Option G — Electromagnetic waves

G1. (a) (i) between lenses and between eye lens and F; ***[1]***

(ii) further from eye lens than image X and same distance from eye lens for both points; (*judge by eye*) ***[1]***

(iii) final image near object and not between lenses; ***[1]***
Accept markings of positions even when shown off the principal axis except for the focal points.

(b) central cross shown straight;
sides curved (outwards or inwards); ***[2]***

(c) lens has different refractive indices for different wavelengths/colours;
so each wavelength/colour has a different focal length; ***[2]***

G2. (a) (i) λ_{red} : allow 620 nm $\rightarrow$ 780 nm; ***[1]***

(ii) λ_{blue} : allow 320 nm $\rightarrow$ 480 nm; ***[1]***

(b) light travels (towards observer) further through atmosphere at sunset (compared to during the day);
(short wavelength) blue light scatters the most;
and so with blue removed (from the light reaching the observer) the Sun looks red; ***[3]***
Award second and third marks for reversal of wavelengths in (a).

G3. (a) (i) (light from the slits has) constant phase difference; ***[1]***

(ii) when two (or more) waves meet;
resultant displacement;
is sum of individual displacements; ***[3]***

or

when the path difference;
is an integral/half-integral multiple of the wavelength;
constructive/destructive interferences take place;
Allow amplitude for 3rd mark.

(b) $x = \frac{\lambda d}{a} = \frac{640\times10^{-9}\times2.4}{0.85\times10^{-3}}$;
$= 1.8\times10^{-3}\,\text{m}$; ***[2]***

(c) bright fringes are less bright;
dark fringes are brighter; ***[2]***

G4. (a) $eV = \frac{hc}{\lambda}$;

$\left(1.6\times10^{-19}\times45\times10^{3} = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{\lambda}\right)$

$\lambda = 2.8\times10^{-11}\,\text{m}$;

range is $2.8\times10^{-11}\,\text{m}$ and longer; ***[3]***

(b) some electrons have enough energy to remove an electron from the inner shell of an atom;
an electron falls from an outer energy level to the inner energy level;
emitting an X-ray photon of characteristic wavelength; ***[3]***

G5. (a) correct reflections at both surfaces;
correct refraction at top surface; ***[2]***

(b) for one angle of viewing, one colour interferes destructively/another interferes constructively;
white light minus that colour is seen / colour seen is determined by colour that interferes constructively;
at different viewing angle, different colour interferes destructively/constructively; ***[2 max]***

Option G — Electromagnetic waves

G1. (a) *Look for these main points.*
(a metastable state *i.e.*) an excited state in which electrons stay (for unusually) longer times than in normal excited states;
population inversion (in which the number of electrons in a metastable state is larger than in the ground state);
stimulated emission in which an electron of the same energy as the difference in energy of atomic energy levels forces a transition from an excited state; ***[3]***
Mark generously as all of these points may be not expressed precisely.

(b) (the laser light is) monochromatic;
(and) coherent;
unidirectional/single beam; ***[2 max]***

G2. (a) (i) correct use of sign convention $\left(\frac{1}{20}=\frac{1}{24}+\frac{1}{v}\right)$;

$v=120\,\text{mm}$; ***[2]***

(ii) real because $v>0$ / image is formed by real rays (and not their extensions) / can be focused on a screen / rays are convergent; ***[1]***

(iii) correct use of sign convention $\left(\frac{1}{60}=-\frac{1}{240}+\frac{1}{u}\right)$;

$u=48\,\text{mm}$; ***[2]***

(b) $M=\left[\frac{120}{24}\right]\times\left[\frac{240}{48}\right]$ ***or*** $M=\frac{120}{24}\times\left[\frac{240}{60}+1\right]$;

$M=25$; ***[2]***

*Award **[1 max]** for answer of 20.*

G3. (a) (i) correct general shape with uniform spacing of maxima;
and equal intensity at maxima; ***[2]***
Accept a small reduction in amplitude if consistently shown from peak to subsequent peak.
*Award **[1 max]** if minima do not touch horizontal axis.*

(ii) $s = \left(\frac{\lambda D}{d} =\right) \frac{6.80\times10^{-7}\times1.40}{0.120\times10^{-3}}$;
$s = 7.93\text{mm}$; ***[2]***

(b) (i) pattern will be shifted horizontally such that the maxima and the minima are interchanged / *OWTTE*;
because the path difference has introduced a path length of $\frac{\lambda}{2}$ / phase difference of π ***or*** 180°; ***[2]***

(ii) no change;
since pattern has shifted by a constant amount; ***[2]***

G4. (a) correct shape of continuous part including cut-off wavelength;
presence of any characteristic lines; ***[2]***
Do not award second marking point if the peaks are clearly not vertical or if their width implies a large range of frequencies – judge by eye.

(b) continuous part is due to radiation emitted when electrons slow down as they strike the metal;
characteristic lines due to transitions inside target atoms;
after target atoms have been excited by electron collision; ***[3]***

(c) rearrangement to get $h = \frac{\lambda eV}{c}$;
$h = \frac{4.8\times10^{-11}\times1.6\times10^{-19}\times2.4\times10^{4}}{3.0\times10^{8}}$;
$h = 6.1\times10^{-34}\,\text{J s}$; ***[3]***

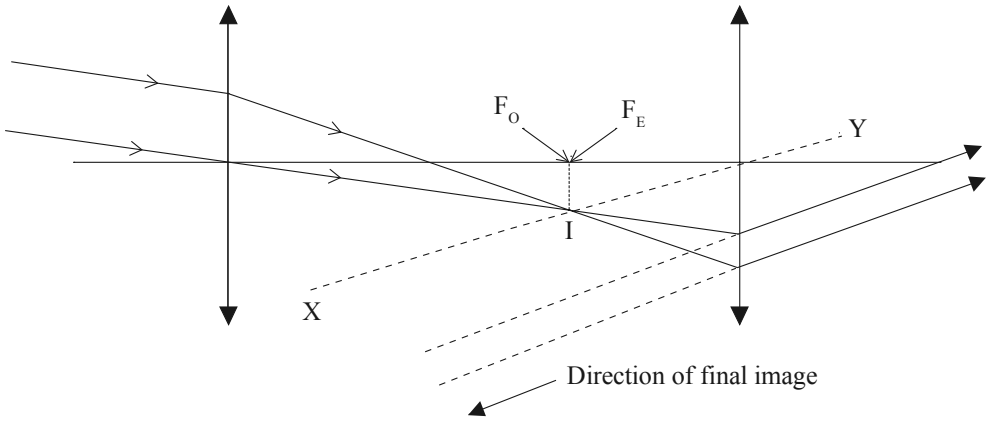
(d) $d = \frac{\lambda}{2\sin\theta}$ so $d = \frac{2.25\times10^{-10}}{2\sin 28.1^\circ}$;
$d = 2.39\times10^{-10}\ \text{m}$; ***[2]***
*Award **[1 max]** if the 2 is missing.*

Option G — Electromagnetic waves

G1. (a) coherent;
monochromatic / single frequency; ***[2]***

(b) <u>normally electrons occupy lowest available energy levels</u>;
to produce laser light a large number of electrons are promoted to a higher energy level / *OWTTE*;
any other valid point; ***[2 max]***

G2. (a)



(i) at F_O; ***[1]***

(ii) as shown on diagram; ***[1]***

(b) at infinity; ***[1]***

(c) two rays parallel to XY; *(judge by eye)*
extrapolated to show direction of final image; ***[2]***

(d) object distance $u = f_O + f_E = 100\,\text{cm}$;
$\frac{1}{v} + \frac{1}{100} = \frac{1}{f_E} = \frac{1}{2}$;
$\frac{1}{v} = \frac{1}{2} - \frac{1}{100}$ to give $v = 2.04\,\text{cm}$;
beyond eyepiece lens / between eyepiece lens and eye;

or

scale drawing: *(not a good idea!)*
suitable scale;
object distance;
rays to locate image;
image distance 2 cm beyond eyepiece lens; ***[4]***

G3. (a) $d = \frac{\lambda D}{s}$;

$= \frac{\lambda}{\theta}$;

$= \frac{6.33\times10^{-7}}{4.00\times10^{-4}} = 1.58\,\text{mm}$;

or

accept use of $d\sin\theta = n\lambda$ with $n = 1$;

$\sin\theta = \theta$;

$d = \frac{6.33\times10^{-7}}{4.00\times10^{-4}} = 1.58\,\text{mm}$; ***[3]***

(b) same number of maxima at the same place but much sharper;
greater intensity than double slit; ***[2]***

(c) fringes are coloured;
blue on the inside / red on the outside;

also accept:
no fringes will be seen;
light is not coherent; ***[2 max]***

G4. (a)

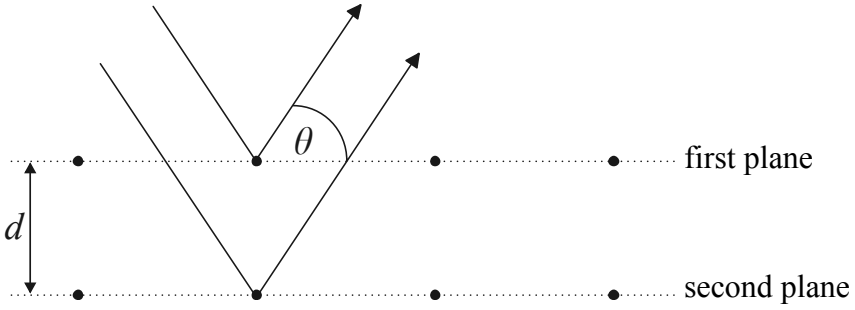


diagram showing X-rays scattered at first and second plane;
there is interference between the two reflected/scattered rays;
if path difference between the rays is integral number of wavelengths the rays will interfere constructively;
some comment to the effect that all rays scattered at this angle from all the adjacent lattice ions will reinforce; ***[4]***

(b) use of $2d\sin\theta = n\lambda$

$d = \frac{1.2\times10^{-10}}{2.0\times0.21}$;

$= 2.9\times10^{-10}\,\text{m}$ ***[1]***

G5. (a) light reflected from the top surface of the wedge interferes with light reflected from the bottom surface;
some statement about the condition for maximum/minimum in relation to the thickness of the film
e.g. path difference depends on wedge thickness so goes through maximum and minimum / *OWTTE*; *(no need to mention phase change on reflection)* ***[2]***

(b) number of fringes in 5.0×10^{-2} m $= 4.2\times10^{2}$;
path difference at edge of tape $= m\lambda = 4.2\times10^{2}\times4.8\times10^{-7}$;
$= 2d$ to give $d = 1.0\times10^{-4}$ m; ***[3]***