The Interference of Light Assignment 1 ***SOLUTIONS***

1. a) They are producing the same part (e.g. crest or trough) of the waves at the same time if in phase, and producing opposite parts if out of phase.

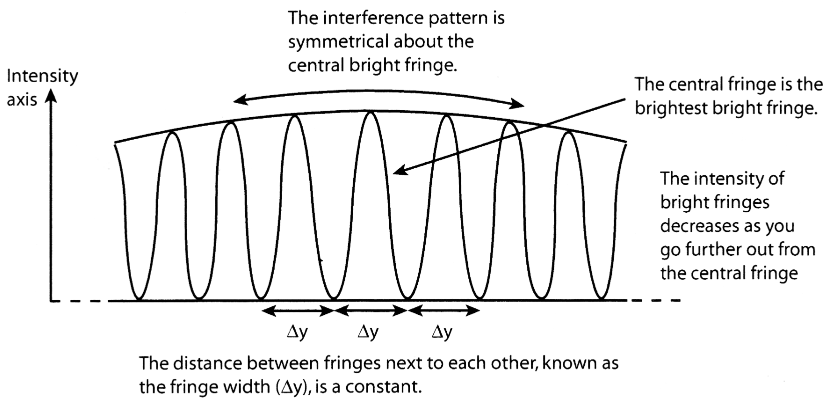
   b) The charges in the filament of an incandescent light vibrate randomly, meaning the waves given off do not have a constant phase relationship (not coherent) and have random frequencies (not monochromatic).

   c) Constructive: two vectors in same direction combine – vector sum is larger
   Destructive: two vectors in opposite directions combine – vector sum is smaller

   d) After passing through the slit, the light spreads out on either side of the slit, forming an approximately semicircular wavefront. The light is faintest furthest to each side of the slit.

2. The light passing through the single slit diffracts, causing it to act like a coherent source. If the double slits are equidistant from the single slit, they will act like coherent, in phase sources (necessary for the interference pattern).

3.



The brighest spots occur when the light has a path difference of mλ therefore constructive. The darkest spots are from a path difference of (m+0.5)λ therefore destructive, and in between are the intermediate path differences.

4. a) See notes for details, but the gist of it:
   - assume L is large compared to d so that the lines from slit to screen are approx. parallel
   - triangle with path difference and triangle with central line and screen are similar
   - triangle with path difference forms equation using trigonometry

   b) $m = 1 \qquad \theta = 5.0° \qquad d = 1.1\times10^{-6}\,\text{m}$

$$d\sin\theta = m\lambda$$

$$\therefore \lambda = \frac{d\sin\theta}{m} = 1.1\times10^{-6}\sin 5.0° = 9.6\times10^{-8}\,\text{m}$$

   INCORRECT METHOD (angle too large) :

   c)
$$\Delta y = \frac{\lambda L}{d} = \frac{9.6\times10^{-8}\times5}{1.1\times10^{-6}} = 0.4\text{ m}$$
   or
$$\Delta y = L\tan\theta = 5\tan 5.0° = 0.4\text{ m}$$

5. a) A symmetrical pattern of thin "maxima" (bright areas) separated by large areas of darkness. The central maximum is the brightest, then the maxima become more separated and fainter as they get further out from the central maximum. The reason for the large areas of dark is that the large number of slits increases the chances of destructive interference at any given point – so there are more places where complete destructive interference occurs.

   b) $\lambda = 5.1\times10^{-7}\,\text{m} \qquad m = 2 \qquad \theta = 20°$

$$d\sin\theta = m\lambda$$

$$d = \frac{m\lambda}{\sin\theta} = \frac{2\times5.1\times10^{-7}}{\sin 20°} = 3.0\times10^{-6}\,\text{m}$$

$$N = \frac{1}{d} = \frac{1}{3.0\times10^{-6}} = 340000\ \text{m}^{-1} = 3400\ \text{cm}^{-1}$$

The Interference of Light Assignment 2 ***SOLUTIONS***

1. See notes for details, but the gist of it:
   - assume L is large compared to d so that the lines from slit to screen are approx. parallel
   - triangle with path difference forms equation using trigonometry
   - show this applies for all slits

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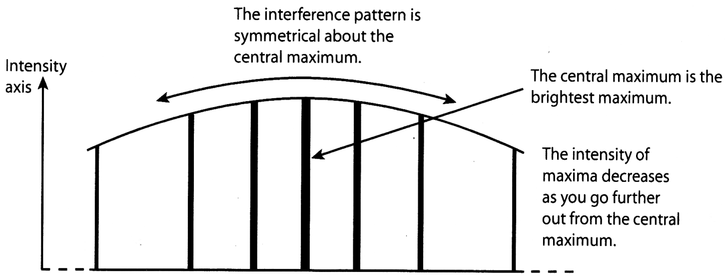
2.

a)



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b) $\lambda = 5.1\times10^{-7}\,\text{m}$ $\quad m = ?$ $\quad \theta = 90°$ $\quad d = \dfrac{1}{N} = \dfrac{1}{430000}\,\text{m}$

$d\sin\theta = m\lambda$

$m = \dfrac{d\sin\theta}{\lambda} = \dfrac{2.3\times10^{-6}}{5.1\times10^{-7}} = 4.6$

Therefore maximum 4 orders. Total maxima 2×4 + 1 = 9

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3. By passing it through a diffraction grating with a known distance between slits, and measuring the angles of the maxima. Each maxima corresponds to a value of *m*, so the formula $d\sin\theta = m\lambda$ can be used.

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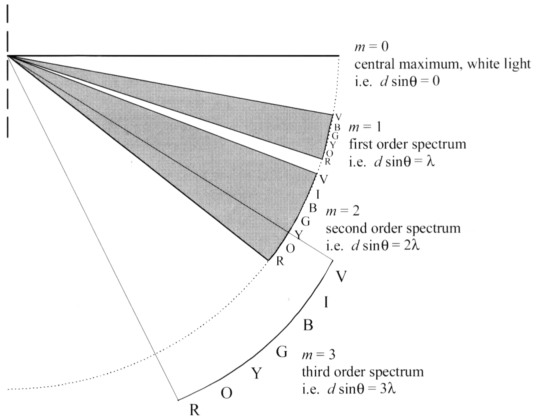
4.

a)



- central maximum is white because light of every colour reinforces there (dsinθ = 0)
- next to the central maximum is a dark area because light of all wavelengths will destructively interfere there
- next is a continuous spectrum, starting at violet because it has the smallest wavelength therefore smallest θ for constructive interference
- next is another area of annulment followed by another spectrum and so on. These spectra will be fainter and fainter and start to overlap (no area of annulment) by the third order.

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b) Diffraction gratings are useful for a process called *spectroscopy* (study of electromagnetic spectra) for the following reasons:

- for close slits, the angular deflection is very large and therefore the angle of any given wavelength can be measured with low error (high precision). The spectrum is clearer and more dispersed than for a triangular prism
- diffraction gratings can spread out the wavelengths of light, allowing for identification of wavelengths for a source that is not monochromatic (this allows for identification of individual atoms and elements since each produce their own spectral lines)
- the grating formula $d \sin\theta = m\lambda$ makes it easy to calculate the wavelengths

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5.

a) Speckle is caused by coherent light reflecting off bumps a least a quarter wavelength high. The rays interfere. The bright dots are constructive interference and the places where no light is seen correspond to destructive interference.

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b) Information on an optical disc is stored as a continuous spiral of ¼ λ deep pits (or bumps, depending which side you look from) around the disc. *Coherent* light is reflected from the disc and detected by a photodiode.

While the beam is over the land (the flat surface) the beam experiences constructive interference as there is no path difference.
When the beam is over a bump (pit) the light returning from the edge of the bump is out of phase with the light returning from the land, and destructive interference occurs.
The intensity of light detected by the photodiode therefore changes as the beam passes from bump to land or land to bump, allowing the data to be read.

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c) The diffraction grating effectively splits off two beams from a brighter central one. These two beams are at such an angle that they should be inbetween tracks, and a detector for their reflection should not be detecting any changes in their intensity. If interference is detected then one of the two beams must be passing onto a neighbouring track. If the beam closest to the centre of the disk experiences interference then the read head needs to move out more, and if the beam closest to the outside of the disk experiences interference then the read head needs to move inwards more.

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TOTAL /22