## State Examination Commission – Physics Higher Level, 2009

## Question 7

When light shines on a compact disc it acts as a diffraction grating causing diffraction and dispersion of the light.
Explain the underlined terms. (12)
Derive the diffraction grating formula. . (12)
An interference pattern is formed on a screen when green light from a laser passes normally through a diffraction grating. The grating has 80 lines per mm and the distance from the grating to the screen is 90 cm. The distance between the third order images is 23.8 cm.
Calculate
(i) the wavelength of the green light;
(ii) the maximum number of images that are formed on the screen. (21)
The laser is replaced with a source of white light and a series of spectra are formed on the screen.
Explain
(iii) how the diffraction grating produces a spectrum;
(iv) why a spectrum is **not** formed at the central (zero order) image. (11)

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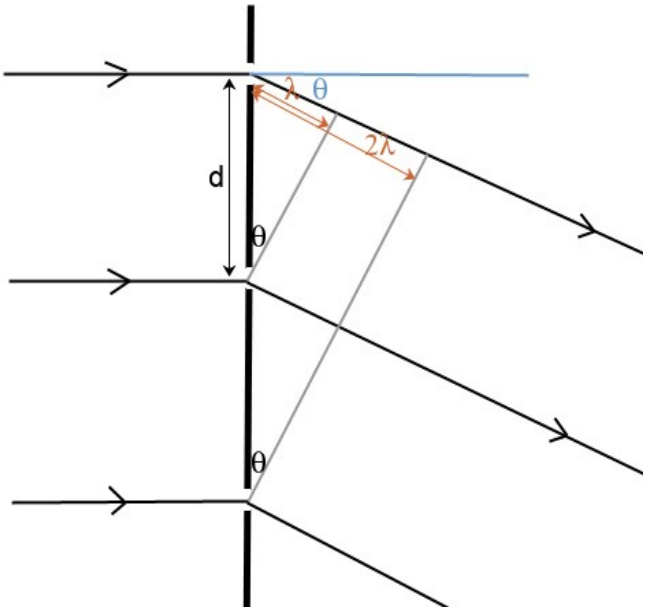
Textbook
Derive the diffraction grating formula. . (12)




The first-order fringe occurs when light from slit one has travelled one wavelength farther than light from slit two. Also the light from slit two has travelled one wavelength farther than light from slit three, and so forth. The extra distance travelled by light from any adjacent slits is one wavelength.

For any two adjacent slits, $\sin \theta_1 = \lambda/d$.

By the same reasoning, the second-order fringe occurs when the extra distance travelled by light from any adjacent slits is two wavelengths.

In general, for the $n^{th}$ order fringe, $\sin \theta_n = n\lambda/d$

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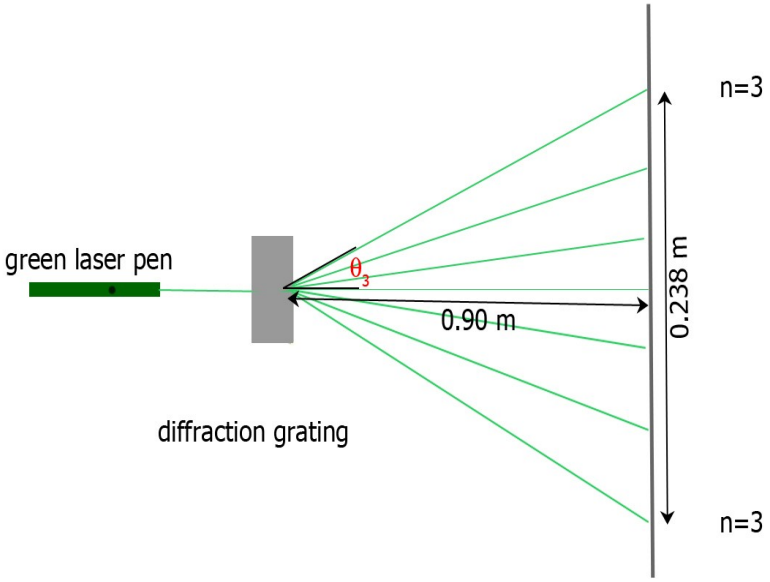


Calculate
(i) the wavelength of the green light;

$\text{Tan}\ \theta_3 = 0.119/0.90 \Rightarrow \theta_3 = 7.532^0$

$\lambda = (d \sin \theta_3)/3 = (1.25 \times 10^{-5} \times \sin 7.532)/3 = 5.46 \times 10^{-7}\ \text{m}$

(ii) the maximum number of images that are formed on the screen. (21)

$$\theta < 90^0$$
$$\sin\theta < \sin 90^0$$
$$\sin\theta < 1$$
$$\frac{n\lambda}{d} < 1$$
$$n < \frac{d}{\lambda}$$
$$n < \frac{1.25 \times 10^{-5}}{5.46 \times 10^{-7}}$$
$$n < 22.9$$
$$n = 22$$

So there are 22 images to left, 22 to the right, and 1 in centre. Therefore 45 on screen

The laser is replaced with a source of white light and a series of spectra are formed on the screen.
Explain
(iii) how the diffraction grating produces a spectrum;

The white light is made up from a whole range of different colours, i.e., different wavelengths, that are all diffracted by different amounts and constructive interference occurs at different values of $\theta$

(iv) why a spectrum is **not** formed at the central (zero order) image.

Because the path difference is zero for all the different colours at the central fringe, and all the different colours meet to produce white light.