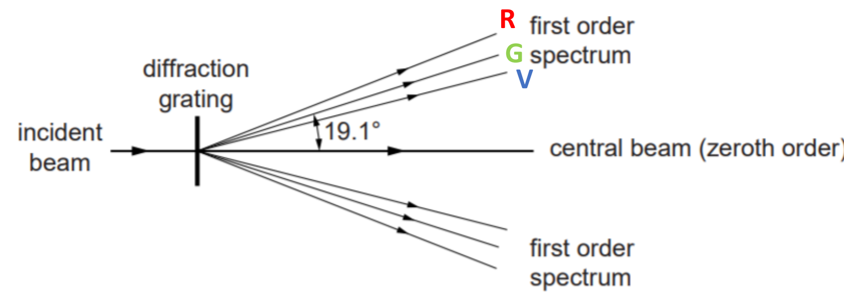


Fig. 6.1

(ii) Explain why the bright central beam appears white.

The three colours superpose (add up) to give the white light.

(iii) The line separation d on the grating is $1.67 \times 10^{-6}\ m$. Calculate the wavelength λ of the light producing the first order line at an angle of $19.1°$ to the central bright beam.

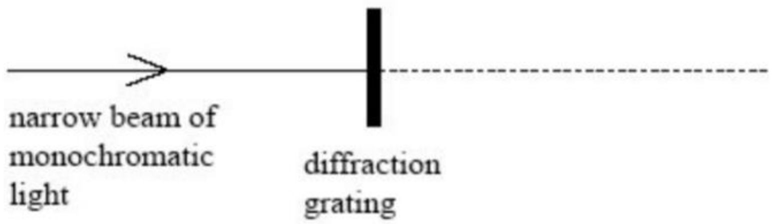
Use $\lambda = d\ sin\theta$

$$\lambda = (1.67 \times 10^{-6}\ m)\sin(19.1°)$$
$$\lambda = 546 \times 10^{-9}\ m$$

Diffraction Grating

Exam Style Question 8

A narrow beam of monochromatic light of wavelength 590 nm is directed normally at a diffraction grating, as shown in the diagram below.



(a) The grating spacing of the diffraction grating is $1.67 \times 10^{-6}\ m$.

(i) Calculate the angle of diffraction of the second order diffracted beam.

(ii) Show that no beams higher than the second order can be observed at this wavelength.

(b) The light source is replaced by a monochromatic light source of unknown wavelength.

A narrow beam of light from this light source is directed normally at the grating.

Measurement of the angle of diffraction of the second order beam gives a value of 42.1°. Calculate the wavelength of this light source.

Diffraction Grating

Exam Style Question 8

(a) (i) Calculate the angle of diffraction of the second order diffracted beam.

Use $d \sin\theta = n\lambda$ and rearrange for θ

$$\sin\theta = \frac{n\lambda}{d} = \frac{(2)(590 \times 10^{-9}\ m)}{1.67 \times 10^{-6}\ m}$$
$$\sin\theta = 0.7065868263$$
$$\theta = \sin^{-1}(0.70658\ldots)$$
$$\theta = 45.0°\ (1\ d.p)$$

(a) (ii) Show that no beams higher than the second order can be observed at this wavelength.

Substitute $n = 3$ into $d \sin\theta = n\lambda$

$$\sin\theta = \frac{n\lambda}{d} = \frac{(3)(590 \times 10^{-9}\ m)}{(1.67 \times 10^{-6}\ m)}$$
$$\sin\theta = 1.05988024$$
$$\theta = \sin^{-1}(1.059\ldots) = Error$$

Therefore no beams higher than the second order can be observed at this wavelength.

(b) Calculate the wavelength of this light source.

Use $d \sin\theta = n\lambda$ and rearrange for λ

$$\lambda = \frac{d\sin\theta}{n} = \frac{(1.67 \times 10^{-6}\ m)\sin(42.1°)}{2}$$
$$\lambda = 5.60 \times 10^{-7}\ m$$

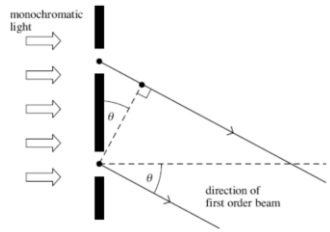
Diffraction Grating

Exam Style Question 9

For a plane transmission diffraction grating, the diffraction grating equation for the first order beam is:

$$\lambda = d \sin\theta$$

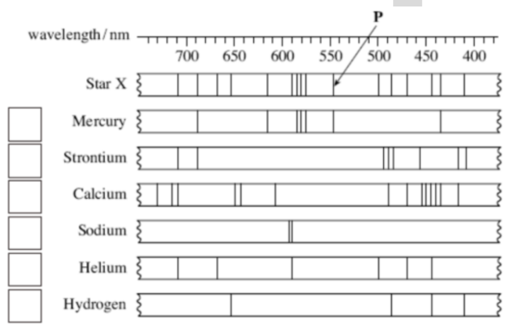
(a) The figure below shows two of the slits in the grating. Label the figure below with the distances d and λ.



(b) State and explain what happens to the value of angle θ for the first order beam if the wavelength of the monochromatic light decreases.

(c) A diffraction grating was used with a spectrometer to obtain the line spectrum of star X shown in the figure below. Shown are some line spectra for six elements that have been obtained in the laboratory.

Place ticks in the boxes next to the three elements that are present in the atmosphere of star X.



(d) The diffraction grating used to obtain the spectrum of star X had 300 $slits\ per\ mm$.

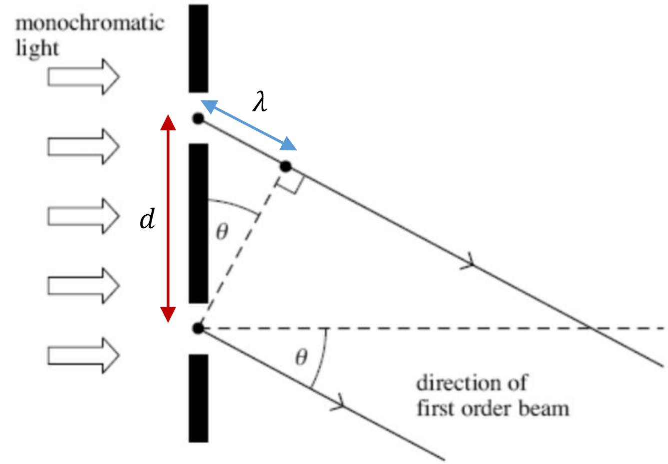
(i) Calculate the distance between the centres of two adjacent slits on this grating.

(ii) Calculate the first order angle of diffraction of line P in the figure above.

Diffraction Grating

Exam Style Question 9

(a)The figure below shows two of the slits in the grating. Label the figure below with the distances d and λ.



(b) State and explain what happens to the value of angle θ for the first order beam if the wavelength of the monochromatic light decreases.

If the wavelength of the light decreases the angle θ gets smaller because path difference gets smaller so sin θ is smaller. $\boldsymbol{d sin\theta = n\lambda}$

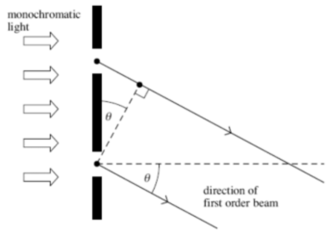
Diffraction Grating

Exam Style Question 9

For a plane transmission diffraction grating, the diffraction grating equation for the first order beam is:

$$\lambda = d \sin\theta$$

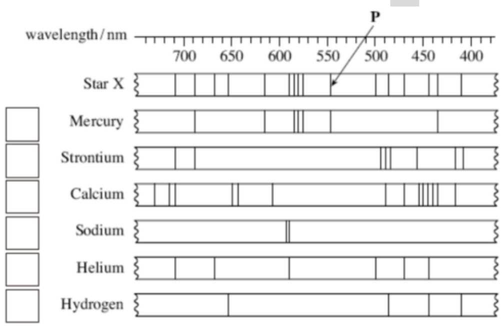
(a) The figure below shows two of the slits in the grating. Label the figure below with the distances d and λ.



(b) State and explain what happens to the value of angle θ for the first order beam if the wavelength of the monochromatic light decreases.

(c) A diffraction grating was used with a spectrometer to obtain the line spectrum of star X shown in the figure below. Shown are some line spectra for six elements that have been obtained in the laboratory.

Place ticks in the boxes next to the three elements that are present in the atmosphere of star X.



(d) The diffraction grating used to obtain the spectrum of star X had 300 $slits\ per\ mm$.

(i) Calculate the distance between the centres of two adjacent slits on this grating.

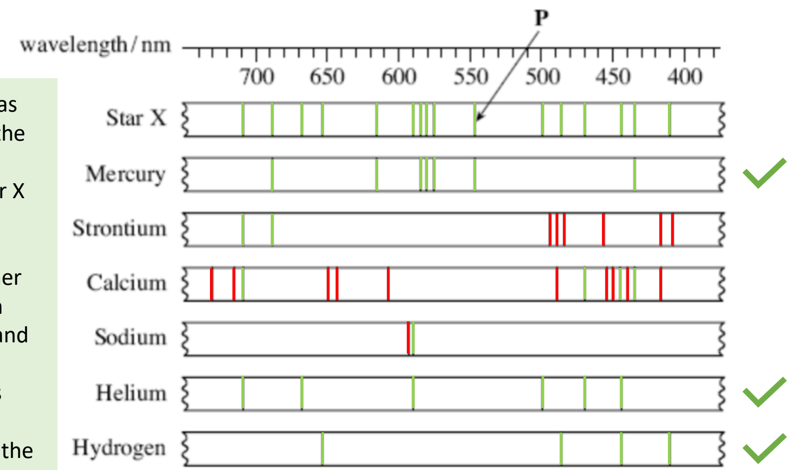
(ii) Calculate the first order angle of diffraction of line P in the figure above.

Diffraction Grating

Exam Style Question 9

(c) Place ticks in the boxes next to the three elements that are present in the atmosphere of star X.

All you have to do is match the lines of the six elements line spectrum to the Star X line spectrum. If the lines match then those elements are present. I.e.:



My approach was to colour-code the lines in the line spectrum of Star X as green. If the lines in the line spectrum of other elements match those of Star X and are also green, then it indicates the presence of that element in the atmosphere.

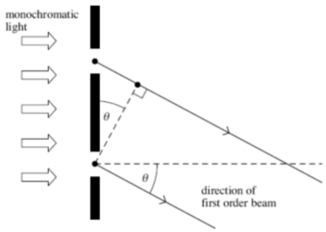
Therefore, Mercury, Helium and Hydrogen have lines that match with Star X line spectrum and are present in the atmosphere of Star X.

Exam Style Question 9

For a plane transmission diffraction grating, the diffraction grating equation for the first order beam is:

$$\lambda = d \sin\theta$$

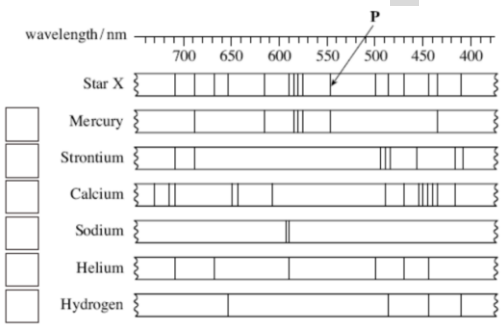
(a) The figure below shows two of the slits in the grating. Label the figure below with the distances d and λ.



(b) State and explain what happens to the value of angle θ for the first order beam if the wavelength of the monochromatic light decreases.

(c) A diffraction grating was used with a spectrometer to obtain the line spectrum of star X shown in the figure below. Shown are some line spectra for six elements that have been obtained in the laboratory.

Place ticks in the boxes next to the three elements that are present in the atmosphere of star X.



(d) The diffraction grating used to obtain the spectrum of star X had 300 $slits\ per\ mm$.

(i) Calculate the distance between the centres of two adjacent slits on this grating.

(ii) Calculate the first order angle of diffraction of line P in the figure above.

Diffraction Grating

Exam Style Question 9

(d) (i) Calculate the distance between the centres of two adjacent slits on this grating.

$$d = \frac{1}{D} = \frac{1}{300} = 3.33 \times 10^{-3}\ mm = 3.33 \times 10^{-6} m$$

(d) (ii) Calculate the first order angle of diffraction of line P in the figure above.

Use $\lambda = d \sin\theta$ and rearrange for θ

$$\sin\theta = \frac{\lambda}{d} = \frac{550 \times 10^{-9}\ m}{3.33 \times 10^{-6}\ m}$$
$$\sin\theta = 0.1651651652$$
$$\theta = \sin^{-1}(0.165165\ldots)$$
$$\theta = 9.5° \ (1\ d.p.)$$

Please see '4.3.1 Superposition notes' pack for revision notes.

For more revision notes, tutorials and worked examples please visit www.tutorpacks.co.uk.