# Markscheme

## May 2015

## Physics

## Standard level

## Paper 3

17 pages

**1.** Follow the markscheme provided, award only whole marks and mark only in **RED**.

**2.** Make sure that the question you are about to mark is highlighted in the mark panel on the right-hand side of the screen.

**3.** Where a mark is awarded, a tick/check (✓) **must** be placed in the text at the **precise point** where it becomes clear that the candidate deserves the mark. **One tick to be shown for each mark awarded.**

**4.** Sometimes, careful consideration is required to decide whether or not to award a mark. In these cases use RM™ Assessor annotations to support your decision. You are encouraged to write comments where it helps clarity, especially for re-marking purposes. Use a text box for these additional comments. It should be remembered that the script may be returned to the candidate.

**5.** Personal codes/notations are unacceptable.

**6.** Where an answer to a part question is worth no marks but the candidate has attempted the part question, use the "ZERO" annotation to award zero marks. Where a candidate has not attempted the part question, use the "SEEN" annotation to show you have looked at the question. RM™ Assessor will apply "NR" once you click complete.

**7.** If a candidate has attempted more than the required number of questions within a paper or section of a paper, mark all the answers. RM™ Assessor will only award the highest mark or marks in line with the rubric.

**8.** Ensure that you have viewed **every** page including any additional sheets. Please ensure that you stamp "SEEN" on any additional pages that are blank or where the candidate has crossed out his/her work.

**9.** There is no need to stamp an annotation when a candidate has not chosen an option. RM™ Assessor will apply "NR" once you click complete.

**10.** Mark positively. Give candidates credit for what they have achieved and for what they have got correct, rather than penalizing them for what they have got wrong. However, a mark should not be awarded where there is contradiction within an answer. Make a comment to this effect using a text box or the "CON" stamp.

# Subject Details: Physics SL Paper 3 Markscheme

## Mark Allocation

Candidates are required to answer questions from **TWO** of the Options **[2 × 20 marks]**.
Maximum total = **[40 marks]**.

**1.** A markscheme often has more marking points than the total allows. This is intentional.

**2.** Each marking point has a separate line and the end is shown by means of a semicolon (;).

**3.** An alternative answer or wording is indicated in the markscheme by a slash (/). Either wording can be accepted.

**4.** Words in brackets ( ) in the markscheme are not necessary to gain the mark.

**5.** Words that are <u>underlined</u> are essential for the mark.

**6.** The order of marking points does not have to be as in the markscheme, unless stated otherwise.

**7.** If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the markscheme then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by ***OWTTE*** (or words to that effect).

**8.** Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

**9.** Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking indicate this by adding **ECF** (error carried forward) on the script.

**10.** Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the markscheme.

**Option A — Sight and wave phenomena**

**1.** (a) rods for night (low light) and cones for day (bright light);
(3 different types of) cones detect colour, but rods do not;
cones in fovea at back of eye, but rods on sides around the fovea;
(hence) sharp image in day, but less sharp at night;
night scotopic vision, day photopic vision; **[3 max]**

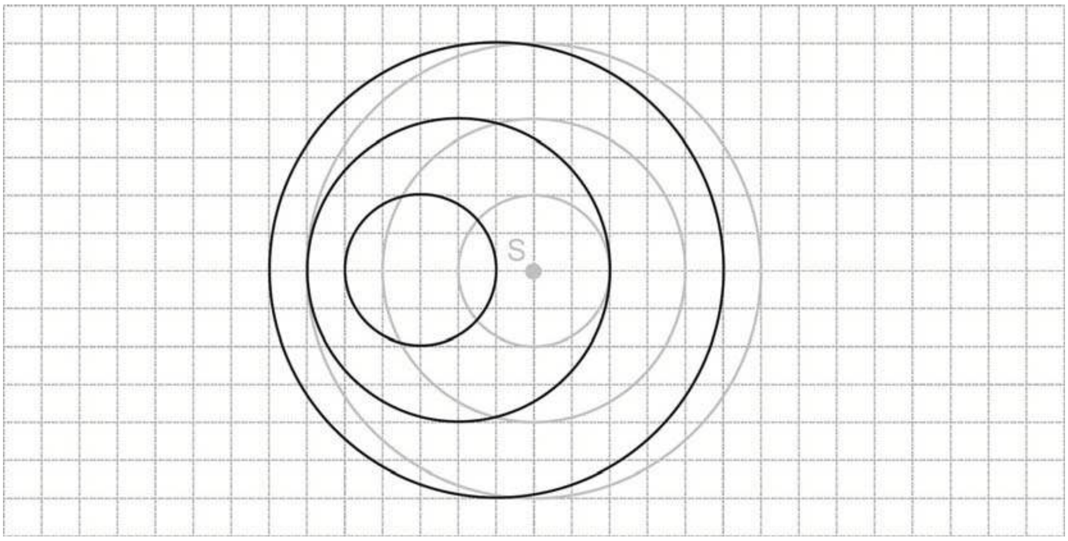
(b) $\theta = \frac{1.22 \times 4.5 \times 10^{-7}}{2.5 \times 10^{-3}}$; *(power of ten error here gives ECF)*
$= 2.2 \times 10^{-4}$ (rad);
distance $= \left(\frac{1.5}{2.2} \times 10^{-4}\right) = 6.8$ (km); **[3]**

**2.** (a) node; **[1]**

(b) (i) wavelength $= \frac{2.4}{2.5} = (0.96\,\text{m})$;
$c = f\lambda = 144\,(\text{m s}^{-1})$; **[2]**

(ii) 60 (Hz); **[1]**

**3.** (a) 3 circular wavefronts;
2 centres/sources of wavefronts move left (by one box); **[2]**




*Drawn circular wavefronts may be larger as in diagram here, or could be equal sized. Both are acceptable.*

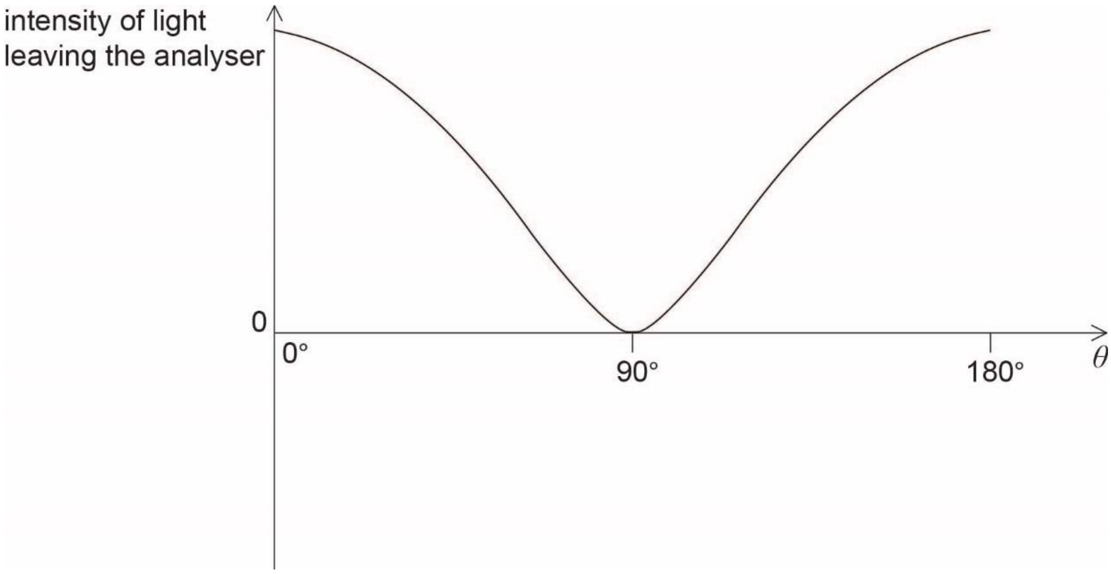
(b) (i) $v = \frac{5 \times 10^{-16} \times 3 \times 10^{8}}{7.5 \times 10^{-9}}$;
20 $(\text{m s}^{-1})$; **[2]**
*Use of sound equation not acceptable.*

(ii) assume speed of X-rays = *c* / assume speed of turntable << *c*; **[1]**

**4.** (a) by crossing the analyser with the polarized light;
the angle of polarization/electric field vector can be determined; **[2]**

(b) (i) $(I = I_0 \cos^2 25^\circ =) 0.82 I_0$; **[1]**

(ii) $\cos^2$ shape; *(allow negative intensities for this mark)*
max at $0^\circ$ and $180^\circ$, zero at $90^\circ$; *(allow non-$\cos^2$ line for this mark)* **[2]**



**Option B — Quantum physics and nuclear physics**

**5.** (a) minimum energy/work required to remove an electron (from the surface of the substance); **[1]**

(b) $f_{min} = \frac{2.9 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}} = (7.0 \times 10^{14})(\text{Hz})$;

$\lambda_{max} = \left(\frac{3.00 \times 10^{8}}{7.0 \times 10^{14}}\right) = 4.3 \times 10^{-7}$ (m); **[2]**

(c) $p = \left(\frac{h}{\lambda_{max}} = \right)\frac{6.63 \times 10^{-34}}{4.3 \times 10^{-7}}$;

$= 1.5 \times 10^{-27}$ (kg m s$^{-1}$); **[2]**

*Allow ECF from (b).*

***or***

$p = \left(\frac{\phi}{c} = \right)\frac{2.9 \times 1.6 \times 10^{-19}}{3.00 \times 10^{8}}$;

$= 1.5 \times 10^{-27}$ (kg m s$^{-1}$);

*Allow ECF from (b).*

**6.** (a) electron has wave-like properties;
it can only have certain/quantized wavelengths to fit the box as a standing wave;
discrete wavelengths imply discrete momenta (according to de Broglie $p = \frac{h}{\lambda}$);
hence discrete energies (that are the energy levels); **[3 max]**

(b) (i) electron energy $= 11.7 \times 1.6 \times 10^{-19}$ $(= 1.9 \times 10^{-18}\ \text{J})$;

$L = \left(\sqrt{\frac{h^2}{8mE_1}} = \sqrt{\frac{\left[6.63 \times 10^{-34}\right]^2}{8 \times 9.11 \times 10^{-31} \times 11.7 \times 1.6 \times 10^{-19}}}\right) = 1.79 \times 10^{-10}$ (m); **[2]**

*Do not allow 2 or 2.0 for second marking point.*

(ii) $\Delta p \geq \frac{6.63 \times 10^{-34}}{4\pi \times 1.79 \times 10^{-10}}$;

$2.95 \times 10^{-25}$ (kg m s$^{-1}$); **[2]**

*$2.0 \times 10^{-10}$ gives $2.64 \times 10^{-25}$ which is acceptable.*

(iii) $n^2 = 9$ so $E_3 = 9 \times 11.7$ / OWTTE; **[1]**

(iv) $\Delta E = (105 - 11.7) = 93.3$ ($eV$);

$f = \left(\frac{93.3 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}}\right) = 2.25 \times 10^{16}$ (Hz); **[2]**

*Award **[2]** for a bald correct answer.*

**7.** (a) spectrum of beta decay is continuous;
with a maximum value of energy;
the resulting energy difference between energy of any $\beta^{(+)}$ and maximum $\beta^{(+)}$ energy is accounted for by the energy of the neutrino / reference to energy difference between parent energy level and excited energy level of daughter; **[3]**

(b) $T_{\frac{1}{2}} = \dfrac{\ln 2}{0.061} = 11.4\ (\text{s})$;

$\left(N = \dfrac{1}{8}N_0 \text{ so}\right) t = \left(3T_{\frac{1}{2}} =\right) 34\,(\text{s})$; **[2]**

***or***

$t = -\dfrac{\ln 0.125}{0.061}$;

$t = 34\,(\text{s})$;

**Option C — Digital technology**

**8.** (a) photons deliver energy to pixel;
electron-hole generation / photoelectric effect liberates electrons;
capacitor stores (liberated) charge;
capacitive action / pixel is a capacitor so charge leads to potential difference across pixel; **[4]**

(b) (i) ratio of length of image on CCD to length of object; **[1]**

(ii) distance between images on CCD $= 7.1\times10^{15}\times10^{-20}\left(=7.1\times10^{-5}\ (\text{m})\right)=7.1\times10^{-2}\ (\text{mm})$;

area of a pixel $=\dfrac{36\times24}{12\times10^{6}}=7.2\times10^{-5}\ (\text{mm}^2)$;

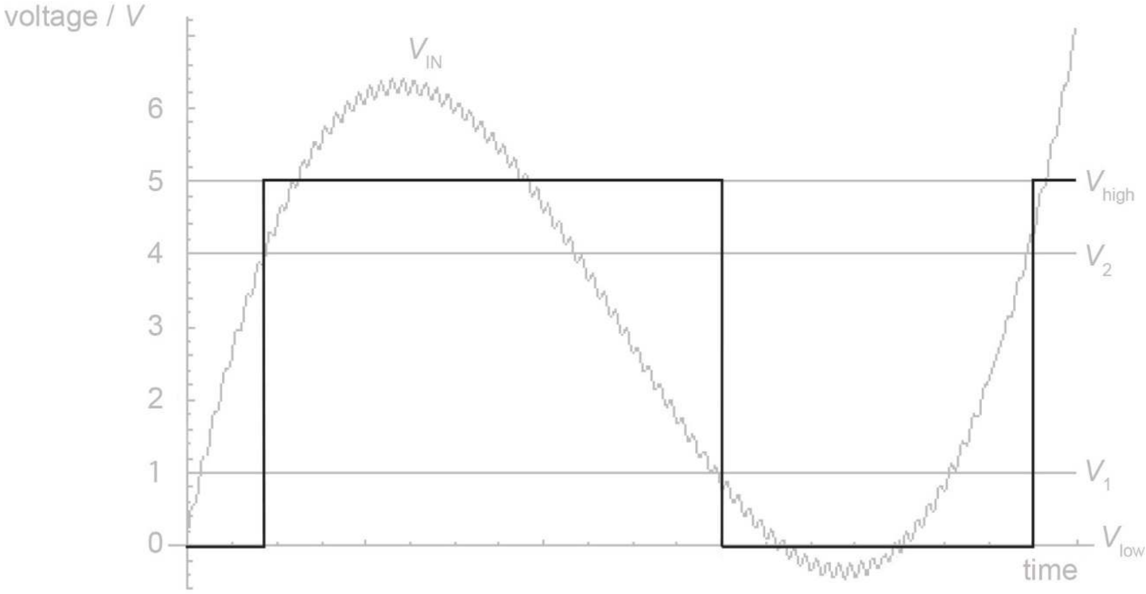
side of a pixel $=\left(\sqrt{7.2\times10^{-5}}=\right)8.4\times10^{-3}(\text{mm})$;

(so images are resolved since) $7.1\times10^{-2}\gg8.4\times10^{-3}$ / the separation of the images is (much) greater than the length of one pixel; **[4]**

(iii) $\dfrac{4\times10^{9}\times8}{16\times12\times10^{6}}$;
$=166$; *(do not accept 167)* **[2]**

**9.** (a) reduction/removal of noise to reshape digital signals;
by returning pulse to its original shape; **[1 max]**

(b) square wave pulse;
between 0 V and 5 V;
verticals intercepting at 4 V; *(judge by eye)*
vertical intercepting at 1 V; *(judge by eye)* **[4]**
*eg:*



**10.** (a) a small area/region;
allocated a specific frequency/range of frequencies;
contains a base station; **[2 max]**

(b) manufacture of a great number of phones leads to depletion of natural sources/production of greenhouse gases/problems with disposal;
any other reasonable issue *eg* electromagnetic smog / mobile transmission towers are considered ugly by many / *etc*; **[2]**

**Option D — Relativity and particle physics**

**11.** (a) theory suggests that no object can travel faster than light;
the 1.7$c$ is not the speed of a physical object;
so is not in violation of the theory; **[2 max]**

(b) (i) $\gamma = 1.90$;
interval on Earth $=\gamma \times$ interval on spaceship;
(interval on Earth $1.90 \times 8$ years $=$ )15 years; **[3]**
*Award **[3]** for a bald correct answer.*

(ii) observer on Earth thinks spaceship has travelled for 15 years;
so distance is $0.85c \times 15 = 12.8 \approx 13\,\text{ly}$; **[2]**
*Award **[2]** for a bald correct answer*

***or***

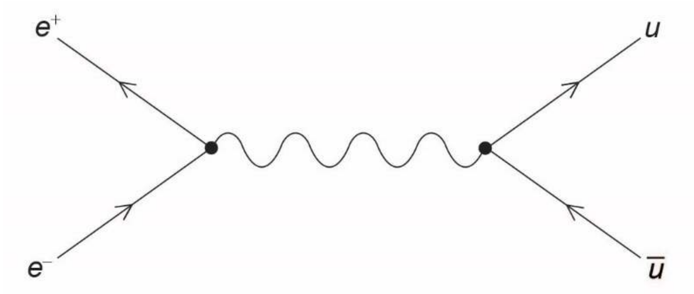
the spaceship observer observes the distance moved by the Earth $= 0.85c \times 8.0\,\text{yr}$;
proper distance $= 1.90 \times 0.85c \times 8.0\,\text{yr} = 12.9 \approx 13\,\text{ly}$;
*Award **[2]** for a bald correct answer*

(iii) *(take time for message to arrive at Earth in spaceship frame to be T)*
distance moved by Earth in spaceship frame before message arrives $= 0.85cT$;
distance of Earth from spaceship when message sent $= 0.85c \times 8.0 = 6.8$ (ly);
$(cT = 0.85cT + 6.8)$ so $T = \dfrac{6.8}{0.15} = 45.3$ years; **[3]**

**12.** (a) $m = 125 \times 10^{9} \times \dfrac{1.6 \times 10^{-19}}{9 \times 10^{16}} \,(= 2.2 \times 10^{-25})(\text{kg})$;
$R = \left(\dfrac{h}{4\pi mc} =\right) \dfrac{6.63 \times 10^{-34}}{4\pi \times 2.2 \times 10^{-25} \times 3 \times 10^{8}}$;
$= 7.9 \times 10^{-19}$ (m); **[3]**

(b) $17\,\text{MeV} = 2.7 \times 10^{-12}$ (J);
$\Delta t > \dfrac{h}{4\pi \times 2.7 \times 10^{-12}}$;
$= 1.9 \times 10^{-23}$ (s); **[3]**

**13.** (a) particles correctly labelled and interaction correctly shown;
arrow directions correct; **[2]**




(b) strong (colour) interaction increases with separation requiring high energy;
high energy allows creation of hadrons/quarks;
confinement requires the formation of two quarks, not one; **[2 max]**

**Option E — Astrophysics**

**14.** (a) J S U N; **[1]**

(b) U N S J; **[1]**

**15.** (a) (i) $T = \frac{0.0029}{\lambda}$;
3080/3090 (K); *(more than 1 SD must be shown)* **[2]**

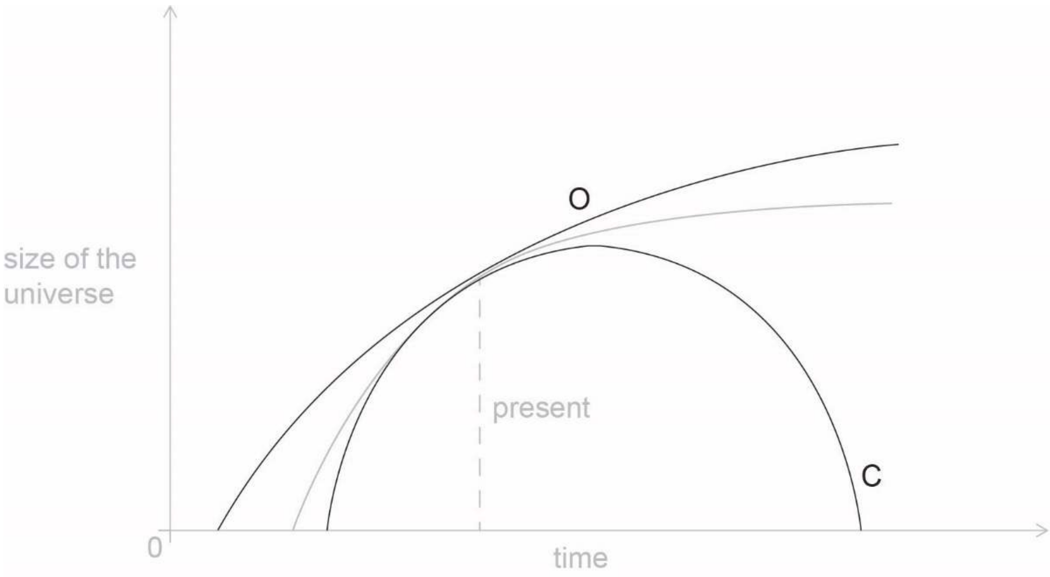
(ii) temperature too low for white dwarf;
not luminous enough for red giant; **[2]**

(b) (i) $L = 4\pi d^2 b$;
$\frac{d_B}{d_S}\left(=\sqrt{\frac{L_B}{L_S}\frac{b_S}{b_B}}\right)=\sqrt{\frac{3.8\times10^{-3}}{2.5\times10^{-14}}}$;
$3.9 \times 10^5$ AU; **[3]**

(ii) conversion of AU to 1.89 pc;
0.53 (arc-seconds); **[2]**

(iii) measure position of star;
with respect to fixed background;
with six months between readings;
parallax angle is half the total angle / *OWTTE*; **[3 max]**
*May be shown in a diagram.*

**16.** (a) after present, open universe curve drawn above flat curve **and** closed universe curve drawn under flat curve; *(both needed for mark)*
all meet at "present time"; **[2]**
*Ignore curves before present time.*




(b) if density less than critical density/too low the universe will expand for ever;
if greater than critical density the universe contracts;
after an initial expansion; **[3]**
*If critical density not mentioned award* ***[1 max]****.*

(c) presence of dark matter / WIMPS / MACHOS *etc*; **[1]**

**Option F — Communications**

**17.** (a) the signal wave is/contains the information;
the carrier wave is modulated by the signal wave; **[2]**

(b) (i) difference between the highest and lowest frequency / range of frequencies in a signal; **[1]**

(ii) 1600 (kHz); **[1]**

(iii) difference in frequencies seen;
60 (kHz); **[2]**

(iv) the amplitude of the sidebands can be seen to vary; **[1]**

**18.** (a) (i) a distortion in the shape of the pulse as it travels through the fibre / *OWTTE*;
different components (frequencies or modes) of the pulse take different times to get across the fibre/get separated in time/are spread out; **[1 max]**

(ii) mention of modal and material dispersion;
(material) dispersion is caused by variation of propagation velocity/refractive index with wavelength;
(modal) dispersion is when rays of light of the same wavelength follow different paths/travel different distances along the fibre; **[3]**

(b) any unwanted signal / *OWTTE*; **[1]**
*Accept "a distortion in the shape of the pulse/signal".*

**19.** (a) polar-orbiting satellite closer to Earth's surface / lower orbit;
so lower power signals required;
so time delay between transmission and reception less; *(do **not** accept faster speed of transmission)*
covers whole of Earth's surface during several orbits; **[2 max]**

(b) (i) time-division multiplexing;
signal divided into chunks;
chunks transmitted sequentially;
chunks recombined in sequence at base station;
by using dead times between bursts of data / by assigning time slots to each signal; **[4 max]**
*Accept marking points in the form of a clearly labelled diagram.*

(ii) interval between samples $\frac{1}{25\,\text{kHz}} = 40\,\mu s$;

so maximum number of signals $\frac{40\,\mu s}{10\,\mu s} = 4$; **[2]**

**Option G — Electromagnetic waves**

**20.** (a) need a (lasing) material/gas with a metastable state;
metastable state has (unusually) long mean lifetime;
which allows a population inversion;
population inversion means greater number of excited atoms than non-excited atoms;
photon stimulates all excited atoms to de-excite (to lower level) at the same time;
(stimulating) photon has energy/phase similar to difference between levels; **[4 max]**

(b) (i) *with the first-order spectrum for beam A:*
read-off $\theta = 18^\circ$ for $n = 1$;
$d = \frac{530\times10^{-9}}{\sin 18^\circ} = 1.7\times10^{-6}$ (m);
lines per millimetre $= \frac{1}{1.7\times10^{-6}}\times10^{-3} = 583$ ($\sim 600$); **[3]**

***or***

*with the second-order spectrum:*
read-off $\theta = 39^\circ$ for $n = 2$;
$d = \frac{2\times530\times10^{-9}}{\sin 39^\circ}$ ($= 1.7\times10^{-6}$ (m));
lines per millimetre $= \frac{1}{1.7\times10^{-6}}\times10^{-3} = 583$ ($\sim 600$);

(ii) *with the first-order spectrum for beam B:*
read-off $\theta = 24^\circ$ for $n = 1$;
$\lambda = \frac{1.7\times10^{-6}\times\sin 24^\circ}{1} = 690$ (nm); **[2]**

***or***

*with the second-order spectrum:*
read off $\theta = 54^\circ$ for $n = 2$;
$\lambda = \frac{1.7\times10^{-6}\times\sin 54^\circ}{2} = 690$ (nm);

(iii) $\frac{3\times690\times10^{-9}}{1.7\times10^{-6}} = 1.2$;
$\sin\theta = 1.2^\circ$ has no solutions (hence third-order peak does not exist); **[2]**
*Allow alternative method using* $\sin 90^\circ$.

**21.** (a) $\left(\frac{1}{0.05}=\right)20$; **[1]**

(b) (i) attempted substitution into thin lens equation; *(allow incorrect signs)*

$v=\left(\frac{2\times 5}{2-5}\right)=(-)\,3.3$;

$m\left(=-\frac{v}{u}\right)=\frac{3.3}{2}=1.7$; **[3]**

(ii) virtual because $v$ is negative;
erect/upright because virtual/because $m$ is positive;
enlarged/magnified because $m$ is greater than 1; **[2 max]**
*Do not allow correct properties without an explanation.*

(c) different colours/wavelengths/frequencies have different refractive indices/speed of light (in glass);
(image with colour distortions due to the) different focal points (of said colours/wavelengths/frequencies); **[2]**

(d) use of a chromatic doublet / use of a combination of lenses; **[1]**

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