International Baccalaureate®
Baccalauréat International
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MARKSCHEME

May 2014

PHYSICS

Standard Level

Paper 3

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.

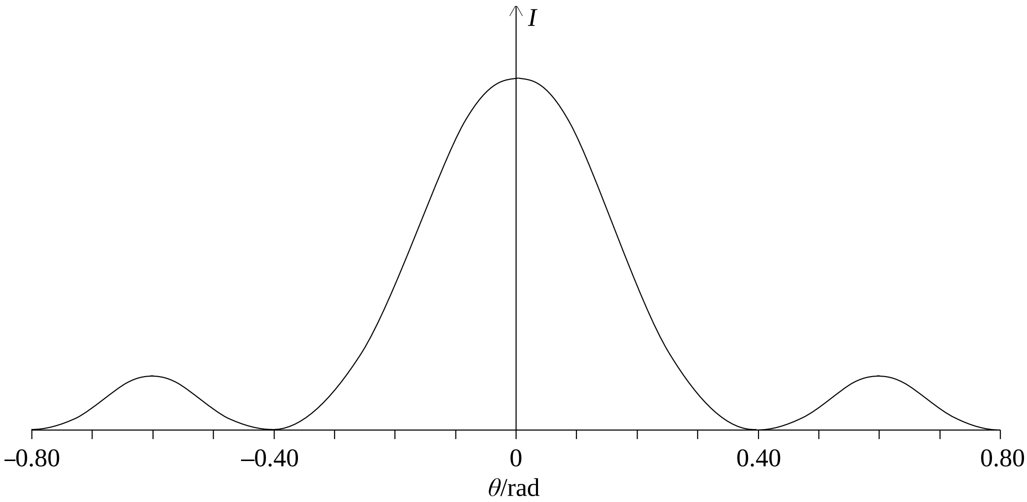
10. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the markscheme.

Option A — Sight and wave phenomena

1. (a) (i) $\theta = \dfrac{1.22 \times 59 \times 10^{-6}}{0.18 \times 10^{-3}}$;
(= 0.40 rad) ***[1]***

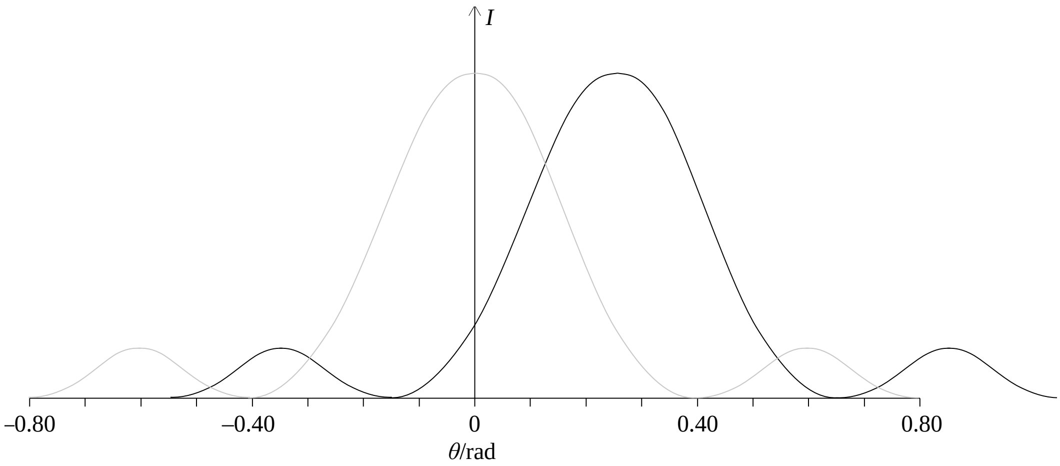
(ii) central symmetrical maximum;
at least one secondary maximum on each side, no more than one third the height of the central maximum; *(judge by eye)*
minima drawn to zero, *ie* touching axis at $\theta = \pm 0.40$ (and ± 0.80); ***[3]***

eg:



(b) shifted horizontally 0.25 rad either direction; ***[1]***
Allow ECF for incorrect shape from (a), correctly shifted.

eg:



(c) (i) the images of two sources are just resolved if the central peak of the diffraction pattern of one source coincides with the first minimum of the diffraction pattern of the other source / *OWTTE*; ***[1]***

(ii) not resolved;
Rayleigh criterion is not satisfied since $0.25 < 0.40$; } *(allow equivalent explanation in terms of maxima of the diffraction patterns)* ***[2]***
Do not award first marking point unless a reason is attempted.

2. (a) (i) $f_1 = \dfrac{v}{4L},\ f_2 = 3f_1 = \dfrac{3v}{4L}$;

$f_2 - f_1 = \dfrac{v}{2L} = 820\,(\text{Hz})$;

$L = \dfrac{330}{2\times 820}$;

$\left(L = 0.20\,\text{m}\right)$ ***[3]***

(ii) $\lambda = 4L = 0.80\,(\text{m})$;

$f = \left(\dfrac{330}{0.8}\right) = 413\ \text{Hz}$; ***[2]***

This is a question testing units for this option. Do not award second marking point for an incorrect or missing unit.

(b) (i) a change in the observed frequency/wavelength of a wave;
when there is relative motion of observer and source; ***[2]***

(ii) $f'\left(= f\dfrac{v}{v-u_s}\right) = 410\times\dfrac{330}{330-50}$;

$f' = 480\ (\text{Hz})$; ***[2]***

Allow ECF from (a)(ii).

3. photopic vision during day/high light intensity, scotopic vision during night/low light intensity;
photopic uses cones, scotopic uses rods;
photopic vision distinguishes colours, scotopic vision cannot;
photopic vision distinguishes detail/provides high resolution, scotopic vision does not; ***[3 max]***

Option B — Quantum physics and nuclear physics

4. (a) all particles have an associated wavelength/behave like waves;
with $\lambda = \frac{h}{p}$ and symbols defined/described using terms; ***[2]***

(b) (i) $p = \left(\sqrt{2mE} = \sqrt{2meV} =\right) \sqrt{2 \times 9.11 \times 10^{-31} \times 1.6 \times 10^{-19} \times 5.0 \times 10^{3}}$;
$= 3.8 \times 10^{-23}$ (N s); ***[2]***

or

$v = \left(\sqrt{\frac{2eV}{m}} =\right) \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 5.0 \times 10^{3}}{9.11 \times 10^{-31}}}$;
$p = (mv =) 3.8 \times 10^{-23}$ (N s);

(ii) $\lambda = \left(\frac{h}{p} =\right) \frac{6.63 \times 10^{-34}}{3.8 \times 10^{-23}}$;
$= 1.7 \times 10^{-11}$ m; ***[2]***
This is a question testing units for this option. Do not award second marking point for an incorrect or missing unit.

(iii) $E = \left(hf = \frac{hc}{\lambda} =\right) \frac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{1.7 \times 10^{-11}}$;
$E = 1.2 \times 10^{-14}$ (J); ***[2]***

or

$E = (cp =)\ 3.0 \times 10^{8} \times 3.8 \times 10^{-23}$;
$E = 1.2 \times 10^{-14}$ (J);
Allow ECF from (b)(ii).

(c) reference to the Heisenberg uncertainty principle / $\Delta x \Delta p \geq \frac{h}{4\pi}$;
$\Delta p = 0$ implies Δx is large / $\Delta x = \infty$; ***[2]***

(d) the (square of the) amplitude gives the probability of finding the electron at a given point in space; ***[1]***

5. (a) the probability of decay of a nucleus per unit time; ***[1]***

(b) (i) alpha particle / helium nucleus; ***[1]***

(ii) number of Po nuclei produced = number of Rn nuclei decayed (*seen or implied*);

$0.5 = 1.6e^{-\lambda t}$;

$$t = \left(-\frac{\ln \frac{0.5}{1.6}}{\lambda} = \right) \frac{1.163}{8.0 \times 10^{-5}};$$

1.5×10^{4} (s); ***[4]***

(c) initial kinetic energy = electric potential energy at closest distance;

kinetic energy $E = \left(6.2 \times 10^{6} \times 1.6 \times 10^{-19} = \right) 9.9 \times 10^{-13}$ (J);

$$d = k\frac{q_1 q_2}{E} = 8.99 \times 10^{9} \frac{2 \times 79 \times \left[1.6 \times 10^{-19}\right]^2}{9.9 \times 10^{-13}} \text{ (m)} \ \textbf{\textit{or}} \ = 3.7 \times 10^{-14} \text{ (m)};$$ ***[3]***

Option C — Digital technology

6. (a) a potential difference/charge develops across each pixel / a potential difference/charge is converted into a digital signal;
the pixel position is also stored; ***[2 max]***

(b) (i) area of CCD $=12\times10^{-3}\times18\times10^{-3}$;
area of one pixel $=\left[8.4\times10^{-6}\right]^2=\left(7.0\times10^{-11}\right)$;
$\left(N=3.1\times10^{6}\right)$ ***[2]***

(ii) $n=\dfrac{12\times25\times3.1\times10^{6}\times16}{680\times10^{6}\times8}$;
$n=3$; ***[2]***
Only accept integer answer.

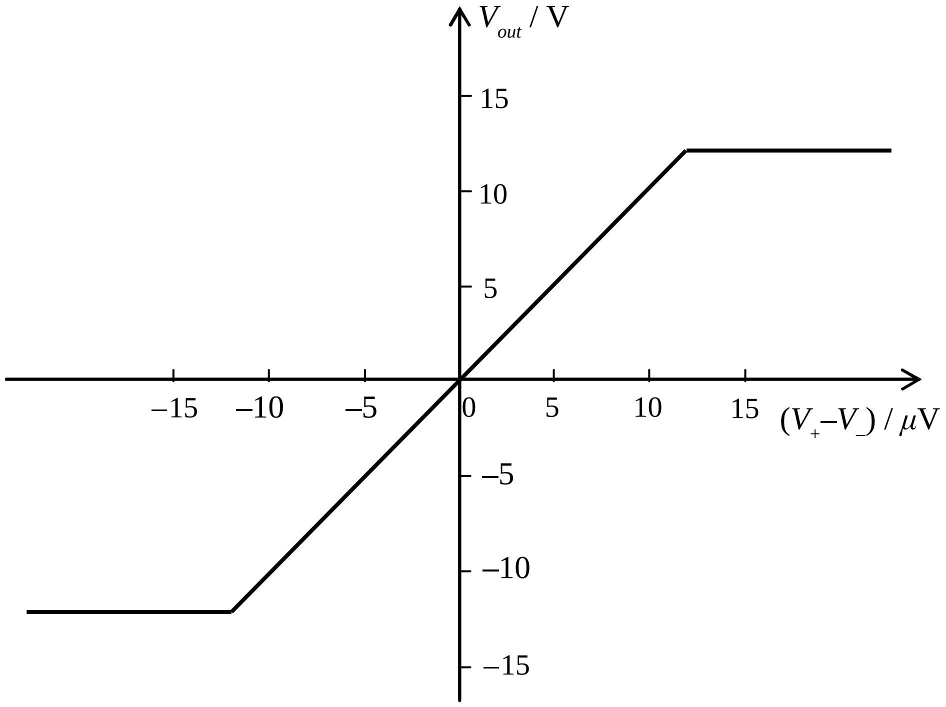
(c) at the boundary between a pit and a land, part of the ray is reflected by the pit and part by the land;
laser light is coherent so reflected light is a superposition of out-of-phase rays;
destructive interference occurs / the sensor reading is zero and this corresponds to the digital signal; ***[3]***

(d) $d=\dfrac{\lambda}{4}=\dfrac{405}{4\times1.61}$;
$d=63$ (nm); ***[2]***
Award ***[1 max]*** *if refractive index is not used, giving an answer of 101 (nm).*

7. (a) 8 (V) ;
−12 (V) ; ***[2]***

(b) linear region shown;
with slope 10^6 ;
saturation regime shown; (*judge by eye*) (*accept values in the range of 10 V–14 V*) ***[3]***

eg:



(c) (i) comparator; ***[1]***

(ii) $V_- = 6\,(\text{V})$;
$\frac{R_2}{R_1} = 3$;
$R_2 = 30\,\text{k}\Omega$; ***[3]***
This is a question testing units for this option. Do not award third marking point for an incorrect or missing unit.
Award ***[3]*** *for a bald correct answer.*

Option D — Relativity and particle physics

8. (a) a co-ordinate system (in which measurements of distance and time can be made);
which is not accelerating;
in which Newton's laws are valid; ***[2 max]***

(b) (i) $\left(\frac{10}{0.90c}=\right)11\ \text{yr}$;
$(=3.5\times10^{8}\ \text{s})$ ***[1]***
This is a question testing units for this option. Do not award mark for an incorrect or missing unit.

(ii) distance according to spaceship observer $=\frac{10}{2.3}(=4.3\text{ly})$;
so time for spaceship $=\left(\frac{4.3}{0.90}=\right)4.8(\text{yr})$; ***[2]***

(c) between two events occurring at the same point in space / shortest time measured;
so proper time interval measured by observer on spaceship; ***[2]***
Do not award second marking point unless a reason has been attempted.

(d) speed of light is the same for both observers O and S / events simultaneous in stationary reference frame are not (necessarily) simultaneous in moving reference frame;
S is moving so PS will be longer than QS when light reaches S;
so if light arrives simultaneously then light from P will have been in transit for longer than Q;
therefore P emits a flash before Q; ***[3 max]***

9. (a) π^{-} / antiparticle of π^{+}; ***[1]***
Do not award mark if sign is omitted.

(b) (i) (electro) weak; ***[1]***

(ii) gluon/photon; ***[1]***

(c) strangeness is not conserved (in interaction B therefore it is a weak interaction);
strangeness is conserved in interaction C/in strong and electromagnetic interactions; ***[2]***

10. (a) (i) a particle that mediates/carries/transmits one of the fundamental forces / a particle that is exchanged between two particles when undergoing one of the fundamental interactions / *OWTTE*; ***[1]***

(ii) $R = \dfrac{hc}{4\pi \times 1.35 \times 10^{8} \times 1.6 \times 10^{-19}}$;
0.73 (fm) ;
(diameter of proton is about 10^{-15} m) ***[2]***

(b) (quarks are confined) a single quark cannot be observed/exist outside nucleon as the interaction strength increases with separation;
(so the) energy supplied will create a hadron/quark-antiquark pair (such as π meson) rather than a free quark; ***[2]***

Option E — Astrophysics

11. icy/dusty object;
moving around the Sun on a (highly) elliptical orbit;
when <u>close to Sun</u> likely to display atmosphere (coma)/tail;
when <u>far from Sun</u> (ice re-freezes and) atmosphere no longer present; ***[2 max]***
Award ***[2]*** *only if it is clearly stated that the object is a part of a Solar system.*

12. balance of two forces/pressures;
(balance) between radiation/pressure and gravitational force/pressure;
(radiation pressure is when) photons/radiation exert outwards force on nuclei/ particles;
(gravitational pressure is when) gravitational force between particles/layers of the star acts inwards; ***[3 max]***

13. (a) $-2.89 = 5\log_{10}\left[\frac{d}{10}\right]$;
$d = 10^{0.422}$;
$2.63\,(\text{pc})\,(= 2.6\,\text{pc})$; *(must see 3+ significant figures to award this mark)* ***[3]***
Award ***[2 max]*** *if d=2.6(pc) is substituted and shown that left side is almost equal to right side.*

(b) $L\left(= 4\pi bd^2\right) = 4\times\pi\times1.2\times10^{-7}\times\left[8.1\times10^{16}\right]^2$;
$9.9\times10^{27}\,(\text{W})$; ***[2]***

(c) higher temperature on HR diagram means more massive;
Sirius A is to left of Sun on diagram so is more massive than Sun; ***[2]***
Do not accept bald answer for this mark.
Award ***[1 max]*** *if no reference is made to relative positions of Sirius and Sun on HR diagram.*

(d) (stellar) parallax;
compare angular direction/position of star at times six months apart (to yield angular change θ);
relative to the background of fixed/distant stars;
use of earth orbital diameter D/1AU to yield distance to star $\left(d = \frac{\text{D}}{\theta}\right)$; ***[4]***
Accept marking points in the form of a diagram.

14. assume uniform density of stars;
number of stars in each shell is proportional to [radius of shell]^2;
apparent brightness from shell is inversely proportional to [radius of shell]^2;
light/radiation from shells adds up;
(intensity of shell is independent of radius and) total intensity is infinite / sky is never dark (because infinite universe/infinite number of stars assumed); ***[4 max]***

Option F — Communications

15. (a) amplitude modulation/AM; ***[1]***

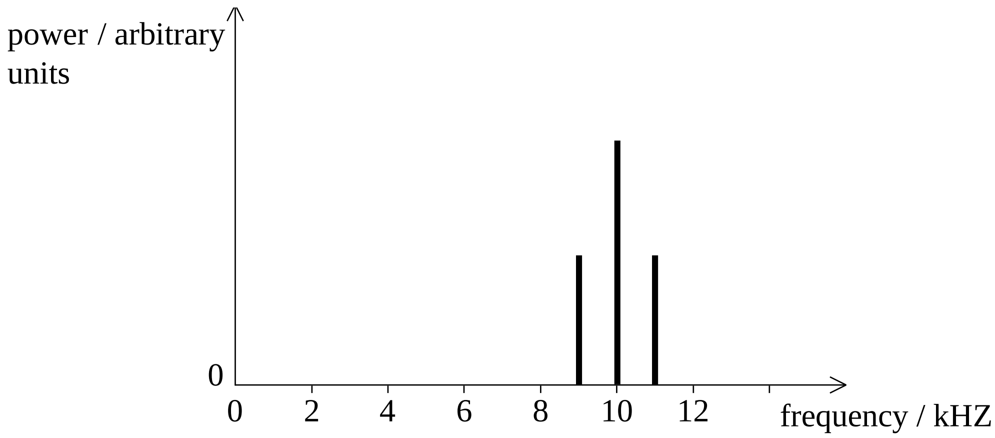
(b) (i) $10\,000\ \text{Hz/s}^{-1}$; ***[1]***
This is a question testing units for this option. Do not award mark for an incorrect or missing unit.

(ii) $1\,(\text{mV})$; ***[1]***

(iii) $1000\,(\text{Hz})$; ***[1]***

(c) central peak at the correct frequency $10\,\text{kHz}$; *(allow ECF from (b))*
sidebands at the correct frequency $9\,\text{kHz}$ and $11\,\text{kHz}$; *(allow ECF from (b))*
central peak higher than sidebands; ***[3]***

eg:



16. (a) 4; ***[1]***

(b) at $t = 0\,\text{ms}$, $v = (10.2\,\text{mV} \rightarrow 10\,\text{mV} \rightarrow) 1010$;
at $t = 1\,\text{ms}$, $v = (12.2\,\text{mV} \rightarrow 12\,\text{mV} \rightarrow) 1100$;
at $t = 2\,\text{ms}$, $v = (15.2\,\text{mV} \rightarrow 15\,\text{mV} \rightarrow) 1111$; ***[2 max]***
Allow ECF if less than 4 bits quoted in (a).

(c) sampling rate/bandwidth too low;
number of bits/resolution/quantization levels too few;
too high change of sample between successive samples / *OWTTE*; ***[2 max]***

(d) $= \dfrac{120 \times 8}{1.3}$;
$= 740\ (\text{kbit}\,\text{s}^{-1})$; ***[2]***

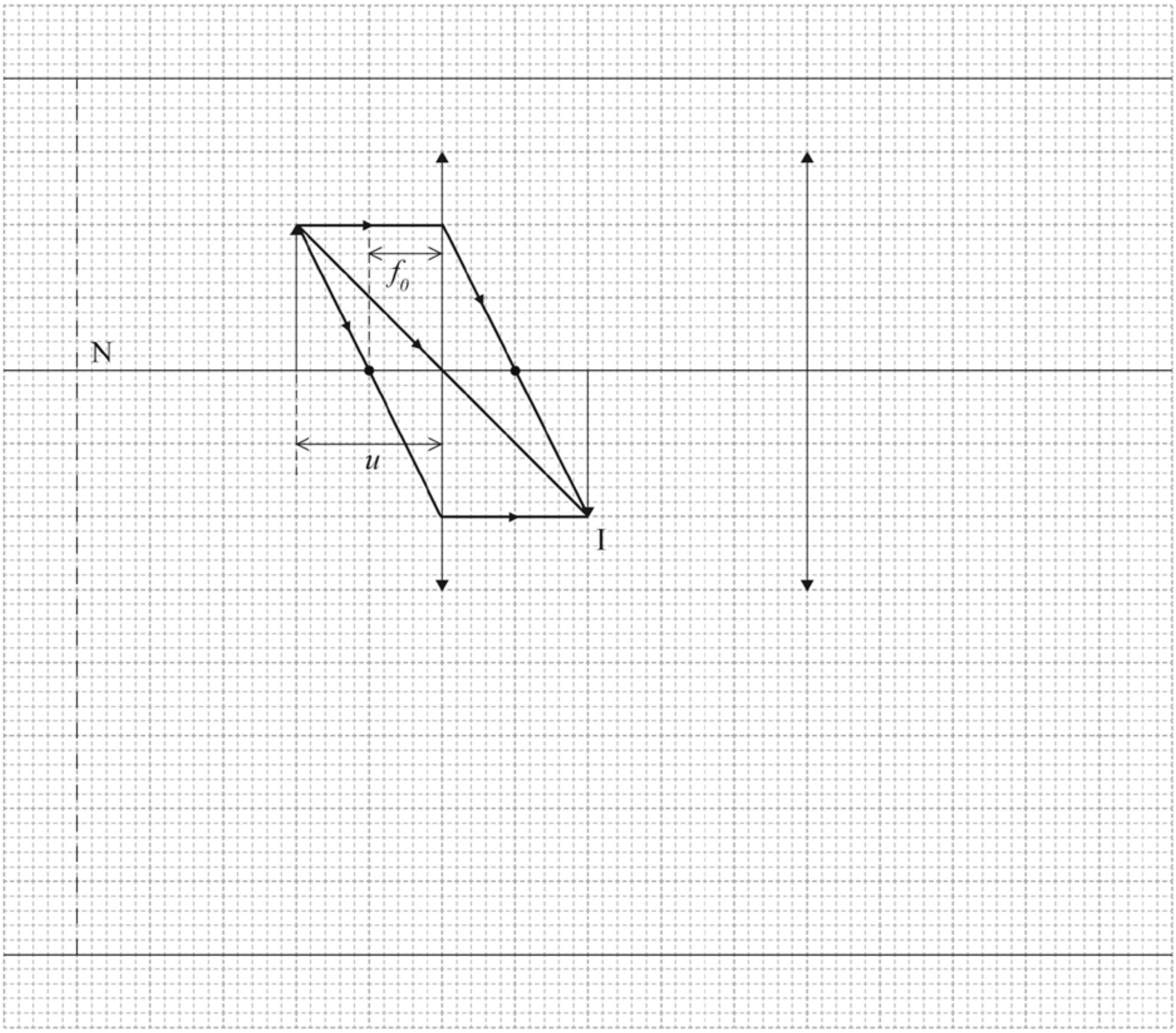
17. (a) *A*: polar-orbiting;
B: equatorial/geostationary/geosynchronous; ***[2]***

(b) type B;
because they are always above the same point on the Earth’s surface; ***[2]***

(c) two frequencies required / up-link and down-link frequencies are kept separated;
to avoid interference between the signals; ***[2]***

Option G — Electromagnetic waves

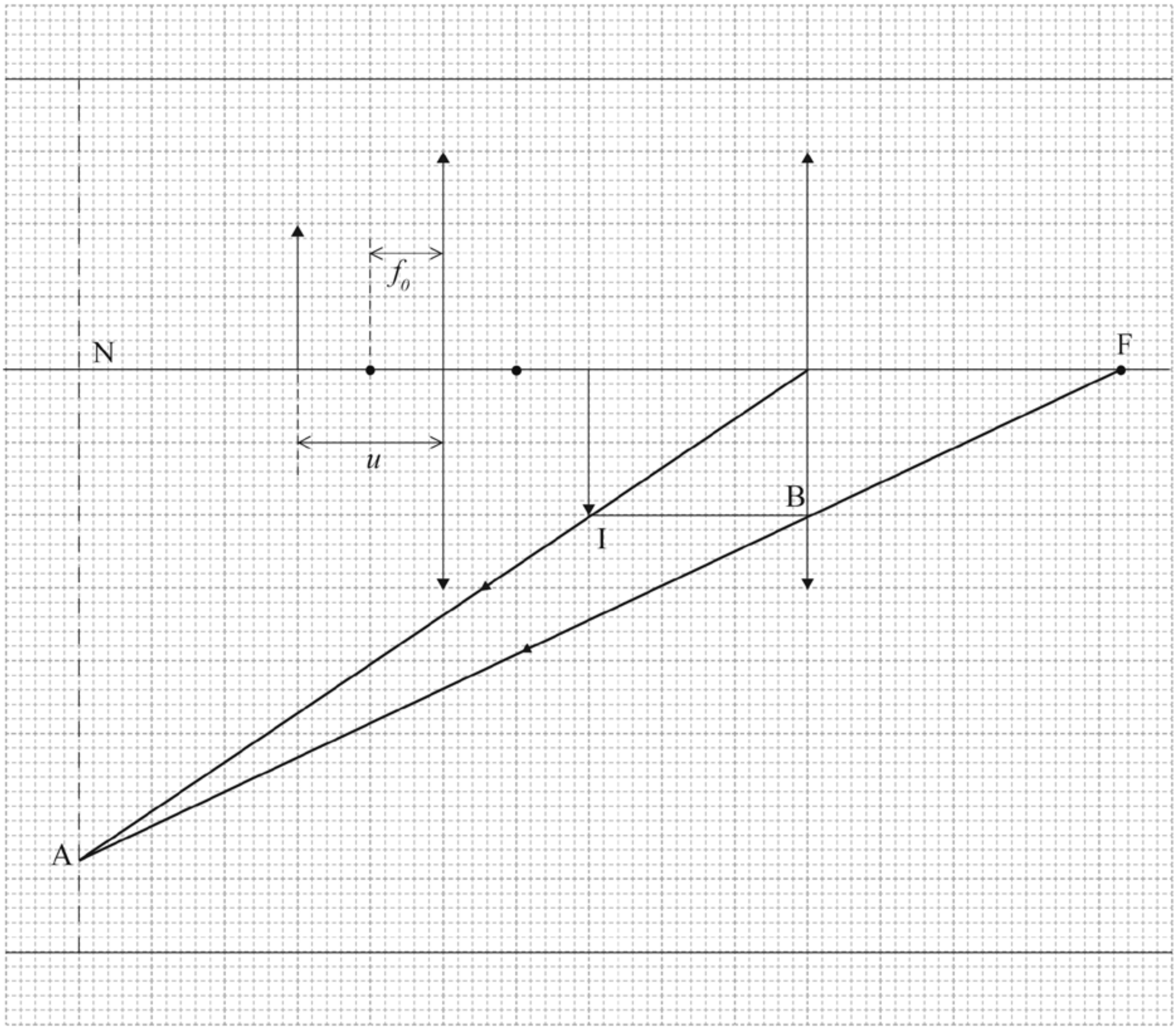
18. (a) (i) any two standard rays out of the three shown below;
converging to locate the image; ***[2]***



(ii) (image is real) because rays of light/energy pass through it; ***[1]***

(b) (i) the closest distance the unaided human eye can focus (without undue strain); ***[1]***
Do not accept 25 cm without explanations.

(ii) standard ray through the center of the eyepiece to locate point A;
standard ray through points A and B;
extrapolated to the principal axis to locate the focus F, 10.7 cm from the eyepiece; *(allow focal lengths between 9 cm and 12.5 cm if the two standard rays are clearly identified)* ***[3]***



or

$v = -25\,\text{cm}$;
$u = +7.5\,\text{cm}$;

$$f = \left[\frac{1}{u} + \frac{1}{v}\right]^{-1} (= 10.7\,\text{cm});$$

(iii) counting small squares, size of final image $= 33.3$ and size of object $= 10$;

$$m = \frac{33.3}{10} = 3.3;$$ ***[2]***

or

$m_1 = 1$ and $M_2 = \left(\frac{25}{7.5} = \right) 3.3$;
$M = (m_1 \times M_2 =) 3.3$;

19. (a) waves of different wavelength/frequency;
travel at different velocities;
the index of refraction of the medium depends on the wavelength/frequency; ***[2 max]***

(b) during simple harmonic motion the charge oscillates/accelerates;
(oscillating/accelerating) charges radiate/produce (varying) electric/magnetic fields / produce electromagnetic waves; ***[2]***

20. (a) (i) intensity at P is zero hence complete destructive interference occurs;
point P is at the same distance from A and B / path difference is zero;
destructive interference comes from a 180° phase difference in the signals; ***[3]***

(ii) separation between minima $s = 3\ (\text{km})$;
$\frac{D}{d}\left(=\frac{s}{\lambda}=\frac{3000}{40}\right)=75$; ***[2]***

(b) R is always equidistant to stations A and B / signals from A and B are always out of phase;
intensity is always zero; ***[2]***