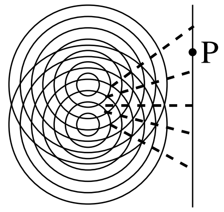
Part I

1. Two in-phase sources produce circular waves of wavelength λ and the interference pattern is shown to the right, with dotted lines indicating where constructive interference occurs.
The difference in the path length from each of the sources to point P is



(a) $\lambda/2$ (b) λ (c) $3\lambda/2$ (d) $5\lambda/2$

Answer (c): The middle dotted line is constructive interference where the difference in path length is zero. The next line up which is just below P shows constructive interference with difference in path length of λ the 2nd line up which is above P shows constructive interference with difference in path length of 2λ. So P indicates a region with destructive interference and the difference in path length must be $3\lambda/2$.

2. A diffraction grating is illuminated with yellow light. The pattern seen on a screen behind the grating consists of three yellow spots, one at zero degrees (straight through) and one each at $\pm 45^o$. You now add red light of equal intensity, coming in the same direction as the yellow light.The new pattern consists of

   (a) red spots at 0^o and $\pm 45^o$
   (b) orange spots at 0^o and$\pm 45^o$
   (c) an orange spot at 0^o, yellow spots at $\pm 45^o$, and red spots slightly farther out.
   (d) an orange spot at 0^o, yellow spots at $\pm 45^o$, and red spots slightly closer in.

   Answer (c): In diffraction there is a spot at 0^o for all wavelengths so the red and yellow combine there to make orange. Since red light has a longer wavelength than yellow light it will be diffracted at a slightly greater angle than yellow.

3. An interference pattern is formed on a screen by shining a planar wave on a double- slit arrangement If we cover one slit with a glass plate (right), the phases of the two emerging waves will be different because the wavelength is shorter in glass than in air. If the phase difference is 180, how is the interference pattern changed?

   (a) The pattern vanishes.
   (b) The bright spots lie closer together.
   (c) The bright spots are farther apart.
   (d) Bright and dark spots are interchanged.

   Answer (d): Since one slit shifts is shifted 180^o out of phase with the other slit then where previously there was constructive interference there will be destructive interference and vice versa.

4. Blue light of wavelength λ passes through a a double slit with separation d and forms an interference pattern on a screen. If the blue light is replaced by red light of wavelength 2λ, the original interference pattern is reproduced if the slit separation is changed to

   (a) $2d$

   (b) $d/2$

   (c) No change is necessary.

   (d) There is no separation that can be used to reproduce the original pattern.

   Answer (a): Doubling the wavelength would tend to double the fringe separation. Doubling the slit separation would tend to halve the fringe separation. Combining both these changes would reproduce the original pattern – but in red rather than in blue.

5. Suppose we cover each slit in Youngs experiment with a polarizer such that the polarization transmitted by each slit is orthogonal to that transmitted through the other. On a screen behind the slits, we see:

   (a) the usual fringe pattern.

   (b) the usual fringes shifted over such that the maxima occur where the minima used to be.

   (c) nothing at all.

   (d) a fairly uniformly illuminated elongated spot.

   Answer (d): Since the light passing through one slit is polarized perpendicular to the light passing through the other slit they cannot interfere (add or subtract). You would therefore expect to see a wide band of light without interference fringes.

Part II

1. In a Young's double slit experiment using yellow light of wavelength 550 nm the fringe separation is 0.275 mm.

   (a) Find the slit separation if the fringes are 2.0 m from the slit.
   If d is the slit separation and Δy is the fringe separation then $\Delta y = x\lambda/d \Rightarrow d = x\lambda/\Delta y = 2.0(550 \times 10^{-9})/(0.275 \times 10^{-}3) = 0.004$ m $= 4$ mm

   The yellow lamp is replaced with a purple one whose light is made of two colours, red light of 700 nm and violet light of 400 nm.

   (b) Find the distance between the violet fringes
   $\Delta y = x\lambda/d \Rightarrow \Delta y = 2.0(400 \times 10^{-9})/0.004 = 2.0 \times 10^{-4}$ m $= 0.20$ mm

   (c) Find the distance between the red fringes
   $\Delta y = x\lambda/d \Rightarrow \Delta y = 2.0(700 \times 10^{-9})/0.004 = 3.5 \times 10^{-4}$ m $= 0.35$ mm

Wave Properties of Light

1. a. For point P the difference in path length $\Delta D = 0$. For Q, $\Delta D = \lambda$ and for R, $\Delta D = 3\lambda/2$.

   b. One fringe separation is the distance between P and Q. This is 2/3 of the distance between P and R ie $1.66 \times 2/3 = 1.11$ mm. Now the slit separation is $d = x\lambda/\Delta y = 2.2\lambda/(1.11 \times 10^{-3}) = 2000\lambda$

   c. i. At point Q the intensity would decrease since less light would reach there to constructively interfere with light from the other slit. At point R the intensity would increase. There is not enough light from the right slit to completely destructively interfere with the light from the left slit.

      ii. It would look like an oscillating wave with max intensity reduced, but minimum intensity increased. The fringe separation would remain the same.

2. a. Increasing the slit separation reduces the fringe separation.

   b. Increasing the wavelength would increase the fringe separation.

   c. Reducing the the distance to the screen would decrease the fringe separation and increase the intensity of the light.

   d. Narrowing the slits would not change the fringe separation but would reduce the intensity.

Model for Single Slit Diffraction

1. The wider the slit, the narrower the central peak (since $\sin\theta \propto 1/a$) so the ranking from largest to smallest width is D,B,F,C,E,A.

2. a. The first minimum occurs when $a\sin\theta = \lambda$ so $a = \lambda/\sin 5^o = 11.5\lambda$

   b. So with $\lambda = 580$ nm, we have $a = 11.7(580) = 6650$ nm $= 6.65\mu$m.

Combined Interference and Diffraction

1. a. Point X is a minimum of the diffraction pattern which remains unchanged so the intensity remains the same (ie zero). Point Y is the maximum of the diffraction pattern and is reduced to one quarter the original intensity because the amount of light reaching the screen is reduced by half (Intensity is proportional to amplitude squared and amplitude is reduced by half). Point Z is the minimum of an interference pattern. Since one slit is now covered there is no longer destructive interference so the intensity increases.

   b. For the diffraction pattern the first minimum occurs for $\sin\theta = \lambda/a$. This angle corresponds to what would be the $n = 5$ fringe for the interference pattern, for which $\sin\theta = 5\lambda/d$. Equating these expressions gives $\lambda/a = 5\lambda/d \Rightarrow d = 5\lambda$

2. The minimum of the diffraction pattern occurs at $\theta = 4^o$ so $a = \lambda/\sin 4^o = 9074$nm $= 9.1\,\mu$m. The $n = 1$ fringe of the interference pattern occurs for $\theta = 1^o$ so $d = \lambda/\sin 1^o = 36300$ nm $= 36.3\,\mu$m.

3. a. Halving the slit width a reduces intensity, moves the diffraction minimum from 4^o to 8^o, but keeps the interference fringes the same.

   b. Halving the slit separation d keeps the intensity the same and keeps the diffraction minimum at 4^o. The fringe separation increases from 1^o to 2^o.

   c. Adding an extra slit keeps the fringe separation the same, and the diffraction minimum the same. However the fringes are brighter and narrower.