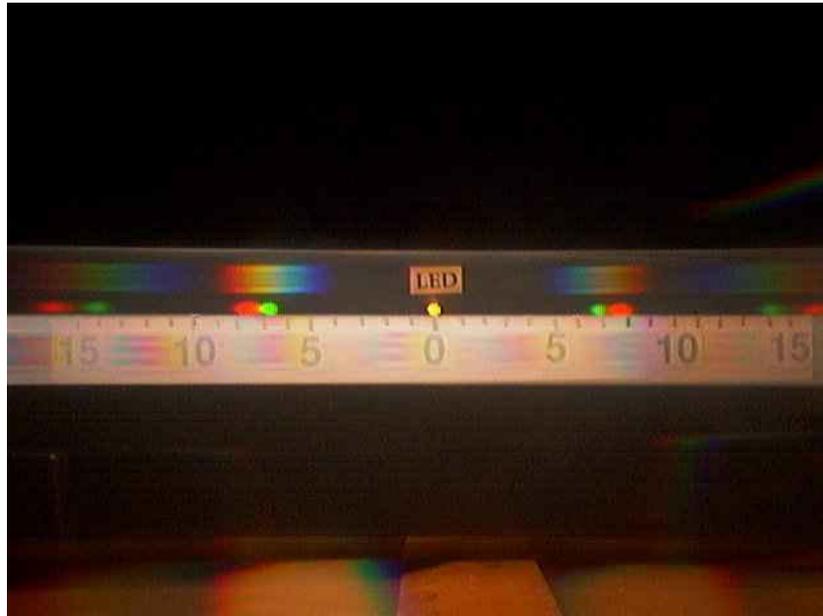# TAP 322- 4: Using diffraction gratings

**Instructions**

The photograph shows a two-colour light-emitting diode (LED) viewed through a diffraction grating. The grating has 300 lines per millimetre and is placed over the camera lens that is 400 mm from the LED. The scale shown is in centimetres.

1.   How can you tell that the LED is giving out two distinct colours?

2.   The grating has 300 lines per millimetre. What is the spacing between the lines?

3.   Look at the first-order green image, and work out the angle at which the green light is being diffracted by the grating.

4.   Calculate the wavelength of the green light

5.   Repeat the calculations for the first-order red image of the LED.

6. Looking at the second-order images, make further measurements to confirm your wavelength calculations.

7. How many further orders could be created using this grating?
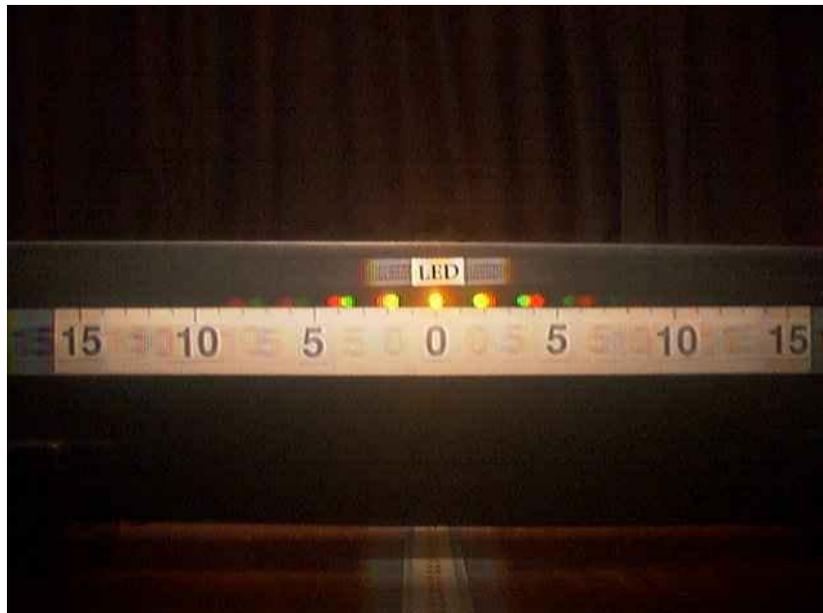
8. This photograph uses a different grating but the same LED as before. Calculate the spacing between the lines in this grating and the number of lines per millimetre on the grating.

Look carefully at the next image. It is street scene taken through a diffraction grating. There are three major light sources A, B, C. Two of these are street lights; the third is a domestic security floodlight.

9.   By looking at the spectra produced by the three sources write down the two sources that are similar. What is the difference in the spectra produced by the two types of light?

The next view of the street light shows the detail of the spectrum more clearly.

10.   How many distinct colours are present in the spectrum from the street light?

11.   Other street lights produce a more yellow light from 'sodium vapour lamps' which consists of only one colour of light. How would such a street light appear if viewed through a diffraction grating?

Hints

3.   It may be helpful to draw a triangle showing the positions of the LED, camera and image. The angle required will be the angle subtended at the camera by the LED and its image.

4.   The grating equation $n\lambda = d\sin\theta$ should be used here.

6.   Remember that here n = 2.

7.   The maximum value that $\sin\theta$ can take is 1.

8.   Use the clearer second-order image to calculate d, using $n\lambda = d\sin\theta$. Remember this is the spacing between adjacent slits.

9.   The second-order spectrum produces clearer separation of the colours.

Practical advice

This gives good practice at using the equation n λ = d sin θ.

Alternative approaches

It is a good idea, if possible, to provide students with cheap diffraction gratings to take home and use to look at a variety of sources of light.

Answers and worked solutions

1. There are two distinct coloured images of the LED in the first-order spectrum.

2. 3.3×10^{-6} m.

3. The first order green image is at about 68 mm.

    tan θ = 68 mm / 400 mm

    θ = 9.5º

4. λ = d sin θ

    λ = 3.3×10^{-6} m sin 9.5°

    λ = 550nm

5. The first order red image is at 75 mm

    tan θ = 75mm / 400 mm

    θ = 10.8°

    λ = d sin θ

    λ = 3.3×10^{-6} m sin 10.8°

    λ = 620nm

6. The second order green image is at 140 mm

    tan θ = 140 mm / 400 mm

    θ = 19.3°

    2λ = d sin θ

    2λ = 3.3×10^{-6} m sin 19.3°

    λ = 545 nm

    The second order red image is at 152 mm.

    tan θ = 160 mm / 400 mm

    θ = 21.8°

    2λ = d sin θ

    2λ = 3.3×10^{-6} m sin 21.8°

    λ = 316 nm

7. Orders are theoretically possible for angles up to 90° for sin θ < 1

    so nλ / d< 1 and hence n < d/ λ:

    For red light n < 3.3×10^{-6} m / 620×10^{-9} m = 5.4 so 5 orders for red light.

For green light $n < 3.3 \times 10^{-6}$ m / 540×10^{-9} m = 6.1 so 6 orders for green light.

8. Second order red image is at 42 mm.

    $\tan \theta$ = 42 mm / 400 mm

    $\theta = 6.0°$

    $2\lambda = d \sin \theta$

    $d = 2\lambda / \sin \theta$

    $d = 2 \times 620 \times 10^{-9}$ m /sin 6.0°

    $d = 1.2 \times 10^{-5}$ m

    = 83 lines / mm

9. A and B. The street light produces only a few specific colours of light whereas the security floodlight produces the whole range of colours in the spectrum.

10. Four colours are present: violet, green, yellow, red.

11. There would be only one band at a specific yellow colour for each order of spectrum produced.

External reference

This activity is taken from Advancing Physics chapter 6, 210S