Worksheet 1 Solutions ⇒ Module 7

1. Monochromatic light falls on 2 slits separated by 0.3 mm. The resulting interference pattern falls on a screen 0.3 m distant from the slits. The centre of the dark band next to the central maximum is found to be 2.25×10^{-4} m from the centre of the central maximum.

   (a) What is the wavelength of the monochromatic light?

   For dark band ⇒ $\lambda = \frac{dy}{(m-\frac{1}{2})L} = \frac{0.3\times10^{-3}\times 2.25\times10^{-4}}{(1-\frac{1}{2})\times 0.3}$

   $= 4.5\times10^{-7}$ m

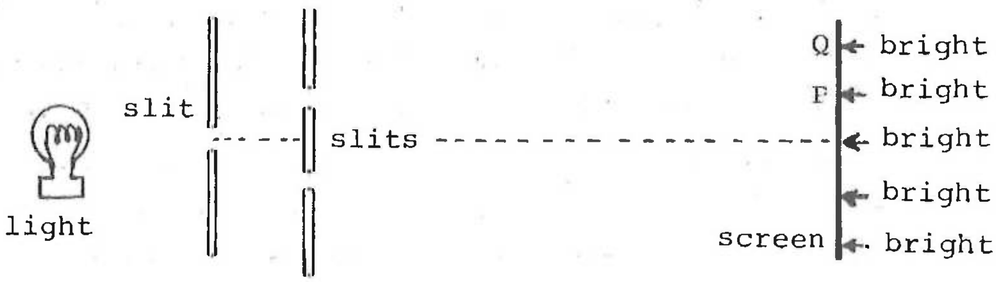
   (b) What is the colour of this light? Blue

   (c) What distance will there be between the central maximum and the third bright band to one side?

   $y = \frac{mL\lambda}{d} = \frac{3\times 0.3\times 4.5\times10^{-7}}{0.3\times10^{-3}}$

   $= 1.35\times10^{-3}$ m

2. The next question refers to the diagram below.



The incident light is a mixture of two wavelengths, one in the red end of the spectrum and one in the blue.

There are two bright bands, adjacent to the central bright band, which are labelled P & Q. Which will be blue and which red?

$d\sin\theta = m\lambda$ P = blue

$\lambda = \frac{d\sin\theta}{m}$, $\lambda \propto \sin\theta \propto \theta$, for θ small. Q = red

So, the larger λ, the larger θ. ∴ Q must be red (larger λ).

1. Light of wave length 580 nm is passed through a diffraction grating of 6000 lines per centimetre. What is the angle at which the first order maxima would be observed.

$d \sin\theta = m\lambda$

$\sin\theta = \frac{m\lambda}{d} = \frac{1 \times 580 \times 10^{-9}}{1.67 \times 10^{-6}} = 0.3480$

$\therefore \theta = 20^\circ 22'$

$d = \frac{0.01\,m}{6000 \text{ lines}} = 1.67 \times 10^{-6}\,m$

2. A laser beam emitting red light of 650 nm is shone upon a diffraction grating which has 2000 lines per cm scratched on it. The grating is positioned immediately in front of the centre of a screen and is 3 metres from the screen. If the screen is 3 metres wide, how many red spots will appear on the screen?

$d = \frac{0.01}{2000} = 5 \times 10^{-6}\,m$

Bandwidth (distance between successive bright fringes) $= \frac{\lambda L}{d}$

$= \frac{650 \times 10^{-9} \times 3}{5 \times 10^{-6}} = 0.39\,m$

Screen is 3 m wide.

$\therefore 3/0.39 = 7$ red spots on screen.

3. A diffraction grating has 8000 lines per centimetre and is used to determine the wavelength of light. It is observed that there is a bright line 6° either side of the central (straight through) position. What is the wavelength and frequency of the light being observed.

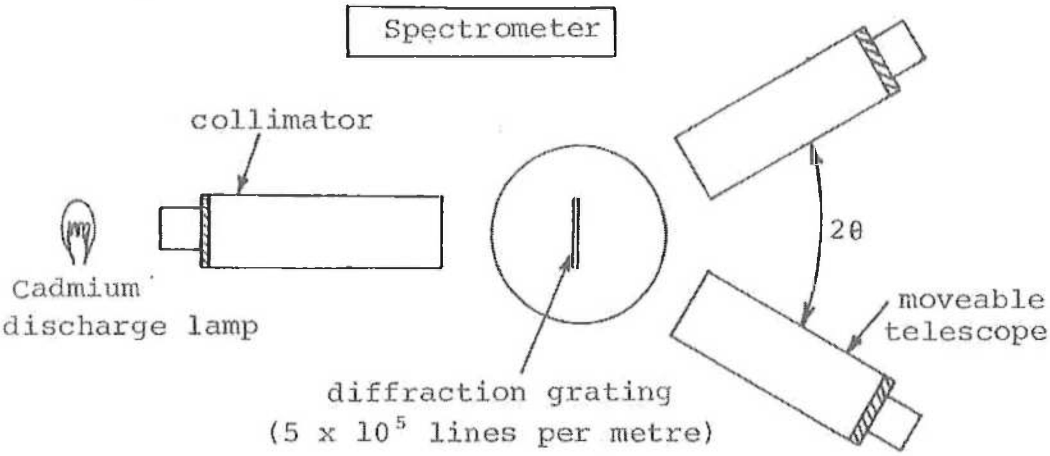
$m\lambda = d \sin\theta$

$\lambda = \frac{1.25 \times 10^{-6} \sin 6^\circ}{1} = 1.3 \times 10^{-7}\,m$

$d = \frac{0.01}{8000} = 1.25 \times 10^{-6}\,m$

From $c = \lambda f$, $f = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{1.3 \times 10^{-7}} = 2.3 \times 10^{15}\,Hz$

1. This question refers to the diagram below.



A student studies the emission spectrum of Cadmium using a spectrometer and diffraction grating as shown. For each spectral line she measures the angle 2θ. Find 2θ for the lines listed below and write your answers in the appropriate column in the table.

$d = \frac{1.0}{5 \times 10^5} = 2 \times 10^{-6}$ m

Use $m\lambda = d\sin\theta$

Assume all lines are first order maxima ∴ m = 1

Colour	Wavelength ($\times 10^{-7}$ m)	2θ
Orange	6.438	37.56°
Green	5.155	29.88°
Green	5.086	29.46°
Blue	4.800	27.77°
Blue	4.678	27.05°
Blue	4.412	25.49°

eg $\sin\theta = \frac{\lambda}{d} = \frac{6.438 \times 10^{-7}}{2 \times 10^{-6}} = 0.3219$

∴ θ = 18.78°

∴ 2θ = 37.56°

2. Monochromatic light falls on a diffraction grating which has 6×10^5 lines per metre. The angle between the two first order maxima is measured to be 60°. What is the wavelength of the light?

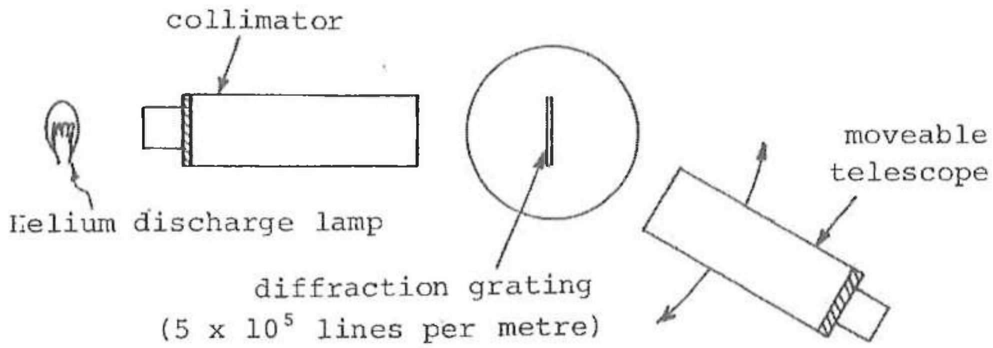
$d = \frac{1.0}{6 \times 10^5} = 1.67 \times 10^{-6}$ m   2θ = 60° ∴ θ = 30°

∴ $m\lambda = d\sin\theta$

$\lambda = \frac{d\sin\theta}{m} = \frac{1.67 \times 10^{-6} \times \sin 30^\circ}{1} = 8.3 \times 10^{-7}$ m

1. This question refers to the diagram below.

Spectrometer



A student uses a spectrometer to find the wavelength of the prominent lines in the emission spectrum of helium. He measures the angle (2θ) between the two first order maxima for each spectral line. His results are tabulated below. Calculate the wavelength of each line. Write your answer in the appropriate column in the table below.

Again
$d = 2\times10^{-6}$ m
Assume all first order maxima ⇒ m = 1.
∴ $\lambda = d\sin\theta$

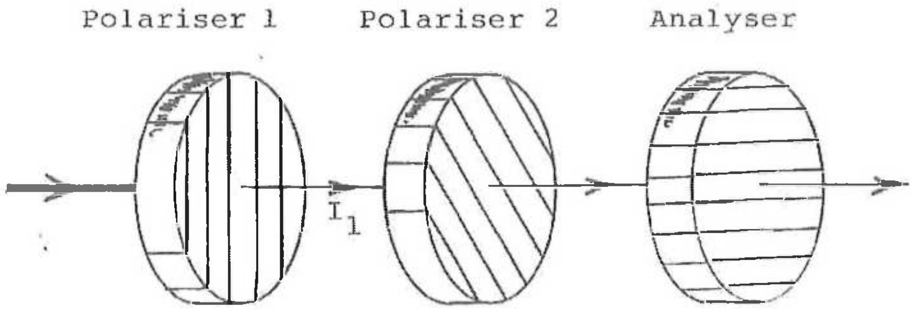
Colour	Angle (2θ)	Wavelength (m)
Red	41.37°	7.06×10^{-7}
Red	39.01°	6.68×10^{-7}
Orange	34.17	5.88×10^{-7}
Blue-green	29.04	5.01×10^{-7}
Blue	28.49	4.92×10^{-7}
Blue	27.28	4.72×10^{-7}
Blue	25.84	4.47×10^{-7}

eg $\lambda = d\sin\theta$

$= 2\times10^{-6}\cdot\sin\left(\frac{41.37^\circ}{2}\right)$

$= 7.06\times10^{-7}$ m

The next 2 questions refer to the diagram below.



1. Light of intensity I_1 is transmitted by polariser 1. Polariser 2 is at 60° to polariser 1 and 30° to the analyser.

What intensity (in terms of I_1), will be transmitted by polariser 2?

$I = I_0 \cos^2\theta$

$I = I_1 \cos^2 60^{\circ}$, $\cos 60^{\circ} = \frac{1}{2}$

$\therefore I = 0.25 I_1$

2. What intensity (in terms of I_1), will be transmitted by the analyser?

$I = I_0 \cos^2\theta$

$I = (0.25 I_1) \cdot \cos^2 30^{\circ}$

$= 0.25 I_1 \times \left(\frac{\sqrt{3}}{2}\right)^2$, $\cos 30^{\circ} = \frac{\sqrt{3}}{2}$

$= 0.25 I_1 \times 0.75$

$= 0.1875 I_1$

$\doteqdot 0.19 I_1$ or $\frac{3}{16} I_1$

1. The wavelength of the pair of dominant yellow lines (which are very close together) in the emission spectrum of sodium is about 5.9×10^{-7} m. When this wavelength is measured in the emission spectrum of galaxies A, B, C, D and E, the results are as shown in the table below.

(a) Fill in the blank spaces in the table below to indicate whether

(i) the measurements indicate a red or a blue shift

(ii) the galaxy in receding or approaching.

(*) If wavelength ↑, light is red shifted, galaxy is receding.

Galaxy	Wavelength of sodium lines as measured on Earth (m)	Red Shift or Blue Shift	Galaxy receding or Approaching
A	7×10^{-7}	Red Shift	Receding
B	3×10^{-7}	Blue Shift	Approaching
C	8×10^{-7}	Red	Receding
D	4×10^{-7}	Blue	Approaching
E	5.9×10^{-7}	None	Neither

(b) Which of the galaxies is

i) receding at the greatest velocity?

C, since it has the largest red shift

ii) approaching at the greatest velocity?

B, since it has the largest blue shift

2. A car is driven towards an observer standing beside the road. The driver of the car continually sounds the car horn.

As the car passes the observer at high speed, explain what happens to the pitch of the car horn as perceived by the:

(a) observer pitch lowers

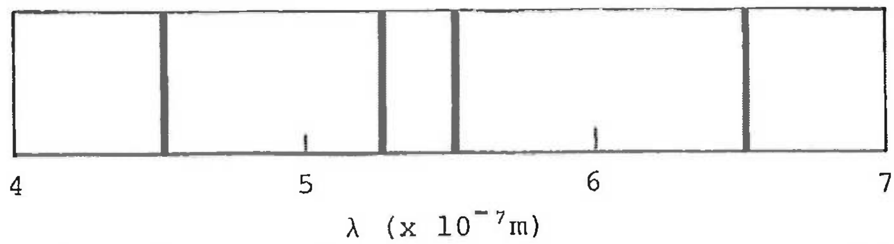
(b) driver no change

(c) A second car overtakes the car which has its horn sounding. What happens to the pitch of the car horn as perceived by the driver of the overtaking car.

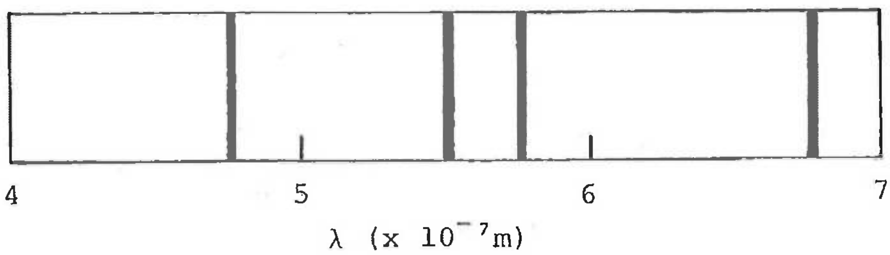
Pitch rises as 2nd car approaches, then falls as it passes + moves further away.

(d) What name is given to this effect? Doppler Effect

1. The emission spectrum of a certain element is shown below:



Emission lines are found in light coming from a distant galaxy as shown below:



Is the relative movement of the galaxy towards or away from the earth? Explain your answer.

Away from Earth ⇒ since lines in the spectrum have been red shifted – that is have moved toward higher wavelength (red end of spectrum).

(a) NOT required for current syllabus

2. A space ship, approaching earth at a velocity of 3×10^7 ms^{-1}, emits a beam of yellow light of frequency 5×10^{14} hz.

(a) What frequency will be detected by an observer on earth?

$$f_o = \frac{f_s(1 + v/c)}{\sqrt{1 - (v/c)^2}} = \frac{5\times10^{14}\left(1 + \frac{3\times10^7}{3\times10^8}\right)}{\sqrt{1 - \left(\frac{3\times10^7}{3\times10^8}\right)^2}}$$

~~Doppler Effect for Light~~ formula

$$= 5.5 \times 10^{14}\ Hz$$

(b) + (c) This could be asked

(b) What is the wavelength of the detected beam ?

$c = f\lambda$, $\lambda = c/f = 3\times10^8 / 5.5\times10^{14} = 5.4\times10^{-7}\ m$

(c) What colour is this? Green