

Exercise walk-through

2.4

Diffraction and pulse-echo (statements 50–56, core practical 6)

Pearson Edexcel · International A-Level · Physics

Intensity needs an area conversion

- 1 **Convert** $A = 25 \times 10^{-4} = 0.0025 \text{ m}^2$
- 2 **Incident** $P = IA = 800 \times 0.0025 = 2.0 \text{ W}$
- 3 **Useful** $P_{out} = \eta P = 0.20 \times 2.0 = 0.40 \text{ W}$

Decision

A 0.50 W device cannot run from this useful output.

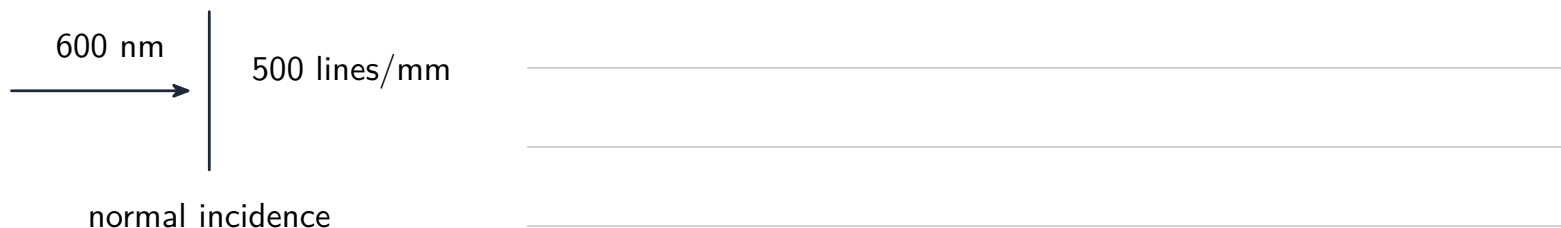
Frequency and intensity change different things

Change	Photon energy	Maximum electron energy
Intensity rises; frequency fixed	Unchanged	Unchanged
Frequency rises	Increases	Increases above threshold

Exercises 2.1·2.2

2.1 Explain using Huygens' construction why waves spread after passing through a narrow gap. [2]

2.2 A grating has 500 lines per millimetre. Light of wavelength 600 nm arrives normally. Calculate the first-order angle. [3]

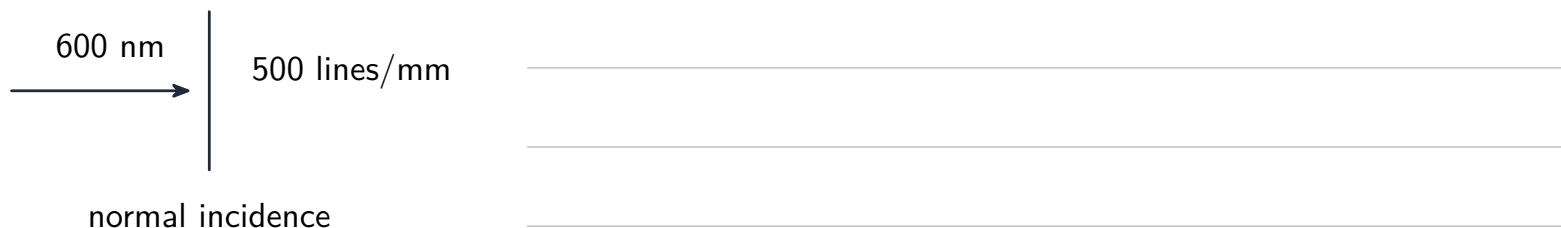


Exercises 2.1·2.2

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2.1 Points within the gap supply secondary wavelets. Their forward envelope forms curved spreading wavefronts beyond the restricted opening.

2.2 A grating has 500 lines per millimetre. Light of wavelength 600 nm arrives normally. Calculate the first-order angle. [3]



2.2 Convert density: $N = 500 \times 10^3 \text{ m}^{-1}$ and $d = 1/N = 2.0 \times 10^{-6} \text{ m}$. $k\lambda = d \sin \theta$, so

Exercises 2.3·3.1

2.3 An ultrasound echo returns $20\ \mu\text{s}$ after transmission in metal. Wave speed is $5000\ \text{m s}^{-1}$. Calculate boundary depth and explain the factor two. [3]

$v = 5000\ \text{m/s}$

echo delay $20\ \mu\text{s}$

boundary

3.1 An electron momentum changes from 2.0×10^{-24} to $4.0 \times 10^{-24}\ \text{kg m s}^{-1}$. Calculate both de Broglie wavelengths using $h = 6.63 \times 10^{-34}\ \text{J s}$. Explain why electron diffraction supports wave behaviour. [4]

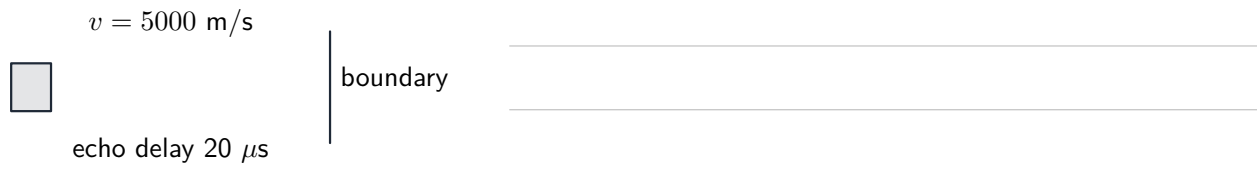
electron momentum

→

2.0×10^{-24} to $4.0 \times 10^{-24}\ \text{kg m/s}$

Exercises 2.3·3.1

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2.3 The time covers travel to the boundary and back. $s = vt/2$. $s = 5000 \times 20 \times 10^{-6}/2 = 0.050\ \text{m}$.

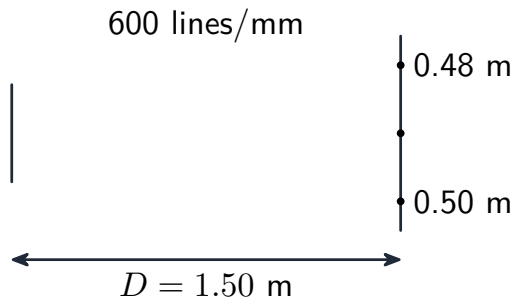
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3.1 $\lambda = h/p$. Initially $\lambda = 3.32 \times 10^{-10}\ \text{m}$; finally $\lambda = 1.66 \times 10^{-10}\ \text{m}$. A regular diffraction

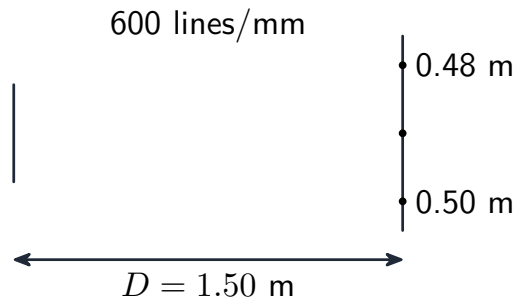
Exercise 3.2

3.2 A laser/grating screen is 1.50 m from the grating. First-order spots are 0.48 m left and 0.50 m right of centre. The grating has 600 lines per millimetre. Find wavelength using the mean displacement. State two improvements or precautions. Explain why $\sin \theta = x/D$ is not exact. [6]



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3.2 Mean $x = (0.48 + 0.50)/2 = 0.49$ m. $\theta = \tan^{-1}(x/D) = 18.1^\circ$. $d = 1/(600 \times 10^3) = 1.67 \times 10^{-6}$ m, so $\lambda = d \sin \theta = 5.17 \times 10^{-7}$ m. Repeat distances or use clearly visible higher orders; keep beam below eye level and never look into it. D is the adjacent side, not the hypotenuse: the exact ratio is $\tan \theta = x/D$.

Exercise 3.3

3.3 Two reflectors in a material are 4.0 mm apart along the beam. Sound speed is 5000 m s^{-1} . Calculate the separation of their echo arrival times. Explain why a $2.0 \mu\text{s}$ pulse makes them difficult to distinguish, and give a change that improves timing resolution. [4]

pulse duration $2.0 \mu\text{s}$



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3.3 The extra round-trip path is $2\Delta s$. $\Delta t = 2\Delta s/v = 2 \times 0.0040/5000 = 1.6 \mu\text{s}$. This is shorter than the pulse duration, so the echoes overlap. Use a shorter pulse, less than their time separation, to improve echo separation.