Mark scheme for Option G

1 **a** Light is a wave in which there are two displacements: an electric and a magnetic field

that are at right angles to each other and to the direction of energy transfer of the wave. **[2]**

Exam tip: put detail in your answers.

b The sun is low in the horizon during sunsets, and so light from the sun travels a long distance in the atmosphere on its way to the observer.

Because low wavelengths scatter more than long wavelengths (Rayleigh scattering $I \propto \frac{1}{\lambda^4}$).

The light that arrives is predominantly reddish (because the blue/violet/green wavelengths have been scattered away). **[3]**

c **i** Laser light is:

coherent;

monochromatic. **[2]**

ii Reference to **stimulated emission**: a photon incident on an atom with an electron in an excited state can force or stimulate the electron to make a transition down to the ground state, emitting a photon that will have the same frequency, phase and direction as the original photon.

Reference to **optical pumping**: the idea is to force electrons to make transitions to excited states. The electrons will then very quickly (within 10^{-8} s) return to a metastable state (a state where electrons spend a relatively long time).

Reference to **population inversion**: the situation when the number of electrons in the metastable state is far greater than that in the ground state.

Reference to **lasing action**: the electrons in the metastable state make transitions to the ground state emitting the laser light photons. These photons, going back and forth in between mirrors, are used to stimulate the emission of identical photons. For every photon causing stimulated emission we get a second identical photon and so very quickly the intense, coherent laser beam is built up. Part of the laser beam emerges from the semitransparent mirror. **[4]**

Exam tip: It is unlikely that all this detail will be produced but you must at least mention the words in bold.

2 a i The closest point at which the eye can see something clearly/focus on (without straining). **[1]**

ii The image is virtual, so $v = -D$

$$\frac{1}{u} = \frac{1}{f} - \frac{1}{v} = \frac{1}{f} - \frac{1}{-D} = \frac{1}{f} + \frac{1}{D} = \frac{D+f}{Df} \Rightarrow u = \frac{Df}{D+f}.$$ **[2]**

Exam tip: It is crucial that you understand the minus sign for the distance of the virtual image.

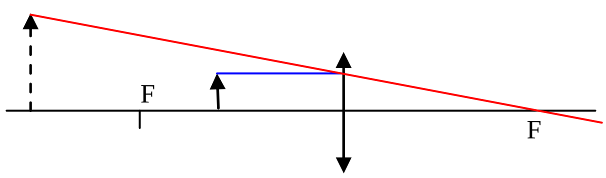
iii

$$M = -\frac{v}{u} = -\frac{-D}{\frac{Df}{D+f}}$$

$$= \frac{D+f}{f} = 1 + \frac{D}{f}$$ **[2]**

b Blue line from object to lens parallel to the principal axis.

Join where blue line intersects lens to top of image (red line) and mark where red line intersects principal axis as the focal point (the second focal point is at the same distance on the other side of the lens).



[2]

c The magnification of the eyepiece is $1 + \frac{D}{f_e} = 1 + \frac{25}{5.0} = 6.0.$

The distance of the image in the objective from the eyepiece is $\frac{1}{5.0} = \frac{1}{u} - \frac{1}{-25} \Rightarrow u = 4.167$ cm.

And so the distance of this image from the objective is $22 - 4.167 = 17.833$ cm.

The object is then at a distance from the objective of $\frac{1}{0.80} = \frac{1}{u} + \frac{1}{17.833} \Rightarrow u = 0.8376$ cm.

And so the overall magnification is $(-)6.0 \times \frac{17.833}{0.8376} = (-)127.7 \approx -130.$ **[5]**

3 **a** **i** Light from the two slits arrives at M, having travelled equal distances, and so the path difference is zero.

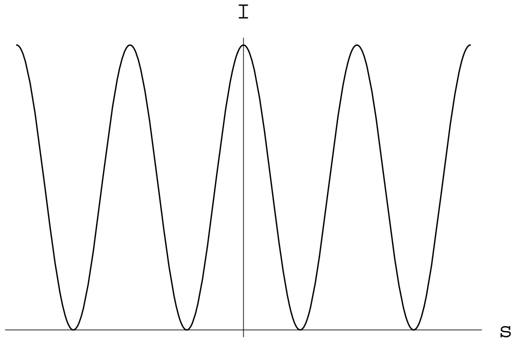
Therefore the two waves **interfere** constructively. **[2]**

Exam tip: Constructive interference must be mentioned.

ii $$MP = \frac{\lambda D}{d} = \frac{656 \times 10^{-9} \times 2.20}{0.150 \times 10^{-3}}$$
$$= 0.00962 \text{ m} = 9.62 \text{ mm}$$ **[2]**

b Equal intensity of maxima.

Equally separated.



[2]

c **[3]** max from:

Position of principal maxima stays the same.

The principal maxima become brighter.

The principal maxima become thinner.

Secondary maxima appear with much less intensity than that of the principal maxima.

Secondary maxima intensity goes to zero as number of slits increases. **[3]**

4 **a** Continuous part:

The accelerated electrons strike the metal atoms and suffer enormous decelerations.

Decelerated electric charges radiate electromagnetic waves.

Discrete part:

Electrons collide with electrons in the metal target atoms and knock these electrons out of the atoms, creating vacancies in lower energy levels.

Electrons in higher energy states make transitions down into the vacant lower levels emitting photons in the process, of energy equal to the difference in energy of the levels involved. **[4]**

Exam tip: there must be detail in answers to this type of questions.

b **i** The minimum wavelength is produced when **all** the energy of one accelerated electron is transferred into **one single** photon.

Hence $qV = hf = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{qV}$

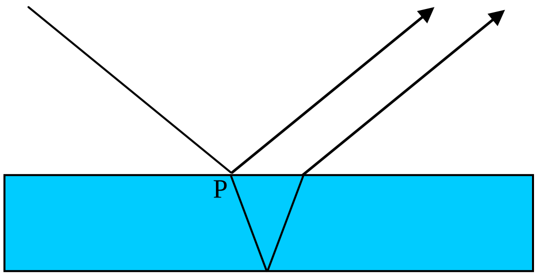
$\lambda = \frac{6.63\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}\times28\times10^{3}} = 4.4397\times10^{-11} \approx 4.4\times10^{-11}$ m. **[3]**

ii An intense beam means constructive interference among the scattered beams of X-rays.

Hence $2d\sin\theta = \lambda \Rightarrow d = \frac{\lambda}{2\sin\theta}$

$d = \frac{2.48\times10^{-10}}{2\sin 28.4^{\circ}} = 2.61\times10^{-10}$ m **[3]**

5 **a** **i** [1] for each correct ray.



[2]

ii Point P marked in diagram above.

A phase difference will occur when the reflection is off a medium of higher refractive index than the medium in which the ray is incident. [2]

b **i** The wavelength in the soap film is $\frac{\lambda}{n}$.

At normal incidence the path difference is $2d$.

Hence for destructive interference the path difference must be an integral multiple of the wavelength $2d = k\left(\frac{\lambda}{n}\right)$

and so the longest wavelength is $\lambda = 2dn$. [3]

ii $\lambda = 2dn = 2 \times 225 \times 1.34 = 603 \text{ nm}$ [1]

iii The reflected light will be missing the wavelength that underwent destructive interference,

and so its colour will be white minus the missing colour. [2]

