**Worksheet 4 – Module 7 – The Nature of Light**

**Light: Wave Model**

1. (a) Drawing on your investigations to analyse qualitatively the diffraction of light,
 identify the pattern of laser light shown below. Give reasons for your answer.



 Diagram From: [Wikimedia Commons](https://www.google.com.au/search?q=single+slit+diffraction+pattern+wikimedia+commons&tbm=isch&source=iu&ictx=1&fir=JrlAU_gpDrqReM%252CPnlVGIjD26E5AM%252C_&vet=1&usg=AI4_-kRPCJp6bi3ymIIJf9iQjDZ4jfEfvQ&sa=X&ved=2ahUKEwjz1rO7-bnyAhXbSH0KHbQRBjUQ9QF6BAgiEAE#imgrc=Qm2nwXJF6dh_MM)

(b) Describe qualitatively how such a pattern is produced. Describe both the practical set-
 up to produce the pattern and the physics that causes the pattern.
2. Two slits are 4 x 10-4 m apart and are one metre from a screen. If the distance, x, from the central maximum to the first order maximum is 1 x 10-3 m, calculate the wavelength of the monochromatic light shining on the slits.
3. Thomas Young in 1801 did an experiment in which he was able to observe the interference of light from two point-sources. In Young’s experiment, he used white light, while in this question we will use orange light of one wavelength, l. This light passes through a hole, h, in the barrier, A. The light then illuminates two holes S1 and S2 in barrier, B, which are equidistant from h. S1 and S2 are a distance d apart. A screen, C, is placed a distance, L away. Points P, Q and R are points on the screen.

1. Explain the need for screen A with its small hole, h.
2. Describe what you would expect to see at P on the screen.
3. Describe what you would expect to see at Q on the screen, if S2Q – S1Q = l/2.
4. Describe what you would expect to see at R on the screen, if S2R – S1R = l.
5. Describe what would happen to the distance between dark bands if the screen was moved closer to the slits.
6. If the distance between the slits is 0.5 mm, the screen is 1.2 m from the slits and the frequency of the orange light is 600 nm, determine the distance between two successive bright bands on the screen.
7. A diffraction grating is often used in optics experiments to produce an interference pattern with light. Describe what happens to the pattern if the number of lines per millimetre on the grating is increased.
8. Monochromatic light of wavelength 540 nm is incident normally on a grating of 600 lines per millimetre.

	1. Calculate the spacing between adjacent lines.
	2. Find the angles at which the first and second order diffraction maxima are deviated.
9. For each scientist, Newton and Huygens, briefly describe the nature of their theory of light. For each theory, assess one piece of evidence that can be given in support of the theory.
10. (a) Evaluate the significance of the discovery of polarisation for the development of
 models of light.

(b) Light of intensity I0 strikes a polariser and an analyser that are crossed. The analyser
 is then rotated through 40º. Calculate the intensity and state of polarisation of the light
 transmitted by (i) the polariser and (ii) the analyser.

**Answers & Solutions**

1. (a) This is a single-slit diffraction pattern. The pattern shows characteristics typical of
 single-slit diffraction patterns. The central maximum is larger than the maxima on
 either side and the intensity of those maxima decreases rapidly.

(b) To produce such a pattern, a laser is set up perpendicular to a metal or plastic plate
 containing a single slit whose width is on the order of the wavelength of light. Typical
 slit width is around 10 mm. A screen is placed at least a metre from the slit and
 parallel to the plate containing the slit. When the laser is turned on, a single slit
 diffraction pattern forms on the screen. The pattern forms because when light passes
 through a single slit whose width, w, is on the order of the wavelength of the light,
 Huygens' principle tells us that each part of the slit can be thought of as an emitter of
 waves.  All these waves travel slightly different distances to the screen, a distance L
 >> w, away from the slit and interfere with each other to produce the observed
 diffraction pattern.  Where crest meets crest, we have constructive interference (a
 bright spot) and where crest meets trough, we have destructive interference (a dark
 spot).

 Note: You do not have to explain why the width of the central maximum is larger than
 that of the other maxima (in fact it is twice the width). To properly explain that you
 require a quantitative look at single slit diffraction.
2. 
3. (a) If the interference of any two waves is to be detected, the following conditions must apply: (i) The two sources must be coherent – that is, they must emit waves that maintain a constant phase relationship with each other and have the same frequency (and therefore, wavelength) and (ii) The sources should emit waves of about the same amplitude, so that almost complete constructive and destructive interference occurs, thus producing maximum contrast.

One way to achieve these two conditions is to use a single source of light such as a narrow slit in front of a light source and allow it to fall on two slits. Since the light reaches the two slits at the same time, the two slits act as two light sources which are in phase with one another, that is, coherent. The two sources also obviously emit waves of the same amplitude. Hence, the need for the screen A, with its small hole, h.

(b) A bright band centred at P.

(c) A dark band centred at Q.

(d) A bright band centred at R.

(e) 

(f) 

 It is probably worth remembering this equation, even though it is not specifically
 mentioned in the Syllabus. It is very useful.

* 1. 
	2. (a) 

(b) 

1. Newton’s Corpuscular Model of Light – Newton’s theory states that light consists of a stream of discrete, extremely small particles called corpuscles. These corpuscles are perfectly elastic, rigid and light. Every luminous source emits these corpuscles. Observation suggests that light travels in straight lines. Sunlight forms sharp shadows behind objects it falls upon. This strongly supports Newton’s model, since it would be expected that extremely small particles would form sharp shadows of objects. Particles striking the object would be reflected. Particles moving past the object, very close to the edge, would create the necessary sharp shadow on a surface behind the object. Newton also explained that light travels so quickly that the effect of gravity on a horizontal beam of corpuscles is negligible. Hence although the beam does move in a parabolic arc, like a ball thrown through the air, the arc is too small to see and so the beam appears to travel in a straight line.

Huygens’ Wave Model of Light – Huygens’ theory states that light travels in the form of waves. Wavefronts are surfaces over which the light wave has constant phase. Every point on a wavefront may be considered a source of secondary spherical wavefronts which spread out in the forward direction at the speed of light. The new wavefront is the tangential surface to all those secondary wavelets. Observation shows that light undergoes diffraction and interference. Young’s double slit experiment indicates light undergoes interference. Fresnel’s and Fraunhofer’s theories and supporting experiments, done by them and many others, demonstrate that light undergoes diffraction. Both diffraction & interference are wave effects and can be explained using Huygens’ Principle. For instance, the diffraction pattern formed when light passes through a single tiny slit can be explained by the diffraction and interference of secondary wavelets as the light passes through the slit. Neither diffraction nor interference can be explained by Newton’s corpuscular theory of light. Therefore, this experimental evidence provides extremely strong support to Huygens’ wave theory of light.
2. (a) The fact that light can be polarised strongly supports two ideas about light. Firstly, light consists of waves. Particles would be unaffected by a polariser. Secondly, light waves are transverse waves. Longitudinal waves would not be affected by a polariser. For example, sound waves cannot be polarised. The fact that light can be polarised is extremely valuable support to the wave theory of light. Any theory of light must be able to explain all aspects of light and its interaction with matter. Polarisation along with diffraction and interference are aspects of light’s interaction with matter that can only be explained by a wave model of light. From the turn of the 19th Century, these phenomena were increasingly viewed by scientists as experimental proof that light had a wave nature rather than a particle nature. The fact that light could be polarised was viewed as especially significant, since it also identified the type of wave motion. Light had to be a transverse wave.

(b) Crossed polariser and analyser means the polariser is at 90º to the analyser. Rotating the analyser by 40º in either direction, clockwise or anticlockwise, results in the angle between the polariser and analyser now being 50º. (If you are unsure of this, draw a diagram – if initially, the polariser’s polarisation axis is horizontal and analyser’s polarisation axis is vertical, rotating the analyser through 40º, moves the top of the analyser down through 40º toward the horizontal axis. Thus, the angle between the horizontal axis and the new polarisation axis of the analyser must be 50º.)

 