1. Plane-polarized light is incident normally on a polarizer which is able to rotate in the plane perpendicular to the light as shown below.

Diagram 1

```
incident light
(intensity = 8 W m⁻²)
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transmitted light
(intensity = 2 W m⁻²)

Diagram 2

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incident light
(intensity = 8 W m⁻²)
```

transmitted light

In diagram 1, the intensity of the incident light is 8 W m⁻² and the transmitted intensity of light is 2 W m⁻². Diagram 2 shows the polarizer rotated 90° from the orientation in diagram 1. What is the new transmitted intensity?

A. 0 W m⁻²  
B. 2 W m⁻²  
C. 6 W m⁻²  
D. 8 W m⁻³

(Total 1 mark)

2. This question is about polarization.

(a) State what is meant by polarized light.

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(Total 1 mark)
(b) Unpolarized light is incident on the surface of a plastic. The angle of incidence is \( \theta \). The reflected light is viewed through an analyser whose transmission axis is vertical.

The variation with \( \theta \) of the intensity \( I \) of the transmitted light is shown in the graph.

(i) Explain why there is an angle of incidence, for which the intensity of the transmitted light is zero.

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(ii) Calculate the refractive index of the plastic.

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(c) Unpolarized light from a source is split, so that there is a path difference of half a wavelength between the two beams.

A lens brings the light to focus at point P on a screen. The lens does not introduce any additional path difference.

State and explain whether any light would be observed at P, in the case in which the polarizers have their transmission axes

(i) parallel.

(ii) at right angles to each other.

(Total 9 marks)
3. The diagram represents a beam of unpolarized light incident on a diamond.

![Diagram of unpolarized light incident on a diamond](image)

The refractive index of the diamond is $n$.

At an angle $\theta_p$, the beam reflected from the diamond is plane polarized normal to the page. The angle $\theta_p$ is

A. $\tan^{-1} n$.    
B. $\tan^{-1} \left( \frac{1}{n} \right)$.    
C. $\sin^{-1} \left( \frac{1}{n} \right)$.    
D. $\cos^{-1} \left( \frac{1}{n} \right)$.    

(Total 1 mark)

4. Unpolarized light is shone through two identical polarizers whose axes are parallel.

![Diagram of unpolarized light passing through two polarizers](image)

The ratio $\frac{I}{I_0}$ is

A. 100 %.  
B. 50 %.  
C. 25 %.  
D. 0 %.  

(Total 1 mark)
5. This question is about polarized light.

(a) Distinguish between polarized and unpolarized light.

(b) A beam of plane polarized light of intensity $I_0$ is incident on an analyser. The direction of the beam is at right angles to the plane of the analyser.

The angle between the transmission axis of the analyser and the plane of polarization of the light is $\theta$. In the position shown the transmission axis of the analyser is parallel to the plane of polarization of the light ($\theta = 0$).

On the axes, sketch a graph to show how the intensity $I$ of the transmitted light varies with $\theta$ as the analyser is rotated through $180^\circ$.

(Total 4 marks)
6. Two polarizing sheets have planes of polarization that are initially parallel.

The incoming light on sheet 1 is unpolarized. The intensity of the light transmitted is \( I \). To reduce the intensity to \( \frac{I}{2} \), which sheet must be rotated and through what angle?

<table>
<thead>
<tr>
<th>Sheet to be rotated</th>
<th>Rotation angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. 1 only</td>
<td>( \theta = \cos^{-1}\left(\frac{1}{\sqrt{2}}\right) )</td>
</tr>
<tr>
<td>B. 2 only</td>
<td>( \theta = \cos^{-1}\left(\frac{1}{2}\right) )</td>
</tr>
<tr>
<td>C. 1 or 2</td>
<td>( \theta = \cos^{-1}\left(\frac{1}{\sqrt{2}}\right) )</td>
</tr>
<tr>
<td>D. 1 or 2</td>
<td>( \theta = \cos^{-1}\left(\frac{1}{2}\right) )</td>
</tr>
</tbody>
</table>

(Total 1 mark)

7. The diagram shows sunlight reflected from a lake surface. The reflected sunlight is plane-polarized.

The plane of polarization of the reflected sunlight is

A. parallel to the lake surface.
B. perpendicular to the lake surface.
C. parallel to the direction of the reflected sunlight.
D. in the plane of the diagram.

(Total 1 mark)
8. Unpolarized light of intensity $I_0$ is incident on a polarizer. The transmitted light is then incident on a second polarizer. The axis of the second polarizer makes an angle of $60^\circ$ to the axis of the first polarizer.

The cosine of $60^\circ$ is $\frac{1}{2}$. The intensity of the light transmitted through the second polarizer is

A. $I_0$.  
B. $\frac{I_0}{2}$.  
C. $\frac{I_0}{4}$.  
D. $\frac{I_0}{8}$.

(Total 1 mark)

9. This question is about polarization and liquid crystals.

(a) A liquid crystal has the property of being able to rotate the plane of polarization of light. Explain what is meant by the expression “able to rotate the plane of polarization of light”.

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(b) The diagram below is a representation of a liquid crystal display.

P$_1$ is a polarizer and P$_2$ is an analyser. The transmission axis of P$_2$ is at right angles to that of
P1. E is an electrode. G is a glass plate upon which a shaped electrode is etched. Unpolarized light is incident on P1.

(i) State, and explain, what the observer would see if the liquid crystal were not present.

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(ii) Outline how the application of a potential difference between E and the electrode etched on G enables the observer to see the shape of the electrode.

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(3)

(Total 7 marks)