1. For fringes to be observed in a double-slit interference experiment, the slits must emit waves that are coherent. What conditions are required for the frequency of the waves and for the phase difference between the waves so that the waves are coherent?

<table>
<thead>
<tr>
<th>Frequency of waves</th>
<th>Phase difference between waves</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. same</td>
<td>variable</td>
</tr>
<tr>
<td>B. same</td>
<td>constant</td>
</tr>
<tr>
<td>C. constant difference</td>
<td>variable</td>
</tr>
<tr>
<td>D. constant difference</td>
<td>constant</td>
</tr>
</tbody>
</table>

Markscheme
B

2. Blue light is incident on two narrow slits. Constructive interference takes place along the lines labelled 1 to 5. The blue light is now replaced by red light. What additional change is needed so that the lines of constructive interference remain in the same angular positions?

A. Make the slits wider
B. Make the slits narrower
C. Move the slits closer together
D. Move the slits further apart

Markscheme
D

3a. Outline what is meant by the principle of superposition of waves.

[2 marks]
when 2 waves meet the resultant displacement
is the «vector» sum of their individual displacements

Displacement should be mentioned at least once in MP 1 or 2.

Red laser light is incident on a double slit with a slit separation of 0.35 mm.
A double-slit interference pattern is observed on a screen 2.4 m from the slits.
The distance between successive maxima on the screen is 4.7 mm.

Calculate the wavelength of the light. Give your answer to an appropriate number of significant figures.

\[ \lambda = \frac{4.7 \times 10^{-3}}{2.4} \times 0.35 \times 10^{-3} \]
\[ = 6.9 \times 10^{-7} \text{ m} \]
answer to 2 SF

Allow missed powers of 10 for MP1.

Explain the change to the appearance of the interference pattern when the red-light laser is replaced by one that emits green light. [2 marks]

green wavelength smaller than red
fringe separation / distance between maxima decreases

Allow ECF from MP1.

One of the slits is now covered. [2 marks]

Describe the appearance of the pattern on the screen.
**Markscheme**

bright central maximum

subsidiary maxima «on either side»

the width of the central fringe is twice / larger than the width of the subsidiary/secondary fringes/maxima

OR

intensity of pattern is decreased

*Allow marks from a suitably labelled intensity graph for single slit diffraction.*

4. Which diagram shows the shape of the wavefront as a result of the diffraction of plane waves by an object? [1 mark]

A.  

B.  

C.  

D.  

**Markscheme**

A

5. Monochromatic light is incident on a double slit. Both slits have a finite width. The light then forms an interference pattern on a screen some distance away. Which graph shows the variation of intensity with distance from the centre of the pattern? [1 mark]

A.  

B.  

C.  

D.  

**Markscheme**

A
6. Light of wavelength $\lambda$ is incident normally on a diffraction grating that has a slit separation of $\frac{\lambda}{2}$. What is the greatest number of maxima that can be observed using this arrangement?

A. 4  
B. 6  
C. 7  
D. 9

Markscheme

C

7. A single-slit diffraction experiment is performed using light of different colours. The width of the central peak in the diffraction pattern is measured for each colour. What is the order of the colours that corresponds to increasing widths of the central peak?

A. red, green, blue  
B. red, blue, green  
C. blue, green, red  
D. green, blue, red

Markscheme

C
In a double-slit interference experiment, the following intensity pattern is observed for light of wavelength \( \lambda \).

The distance between the slits is \( d \). What can be deduced about the value of the ratio \( \frac{\lambda}{d} \) and the effect of single-slit diffraction in this experiment?

<table>
<thead>
<tr>
<th>( \frac{\lambda}{d} )</th>
<th>Single-slit diffraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. 100</td>
<td>non-negligible</td>
</tr>
<tr>
<td>B. 0.01</td>
<td>non-negligible</td>
</tr>
<tr>
<td>C. 100</td>
<td>negligible</td>
</tr>
<tr>
<td>D. 0.01</td>
<td>negligible</td>
</tr>
</tbody>
</table>

**Markscheme**

B
This question is about interference of light.

Coherent monochromatic light is incident on two narrow slits $S_1$ and $S_2$ a distance $d$ apart. A screen is placed a distance $D$ from the slits. An interference pattern of bright fringes and dark fringes appears on the screen. The central maximum is at Q.

9a. State **one** way to ensure that the light incident on the slits is coherent. 

**Markscheme**

single slit before the double slit / use a laser light / single source;

9b. Light emerging from $S_1$ and $S_2$ reaches the screen. Explain why the screen appears dark at point P.

**Markscheme**

destructive interference;

path lengths from slits differ by half a wavelength;

waves arrive antiphase / $180^\circ$ out of phase / $\pi$ out of phase;

9c. When red light of wavelength 660 nm is used the first fringe at P subtends an angle $0.0045 \text{ rad}$ from midpoint of $S_1$ and $S_2$.

Determine the change in angle when blue light of wavelength 440 nm is used.

**Markscheme**

\[
\theta_{\text{blue}} = \left( \frac{\theta_{\text{red}} \lambda_{\text{blue}}}{ \lambda_{\text{red}} } \right) = \left( \frac{0.0045 \times 440 \text{ nm}}{660 \text{ nm}} \right) = 0.0030 \text{ (rad)};
\]

\[
\Delta \theta_{\text{blue}} = (0.0045 - 0.0030) = 0.0015 \text{ (rad)};
\]
This question is about thin-film interference.
Monochromatic light with wavelength 572 nm is incident from air on a thin soap film.
The soap solution has a refractive index of 1.3.

10a. Calculate the wavelength of the light within the soap solution. [1 mark]

**Markscheme**

\[ \lambda' = \frac{\lambda}{n} = \frac{572}{1.3} = 440 \text{ nm}; \]

10b. Calculate the minimum thickness of the soap film that results in constructive interference for the reflected light. [1 mark]

**Markscheme**

110 nm;

10c. Without a calculation, explain why a soap film that is twice as thick as that calculated in (b) results in destructive interference. [2 marks]

**Markscheme**

there would be a full wavelength within the film;
but the phase change at the first surface means that there is always destructive interference;

This question is about the properties of waves.

Microwaves from a microwave transmitter are reflected from two parallel sheets, A and B. Sheet A partially reflects microwave energy while allowing some to pass through. All of the microwave energy incident on sheet B is reflected.

Sheet A is fixed and sheet B is moved towards it. While sheet B is moving, the intensity of the signal detected at the receiver goes through a series of maximum and minimum values.

11a. Outline why a minimum in the intensity occurs for certain positions of sheet B. [3 marks]
The apparatus is arranged to demonstrate diffraction effects.

(i) Outline what is meant by diffraction.

(ii) A maximum signal strength is observed at P. When the receiver is moved through an angle $\theta$, a first minimum is observed. The width of the aperture of the transmitter is 60 mm. Estimate the value of $\theta$.

Markscheme

(i) spreading out of a wave; (do not allow "bending" even if context is obstacle) when it meets an aperture/gap/slit/obstacle; Allow credit for answers appearing on clear labelled diagram for both marks.

(ii) $\left(\theta = \frac{32}{60} = \right) 0.533 \text{ (rad)}$ or $30.6(\text{rad})$; Award [0] for calculation that uses 1.22 (0.65 rad). Award [0] for 0.533 or 30.6 rad. At least one centre is using the abbreviation $\text{rad}$ for rad. Please allow this.

Microwaves can be used to demonstrate polarization effects. Outline why an ultrasound receiver and transmitter cannot be used to demonstrate polarization.

Markscheme

sound waves (in air) are longitudinal; longitudinal waves cannot be polarized / only transverse waves can be polarized; Award [0] for any suggestion that ultrasound is an electromagnetic wave.
12a. Explain why an interference pattern is produced on the screen. [2 marks]

**Markscheme**

reference to:
- diffraction at slits / slits are coherent sources;
- path/phase difference;
- constructive and destructive interference;

*Do not reward just "interference" as this is mentioned in the question.*

12b. The two slits are separated by 2.2 mm and the distance from the slits to the screen is 1.8 m. The wavelength of the light is 650 nm. [2 marks] Calculate the distance MP.

**Markscheme**

for single fringe:
\[ s = \frac{\lambda d}{2\ell} = \frac{650 \times 10^{-9} \times 2.2 \times 10^{-3}}{1.8} \approx 5.3 \times 10^{-4} \text{ m} \]; (also award this mark if the factor of 3 is seen in the numerator)

Distance
\[ MP = (5.3 \times 10^{-4} \times 3 =) 1.6 \times 10^{-3} \text{ m}; \]

*Allow ECF from first marking point. Award [2] for a bald correct answer.*
This question is about diffraction and resolution. 
Monochromatic light is incident on a narrow rectangular slit.

The light is observed on a screen far from the slit. The graph shows the variation with angle \( \theta \) of the relative intensity for light of wavelength \( 7.0 \times 10^{-7} \) m.

13a. Estimate the width of the slit. 

**Markscheme**

diffraction angle = 0.05 rad; 
\[ b = \left( \frac{\lambda}{\theta} \right) = \left( \frac{7.0 \times 10^{-7}}{0.05} \right) = 1.4 \times 10^{-5} \text{ (m)} \); (do not accept use of 1.22) 

Award [2] for a bald correct answer.

13b. On the graph, sketch the variation of the relative intensity with \( \theta \) when the wavelength of the light is reduced.

**Markscheme**

same shape with narrower central maximum; 
*Ignore height of intensity peak.*

13c. State and explain, with reference to your sketch in (b), whether it is easier to resolve two objects in blue light or in red.

**Markscheme**

State and explain with reference to your sketch in (b), whether it is easier to resolve two objects in blue light or in red.
14a. Outline the process by which coloured fringes are formed. 

**Markscheme**
- Light reflects from the top surface of the oil and the top surface of the water; 
- Mention of interference/superposition; 
- Path difference exists between both reflected rays; 
- Different wavelengths interfere constructively for different positions/angles (hence colours appear/shift);

14b. The following data are available:
- Refractive index of oil = 1.4
- Refractive index of water = 1.3
- Thickness of the oil film = 250 nm

Calculate the maximum wavelength of the incident light for which destructive interference occurs.

**Markscheme**

\[ \lambda \left( \frac{2n}{\pi} \right) = 250 \times 10^{-9} \times \frac{2 \times 1.4}{1} ; \]
\[ \lambda = 700 \text{ (nm)} ; \]

15. A high solid wall separates two gardens X and Y. Music from a loudspeaker in X can be heard in Y even though X cannot be seen from Y. The music can be heard in Y due to

A. absorption. 
B. diffraction. 
C. reflection. 
D. refraction.

**Markscheme**
B