2018 Ph H2 Q8

Section: Particles and Waves

Topic: Diffraction grating, interference, coherence

(a)(i) Explain, in terms of waves, how bright spots are produced in a diffraction grating pattern.
(ii) Laser λ = 630 nm, grating 250 lines/mm. Calculate θ for the 3rd order maximum.
(iii) Grating replaced with 600 lines/mm. State and justify effect on pattern.
(iv) Define coherent light.

(b) Laser shines through transparent part of a £5 note and produces a diffraction pattern. Suggest a reason for the difference compared with a regular grating.

Worked solution

(a)(i)
Bright spots are produced by constructive interference. Light waves from adjacent slits travel different path lengths. When the path difference equals an integer multiple of the wavelength, the waves arrive in phase and reinforce, producing bright maxima.

Answer: Constructive interference of coherent waves

(a)(ii)
Grating spacing $d = 1/(250 \times 10^{3}) = 4.0 \times 10^{-6}$ m.
Condition: $d \sin\theta = m\lambda$.
$\sin\theta = (3 \times 630 \times 10^{-9}) / (4.0 \times 10^{-6}) = 0.473$.

θ = 28.2°.

Answer: 28°

(a)(iii)
More lines per mm → smaller slit spacing d. This increases angular separation (larger θ), so the bright spots are spread further apart. Also, sharper/narrower maxima are observed due to increased interference.

Answer: Spots further apart and sharper

(a)(iv)
Coherent light means waves have a constant phase relationship and the same frequency. This ensures stable interference patterns.

Answer: Constant phase difference, same frequency

(b)
The transparent section of the £5 note contains a fine diffraction grating or holographic pattern. This diffracts light and produces its own interference pattern, which is different from that of a uniform grating.

Answer: £5 note has microstructures acting as a grating/hologram

Final answers

(a)(i) Bright spots: constructive interference

(a)(ii) θ = 28°

(a)(iii) Spots further apart, sharper

(a)(iv) Coherent = constant phase difference, same frequency

(b) £5 note has microstructured diffraction grating

Revision tips

- Diffraction gratings: $d \sin\theta = m\lambda$.
- More lines per mm → larger angular spread, sharper maxima.
- Constructive interference: path difference = $m\lambda$.
- Coherent sources: constant phase relationship.
- Everyday objects (banknotes, CDs) act like diffraction gratings.