How does the grating constant affect the diffraction pattern of the grating?

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Problem
Using transmission gratings with different grating constants investigate the relationship between the grating constant g and the distance d of the interference fringes.

Equipment

Light box, halogen, 12 V/20 W	09801.00	1
Base with rod for light box	09802.10	1
Support base, variable	02001.00	1
Support rod, l = 600 mm	02037.00	2
Meter scale for optic bench	09800.00	1
Red filter from	09807.00	1
Lens on slide mount, f = +50 mm	09820.01	1
Lens on slide mount, f = +300 mm	09820.04	2
Slide mount for optic bench	09822.00	2
Mount with scale on slide mount	09823.00	1
Screen, 150 x 150 mm	09826.00	1
Plate mount	09830.00	2
Observation lens (magnifying glass)	09831.00	1
Diffraction grating, 4 lines/mm	08532.00	1
Diffraction grating, 8 lines/mm	08534.00	1
Diffraction grating, 10 lines/mm	08540.00	1
Diffraction grating, 80 lines/mm	09827.00	1
Slit, adjustable to 1 mm	11604.07	1
Diaphragm holder, attachable	11604.09	1
Power supply, 0...12 V, DC/6 V, 12 V AC	13505.93	1
Tape measure, l = 2 m	09936.00	
Ruler		

Set-up
— Set up the optic bench with the two support rods and the support base and place the scale in position.

— Clamp the light box into the left part of the support base with the lens end pointing away from the optic bench. Insert the light-tight diaphragm into the well in front of the lens.

— Position lens with f = +50 mm at 6 cm on the optic bench.

— Set up mount with scale at 9.5 cm and attach diaphragm holder with adjustable slit (light aperture) to the mount.

— Position one lens with f = +300 mm at approx. 40 cm and the other at the very end of the optic bench.

— Position a plate mount on a slide mount inbetween these two lenses (Fig. 1).

Procedure
— Plug the light into the power supply (12 V~)and switch on power supply.

— Position the other slide mount with plate mount and observation lens on the table approx. 30 cm away from the optic bench. Slide observation lens along the optical axis until the light aperture is sharply focused in the observation plane.

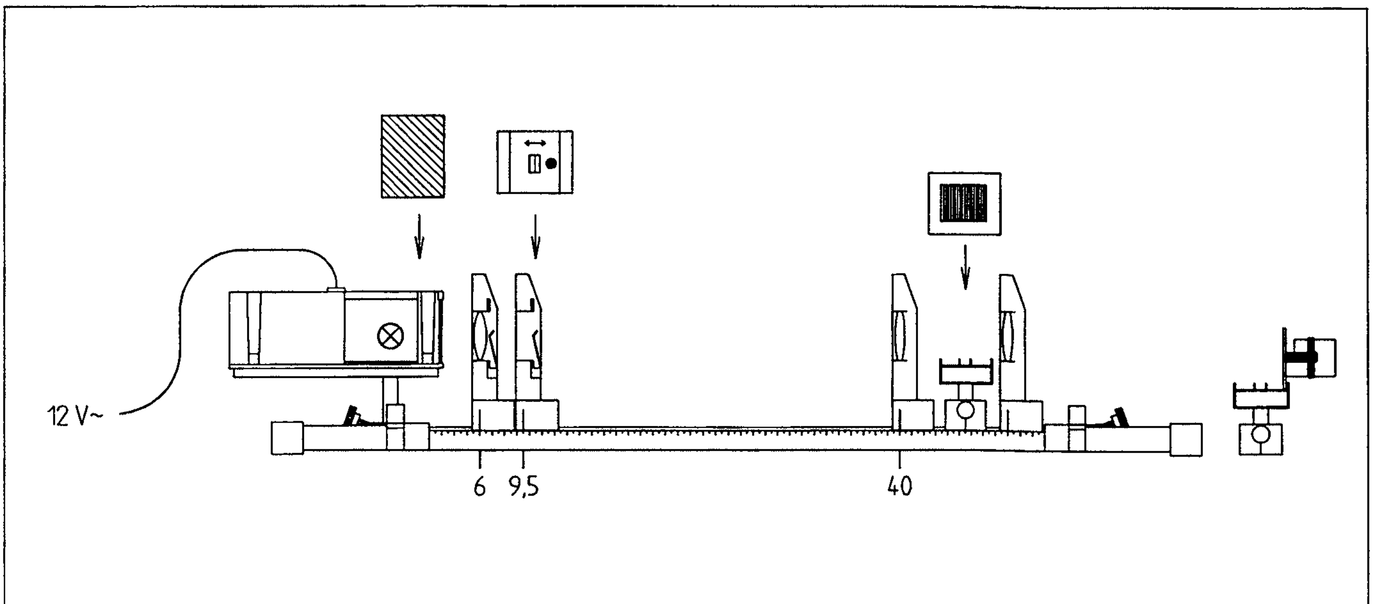
— Attach grating with 4 lines/mm (g = 0.25 mm) to the right-hand attachment of the plate mount.

— Adjust the arrangement: light aperture parallel to the grating lines; optimum width of light aperture to ensure that interference patterns are both sharply focused and bright enough.

— Examine diffraction pattern.

— Insert red filter into well of light and measure gap d between the interference fringes. Do this by measuring the distance d_n of the nth fringe from the middle and divide by n; enter result in Table 1.

Fig. 1



- Leaving the general set-up unchanged, remove red filter and now insert grating with 8 lines/mm (g = 0.125 m); regard interference patterns; reinsert red filter and measure d.
- Proceed in the same way with the 10 line/mm grating.
- Finally insert the grating with 80 lines/mm; in this case use the screen instead of the observation lens and measure d with a ruler.
- Switch off power supply.
- Measure and note down the distance e of the observation plane from the middle of the right-hand lens.
- Describe the interference pattern for white light and how it changes with each grating.

Observations and Results

Table 1

e =

Lines/mm	g/mm	d/mm	$g \cdot d$/mm^2	λ /nm
4	0.25			
8	0.125			
10	0.1			
80	0.0125			

Description of the interference patterns:

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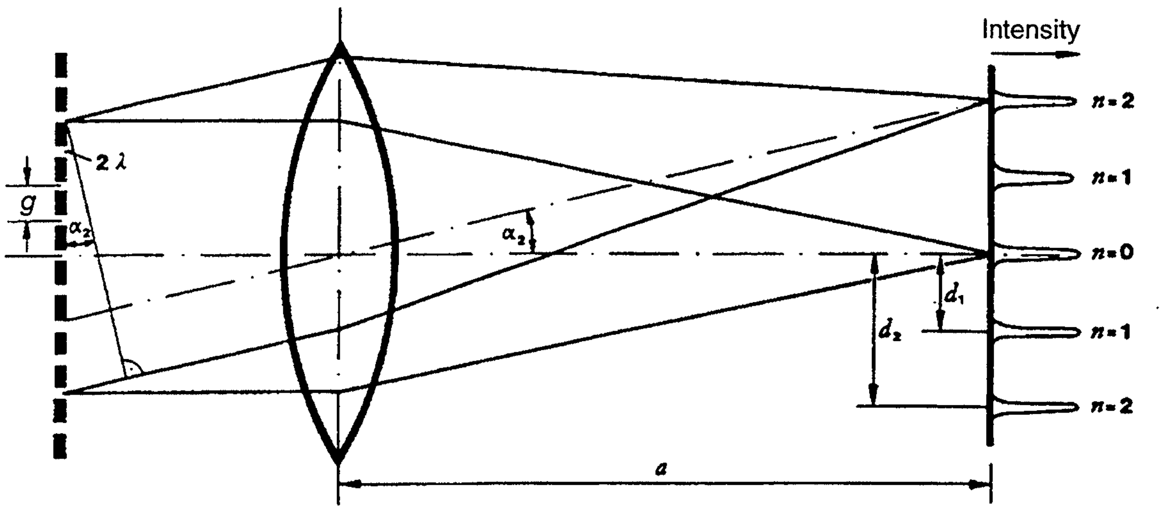
Fig. 2



Evaluation

1. What correlation exists between the distance *d* of the diffraction fringes and the grating constants *g* ?
   Hint: find the products of *g* and *d* and enter the results in the 4th column of Table 1.

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2. Fig. 2 shows how the nth interference fringe (brightness peak of the nth order) comes about when light is diffracted from a grating.
   From Fig. 2 you can also derive the equation for calculating the wavelength λ of the light under investigation:
   $\lambda = g \cdot d_n/(n \cdot e)$ or
   $\lambda = g \cdot d/e$ for the interference fringe of the 1st order.
   Derive this equation and remember that for small angles α: $\sin\alpha = \tan\alpha$.

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3. Calculate the wavelength of the red light transmitted by the colour filter used. Enter your calculated values in the 5th column of Table 1.

How does the grating constant affect the diffraction pattern of the grating?

Space for notes

Diffraction from a grating

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(How does the grating constant affect the diffraction pattern produced by the grating?)

By carrying out this experiment using transmission gratings with greatly differing grating constants, students should gain an understanding of how these affect the interference pattern.
Establishing the wavelength of the red filter light is a by-product of the experiment which could prompt consideration of error, since the individual measurements will result in differing values for wavelength λ.

Suggestions for Set-up and Performance

One advantage of this experiment is that – except for the grating with 80 lines/mm – it can be performed under almost normal lighting conditions.
The experimental set-up is simple to adjust. The teacher should ensure that the students have selected the optimum width of the light aperture.

Observations and Results

Table 1 (Examples of measurements and calculations)
$e = 32.0$ cm

Lines/mm	g/mm	d/mm	$g \cdot d$/mm^2	λ /nm
4	0.25	0.83	0.208	648
8	0.125	1.7	0.212	664
10	0.1	2.0	0.20	625
80	0.0125	16.0	0.20	625

Description of the interference patterns: when white light is diffracted from a grating, parallel, coloured fringes (spectra) are created which are arrayed symmetrically around a bright white stripe. Viewed from this white stripe, the colour red is furthest away from and the colour violet nearest to it.
The spacing of the diffraction fringes increases with decreasing grating constant.

Evaluation

1. The distance d and grating constant g are inversely proportional to one another:
   $g \cdot d = \text{constant} \rightarrow g \sim 1/d$
   (Result of product-finding, see Table 1, column 4).
2. $\sin \alpha_n = n \cdot \lambda / g$; $\tan \alpha_n = d_n / e$
   Since for small angles α_n: $\sin\alpha_n = \tan\alpha_n$ it follows that:
   $$n \cdot \lambda / g = d_n / e;$$
   $$\lambda = g \cdot d_n / (n \cdot e)$$

or specifically for the interference fringe (brightness peak) of the 1st order:

$$\lambda = g \cdot d / e$$

3. Compare the values for λ in Table 1, column 5.

Remark

If the mirror box (order no. 09832.00) is available, use it to hold the observation lens instead of the plate mount.

Diffraction from a grating

(How does the grating constant affect the diffraction pattern produced by the grating?)

Space for notes