N13/4/PHYSI/SP3/ENG/TZ0/XX/M

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MARKSCHEME

November 2013

PHYSICS

Standard Level

Paper 3

16 pages

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 underlined 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) accommodation is the ability of the eye to bring into focus objects at different distances from the eye / *OWTTE*;
the near point is the closest distance from the eye at which objects can be accommodated/seen clearly/brought into focus;
the far point is the furthest distance from the eye at which objects can be accommodated/seen clearly/brought into focus; ***[3]***

(b) (i) the ciliary muscles change the curvature/shape of the eye lens;
the ciliary muscles contract thereby decreasing its focal length; ***[2]***

(ii) the ciliary muscles relax thereby increasing the focal length of the eye lens; ***[1]***
Award the first marking point in (b)(i) even if the answer only appears in (b)(ii).
Award ECF (b)(ii) if relax and contract are the wrong way round in both parts of (b).

2. (a) observed/perceived change in pitch/frequency;
when there is relative motion between source and observer; ***[2]***

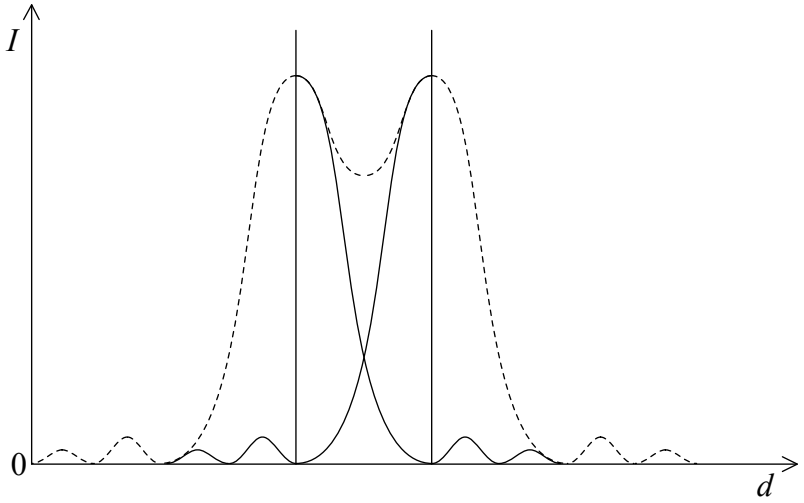
(b) recognize that $f' = \left[\frac{v}{v - u_s}\right] f$;

$566 = \left[\frac{v}{v - 28}\right] 520$;

to give $v = 345\,(\mathrm{m\,s^{-1}})$; ***[3]***

*Award **[0]** for use of the moving observer Doppler equation.*
*Award **[2 max]** for the use of +28 to give $-345\,(\mathrm{m\,s^{-1}})$.*
Otherwise award only the first marking point for substitution of the incorrect values in the correct equation.

3. (a)



correct shape of two diffraction patterns showing central maximum and at least one secondary maximum each side of central maximum;
intensity of secondary maxima no greater than one third intensity of central maxima; } *(judge by eye)*
first minimum of one pattern coincident with central maximum of other pattern; ***[3]***

or

Allow just the approximate dotted resultant intensity patterns:
correct pattern of two symmetrical principal maxima;
with local minimum between them;
at least one secondary maximum on each side which are no more than $\frac{1}{3}$ of the intensity of the principal maxima;

(b) angular separation for resolution $= 1.22\frac{\lambda}{b} = 1.22 \times \frac{5.0 \times 10^{-7}}{1.9 \times 10^{-3}} = (3.21 \times 10^{-4})$ (rad);

$= \frac{1.4}{d}$;

$d = 4.4\,(\text{km})$; ***[3]***

*Award **[2 max]** if 1.22 not used and answer is 5.3 km.*
*Award **[3]** for a bald correct answer.*

(c) light in which the electric/magnetic field (vector) vibrates only in one plane/direction; ***[1]***

(d) $(\tan^{-1}[n] =)\ \phi = 52^\circ$;

angle to surface $= 38^\circ$; ***[2]***

*Award **[2]** for a bald correct answer.*
*Award **[2]** if workings and answer are in radians, giving an answer of 0.66.*

Option B — Quantum physics and nuclear physics

4. (a) (i) electrons in the metal require a minimum amount of energy to be ejected from the metal;
(according to wave theory) the energy of a wave is dependent on intensity and not frequency;
so given enough time to absorb energy electron emission should take place at any frequency no matter what the intensity / *OWTTE*; ***[3]***

(ii) photons have energy *hf*/proportional to frequency (of the light);
an electron may be ejected if this energy is equal to or greater than a threshold value/work function;
the intensity determines the rate of release of photoelectrons, but not their energy; ***[3]***

(b) (i) recognize that slope of graph $= \frac{h}{e}$ ***or*** h (in eV s);

evidence of finding slope *eg.* $\frac{0.5}{[6.8-5.6]\times10^{14}} = 4.17\times10^{-15}$; } *(accept values in the range of 4.0 to 4.2 × 10⁻¹⁵)*

$h = 1.6\times10^{-19}\times4.17\times10^{-15} = 6.7\times10^{-34}\,(\text{J s})$; } *(accept values in the range of 6.4 and 6.7 × 10⁻³⁴ (Js))* ***[3]***

*Award **[0]** for an unsupported correct answer.*

(ii) threshold frequency $= 5.6\times10^{14}\,(\text{Hz})$;
work function $(hf_0) = 6.63\times10^{-34}\times5.6\times10^{14} = 3.7\times10^{-19}\,(\text{J})$ ***or*** $2.3\,(\text{eV})$; ***[2]***
*If necessary award **[2]** for use of ECF value of h from (b)(i).*
*Award **[2]** for use of any data point and $W = hf - Ek$ giving an answer of $3.7(\pm0.1)\times10^{-19}$ (J).*
*Award **[2]** for a bald correct answer.*

(c) use $p = \frac{h}{\lambda}$ and $E_K = \frac{p^2}{2m}$ to show that $\lambda = \frac{h}{\sqrt{2mE_K}}$; *(allow equivalent working)*

electron kinetic energy $= 0.5\times1.6\times10^{-19}\,(\text{J})$ ***or*** $8.0\times10^{-20}\,(\text{J})$;

$\lambda = \left(\frac{6.63\times10^{-34}}{\sqrt{2\times9.11\times10^{-31}\times8.0\times10^{-20}}} =\right) 1.74\times10^{-9}\,(\text{m})$; } *(must see to three significant figures or better)*

$(\approx 1.7\times10^{-9}\,\text{m})$ ***[3]***

Award marks for evidence of valid working, as the answer is given in the question.

5. (a) $\left({}^{40}_{19}\text{K} \rightarrow {}^{40}_{18}\text{Ar} + {}^{0}_{1}\beta^{+} + \nu\right)$

${}^{40}_{18}\text{Ar}$;

ν ; *(do not accept $\bar{\nu}$)* ***[2]***

(b) original number of K-40 atoms $= \left(1.6\times10^{22} + \left[8.4\times10^{21}\times10\right] =\right) 1.0\times10^{23}$;

decay constant $= \dfrac{\ln 2}{1.2\times10^{9}}$ ***or*** $5.8\times10^{-10}\,(\text{yr}^{-1})$;

$1.6\times10^{22} = 1.0\times10^{23}\ \text{e}^{-5.8\times10^{-10}t}$;

to give $t = 3.2\times10^{9}\,(\text{yr})$; ***[4]***

Accept any alternative method that leads to the correct answer.
*Award **[3 max]** ECF after incorrect value for N_0 (eg. use of 2.44×10^{22} to give 7.3×10^{22} yr).*
*Award **[2 max]** for approximate answers (eg. 3.0×10^{9} yr based on an estimate of between two and three half-lives.)*

Option C — Digital technology

6. (a) photons release energy that creates an electron/hole/electron-hole pair;
charges migrate to electrodes in pixel;
pixel has capacitance and so build up of charge develops potential difference; ***[3]***

(b) number of pixels $= 18.2 \times 10^6$;
each picture has 54.6×10^6 bytes;
$\left(\frac{16\,\text{GB}}{54.6\,\text{MB}} = \right) 293$ pictures; ***[3]***
*Award **[3]** for 296 pictures if two significant figures used.*
*Award **[3]** for a bald correct answer.*

(c) (i) laser light is incident on the disc;
light reflected from pits/lands is read as binary 0;
light reflected from the edge of a pit/land suffers destructive interference and is read as binary 1;
recognition of depth of pit as quarter wavelength; ***[3 max]***
Accept, with no penalty, answers where the 0 and the 1 are interchanged.
Look for marking points within a diagram.

(ii) more portable / easily manipulated / less space required; ***[1]***
Accept any other reasonable answer.

7. (a) *Look for these main ideas*:
V_{OUT} is either +15 (V) or –15 (V) / *OWTTE*;
V_{x} is $\pm 15\,\text{V} \times \frac{R_1}{(R_1 + R_2)}$ ***or*** $V_{\text{OUT}} \times \frac{R_1}{(R_1 + R_2)}$;
when V_{IN} becomes $> +V_{\text{x}}$, V_{OUT} switches to –15 (V);
when V_{IN} becomes $< -V_{\text{x}}$, V_{OUT} switches to +15 (V); ***[4]***
Accept similar arguments which refer to V_{supply} instead of 15 (V).
Accept answers which use values for V_{x} (±1.5 (V)) in second, third and fourth marking points.
Allow third and fourth marking points even if the polarities are the other way round.

(b) use of $\left[\frac{R_1}{R_1 + R_2} \right]$ ***or*** $\text{gain} = 1 + \frac{R_2}{R_1}$;
(magnitude of) $V_{\text{X}} = 1.5\,\text{(V)}$;
switches at ± 1.5 (V); ***[3]***
Allow ECF from second to third marking point.

8. cellular exchange monitors signal strength;
between phone and base stations;
cellular exchange switches between base stations;
to maintain maximum signal strength; ***[3 max]***

Option D — Relativity and particle physics

9. (a) a set of coordinates that can be used to locate events/position of objects; ***[1]***

(b) (i) $\frac{1.80\times10^{11}}{0.750\times3\times10^{8}}$;
$=800\,(\text{s})$; ***[2]***
*Award **[2]** for a bald correct answer.*

(ii) $\gamma=\left(\frac{1}{\sqrt{1-0.750^{2}}}=\right)1.51$;
$\text{time}=\left(\frac{800}{1.51}=\right)530\,(\text{s})$; ***[2]***
Watch for ECF from (b)(i) or first marking point in (b)(ii).
*Award **[2]** for a bald correct answer.*

(iii) only S's clock measures proper time;
because S's clock is at both events / events occur at same place in S's frame; ***[2]***

(iv) according to S, Y moves towards/X moves away from the radio signal;
the signal travels at the same speed/at the speed of light in each direction;
therefore according to S's clock the signal reaches Y before it reaches X/X after reaching Y; ***[3]***

or

S's frame is different/moving relative to the X and Y frame;
the two events/arrival of signals are separated in space;
so if simultaneous for XY, cannot be simultaneous for S;

10. (a) (i) W^-; *(allow W^+, W boson)* ***[1]***

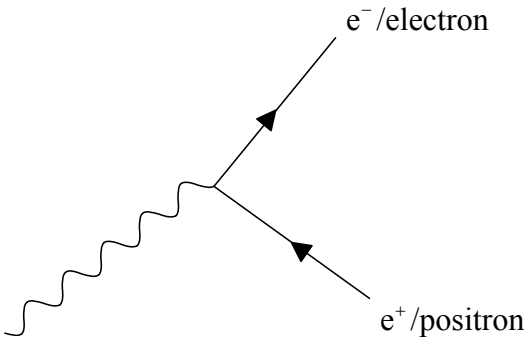
(ii) proton; ***[1]***

(iii) π^0 is a (neutral) meson;
π^0 has integer spin/is a boson;
π^0 is unstable;
π^0 is its own antiparticle; ***[2 max]***

(b) $m = \frac{h}{R4\pi c}$; *(must see evidence of rearrangement to award this mark)*
82 $(\text{MeV}\,\text{c}^{-2})$; *(do not accept answers in kg)* ***[2]***
*Award **[2]** for a bald correct answer.*

(c) (i) pair production; ***[1]***

(ii)



single vertex showing photon and two correctly labelled particles;
arrow direction correct for e^+ and e^-; ***[2]***
Allow time axis to run vertically.
If Feynman diagrams include the meson decay, only consider either gamma's pair production.

(d) strangeness is not conserved, changes from –1 to 0;
weak interaction does not have to conserve strangeness in decay of Σ^+; ***[1 max]***
To award the mark reasoned answers are required.

Option E — Astrophysics

11. (a) realizes that motion of Canis Minor is due to Earth's rotation (relative to stars);
specific reference to west to east rotation of Earth and relative opposite rotation of Canis Minor; ***[2]***
If second marking point is awarded then award first marking point also.

(b) apparent magnitude / brightness of a star;
at a distance of 10 pc (from observer); ***[2]***

or

a logarithmic measure/scale;
of the star's luminosity;

(c) (i) apparent magnitude is smaller than/similar to absolute magnitude;
so Luyten's star must be closer than 10 (pc) / must be relatively close to Earth;
this is less than 100 (pc); *(allow values in the range of 10 (pc) to 1000 (pc) for upper limit)* ***[3]***

or

$9.9 - 11.9 = 5\lg\left(\frac{d}{10}\right)$;
so $d = 4.0$ (pc);
this is less than 100 (pc); *(allow values in the range of 10 (pc) to 1000 (pc))*
Allow ***[2 max]*** *ECF if magnitudes are reversed giving 25 (pc).*
Allow third marking point (ECF) after incorrect value for d only if value is less than 1000 (pc).
Do not award the third marking point for vague statements that the distance is within parallax range.

(ii) *Allow a very wide range of upper limits*:
up to X; *(where 10 kpc < X < 10 Mpc)* ***[1]***
Ignore any lower limit.

(d) (i) $2.9 = -0.7 + 5\lg\left(\frac{d}{10}\right)$;

$\frac{d}{10} = 10^{\frac{3.6}{5}}$;

52 (pc); ***[3]***

*Award **[2 max]** ECF if magnitudes are reversed giving 1.9 (pc).*
*Award **[2 max]** if data for Lutyen's star is used and no credit for the distance of 4 (pc) has already been given in (c)(i).*
*Award **[3]** for a bald correct answer.*

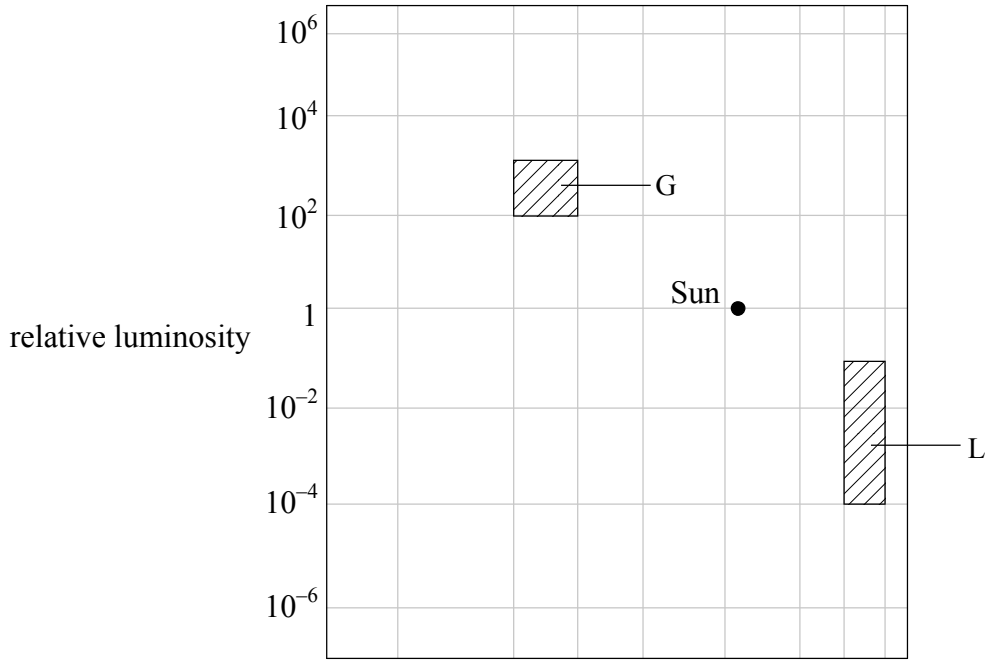
(ii) $\frac{L_G}{L_S} = \left[\frac{R_G}{R_S}\right]^2 \left[\frac{T_G}{T_S}\right]^4$;

$= 4^2 \times \left[\frac{11000}{5800}\right]^4$;

$= 210$; *(must see this answer to better than 1 significant figure)* ***[3]***

Approximate answer of 200 is given in the question so correct steps in the working are required to award any marks.

(e)



(i) G correct within region shown; ***[1]***

(ii) L correct within region shown; ***[1]***

12. (a) uniform / homogeneous / isotropic;

has existed forever/infinite age; } *(must refer to "time", as infinite (space) is given in the question)* ***[1 max]***

(b) the light from (distant) galaxies is red-shifted;
this shows that they are moving away from us/each other;
so the universe is expanding/changing; ***[3]***

or

CBR is red-shifted (remnant of the Big Bang);
CBR was originally very short wavelength/very high frequency/very high temperature;
its current longer wavelength/low temperature is evidence that the universe has expanded;

Allow reverse arguments eg. universe expansion so galaxies moving apart so red-shift.

Option F — Communications

13. (a) carrier wave is changed by a signal wave;
to allow the carrier to transfer information; ***[2]***

(b) (i) amplitude is constant; ***[1]***

(ii) frequency changes by $\pm 1.5 \times 12$ (kHz) (18 kHz);
so from 93.982 (MHz) to 94.018 (MHz);
6000 times every second; ***[3]***
If second marking point is awarded, award first marking point also, even if it is not explicit.

(c) $(2 \times 18) = 36\,(\text{kHz})$; ***[1]***

or

$(2 \times [18 + 6]) = 48\,(\text{kHz})$;
Allow ECF from (b)(ii).

14. (a) (i) dispersion occurs;
resulting in signals/light taking different times to travel along the fibre;
(modal dispersion) is dependent on path taken/internal reflections;
(material dispersion) depends on variation of wave speed with wavelength; ***[3 max]***

(ii) pulses sent separately can overlap when received; ***[1]***

(iii) area of pulse indicates energy in pulse;
smaller, so energy less; ***[2]***
*Award **[1 max]** for discussion of height of pulse.*

(b) reference to time gaps/dead time between pulses in signal transmission;
(time-division multiplexing) merges many separate signals to fill these gaps;
(this is cost-effective since) the rate of information/data transfer rate along a fibre increases / fewer fibres needed; ***[3]***

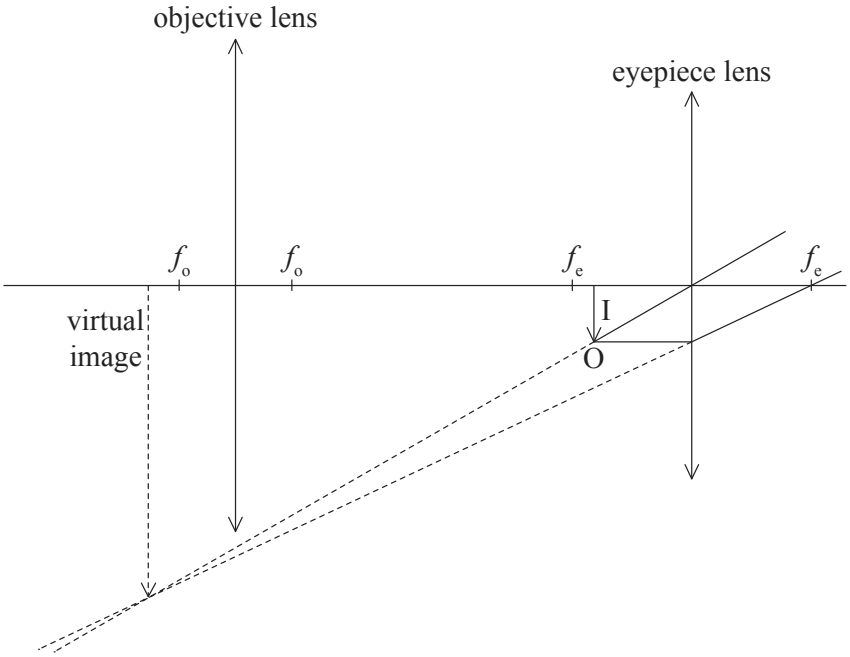
(c) (i) wire pair / coaxial cable / radio waves; ***[1]***

(ii) lower cost;
less time delay;
easier to maintain;
less attenuation; (*this is uncertain but allow*) ***[1 max]***
Allow other reasonable responses.

(iii) less power required each way;
less expensive to put into orbit;
less time delay on message round trip;
can cover whole surface over several orbits rather than continuous over smaller area; ***[2 max]***
Do not reward a response of "different heights" without consideration of the above marking points.

Option G — Electromagnetic waves

15. (a)



at least two rays from O correctly refracted at eyepiece;
completed extrapolation of these rays to form a virtual image; ***[2]***

Ignore rays refracted by the objective lens.
*Award **[1 max]** ECF in second marking point.*
Allow virtual image positions to be either side of objective lens.
*Award **[0]** for formation of a real image.*

(b) (i) $u = (18.1 - 14.8 =) 3.3\,(\text{cm})$;

$\frac{1}{v} = \frac{1}{3.8} - \frac{1}{3.3}$;

$(-)25.1\,(\text{cm})$; ***[3]***

*Award **[2 max]** ECF for wrong u value (eg. 14.8 (cm) giving an answer of $v = 5.1$ (cm).*
*Award **[1 max]** if positive sign appears in second term in right-hand side of equation.*
*Award **[3]** for a bald correct answer.*

(ii) $M_{\text{eye}} = \left(\frac{D}{f} + 1 = \frac{25.1}{3.8} + 1 = \frac{25.1}{3.3} =\right) 7.6$;

overall magnification $= (6 \times 7.6 =) 46$; ***[2]***

*Award **[2]** ECF from (b)(i).*
*Award **[1 max]** ECF from first to second marking point.*
*Award **[2]** for a bald correct answer.*

(c) each colour/wavelength has a different refractive index / *OWTTE*;
a range of wavelengths focuses different colours/wavelengths at different points/distances;
reducing the range of wavelengths reduces the range of image distances/reduces the coloured edging to images/reduces dispersion; ***[2 max]***

16. (a) net displacement of the medium;
equals the resultant/sum of individual displacements; ***[2]***
*Award **[1 max]** for reference to amplitude rather than displacement.*
*Award **[0]** for reference only to troughs and crests.*

(b) (i) division of wavefront so constant phase; ***[1]***

(ii) interference/superposition occurs at A;
between waves from each opening;
waves arrive in phase / path difference is <u>one</u> wavelength;
producing a (1st order) maximum; ***[3 max]***
*Award **[3 max]** for clear points that appear on diagram.*

(iii) maxima occur when the path difference is an integral number of wavelengths;
because wavelength doubles, larger distances/angles required to achieve same path difference;
successive maxima fringes are twice as far/further apart; ***[3]***

or

quotes double slit/grating formula;
substitute 2λ into equation and states all other terms stay constant;
successive maxima fringes are twice as far/further apart;

(c) *Assuming spacing of openings stays the same.*
same separation of maxima;
maxima increase in amplitude/intensity;
maxima narrower/sharper;
formation of secondary maxima; ***[2 max]***
*Award **[2 max]** for other reasonable responses if the response clearly states an assumption that the openings are closer or further apart than before.*