Markscheme

November 2015

Physics

Standard level

Paper 3

14 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.

Option A — Sight and wave phenomena

1. (a) scotopic vision uses rods (not cones);
the spectral response of all rods peaks at the same wavelength;
so rods can only signal presence or absence of light;
three types of cones respond to different peak wavelengths (allowing colour vision); **[3 max]**
The second and fourth marking points may be shown on a spectral response graph.

(b) cones found in fovea/centre allowing clear colour vision;
rods over rest of retina allow better night sight/motion/peripheral vision; **[2]**

2. (a) (i) third harmonic means 1.5 loops; *(accept in form of a diagram)*
$\frac{2}{3}\times 0.27\ (=0.18)$; **[1 max]**

(ii) length is $\frac{3}{4}$ of a wavelength so $\lambda = 0.36\,\text{m}$;
$f = 940\,\text{Hz}$; **[2]**

(b) $f' = 940\left(\frac{340}{340+22}\right)$;
880 Hz; **[2]**

3. (a) large central peak and at least one subsidiary maximum on each side;
minima have intensity of zero and intensity of secondary maxima at most 25 % of central maximum; *(judge by eye)* ***[2]***

(b) explanation of resolving – seeing images as being from separate objects;
idea of diffraction patterns overlapping;
central maximum being at least as far from companion as the first minimum; **[3]**

(c) equating $1.22\frac{\lambda}{b}$ to $\frac{x}{D}$;
0.43 (m); **[2]**

4. use polarizing filter/Polaroid and place over display and rotate;
when display becomes totally dark the Polaroids are crossed;
the planes of polarization are at right angles so the display must emit plane polarized light; **[3]**

Option B — Quantum physics and nuclear physics

5. (a) light made of photons of energy $E = hf$;
electrons are released immediately from the metal;
if electron gains sufficient energy (from a photon); **[2 max]**

(b) different electrons may be bound by a different amount of energy to the metal; **[1]**

(c) insufficient photon energy to eject surface electrons;
greater intensity means more photons but still none with enough energy; **[2]**

(d) $E_{\text{max}} = (1.75 \times 1.60 \times 10^{-19} =)\ 2.80 \times 10^{-19}\ \text{J}$;

$$\phi = \left(hf - E_{\text{max}} = 6.63 \times 10^{-34} \times \frac{3.00 \times 10^{8}}{620 \times 10^{-9}} - 2.80 \times 10^{-19} = \right) 4.1 \times 10^{-20}\ \text{J};$$ **[2]**

6. (a) (i) only the three correct arrows on diagram; **[1]**
(–1.51 to –3.40, –1.15 to –13.6 and –3.40 to –13.6)

(ii) 1.89 eV; **[1]**

(b) (i) photon is absorbed;
electron (in a hydrogen atom) raised to higher/–3.40 eV/excited state; **[2]**

(ii) no absorption / photon pass through; **[1]**

7. (a) *X*: 26 and *Y*: 12; *(both needed for* ***[1]****)*
Z: *v*/neutrino; **[2]**
Do not allow the antineutrino.

(b) total energy released is fixed;
neutrino carries some of this energy;
(leaving the beta particle with a range of energies) **[2]**

(c) (i) the time taken for half the radioactive nuclides to decay / the time taken for the activity to decrease to half its initial value; **[1]**
Do not allow reference to change in weight.

(ii) $\lambda = \left(\frac{\ln 2}{7.2 \times 10^{5}} = \right) 9.63 \times 10^{-7}$;

$11.2 = 36.8 e^{-\left(9.63 \times 10^{-7}\right) t}$;

$t = 1.24 \times 10^{6}\ \text{yr}$; **[3]**

Option C — Digital technology

8. (a) ability to make more copies easily / faster retrieval / text can be manipulated / more can be stored in the same volume; **[1]**
Allow any other sensible suggestion.

(b) estimation 3000 characters per page; *(allow a range between 2000 and 4000)*
number of bits per page $= 3000 \times 16 (= 48\,000)$;

number of pages $= \dfrac{700 \times 10^6 \times 8}{3000 \times 16} = (1.17 \times 10^5)$; **[3]**

Allow sensible answers based on estimation of characters per page.

9. (a) the ratio of charge to potential difference / $C = \dfrac{Q}{V}$ with pronumerals explained; **[1]**

(b) energy received by pixel $= 1.6 \times 10^{-3} \times 2.1 \times 10^{-12} \times 0.15 \ (= 5.04 \times 10^{-16}\text{ J})$;

number of photons incident on the pixel $= \dfrac{5.04 \times 10^{-16}}{4.8 \times 10^{-19}} (= 1050)$;

number of electrons ejected $= 0.6 \times 1050 \ (= 630)$;

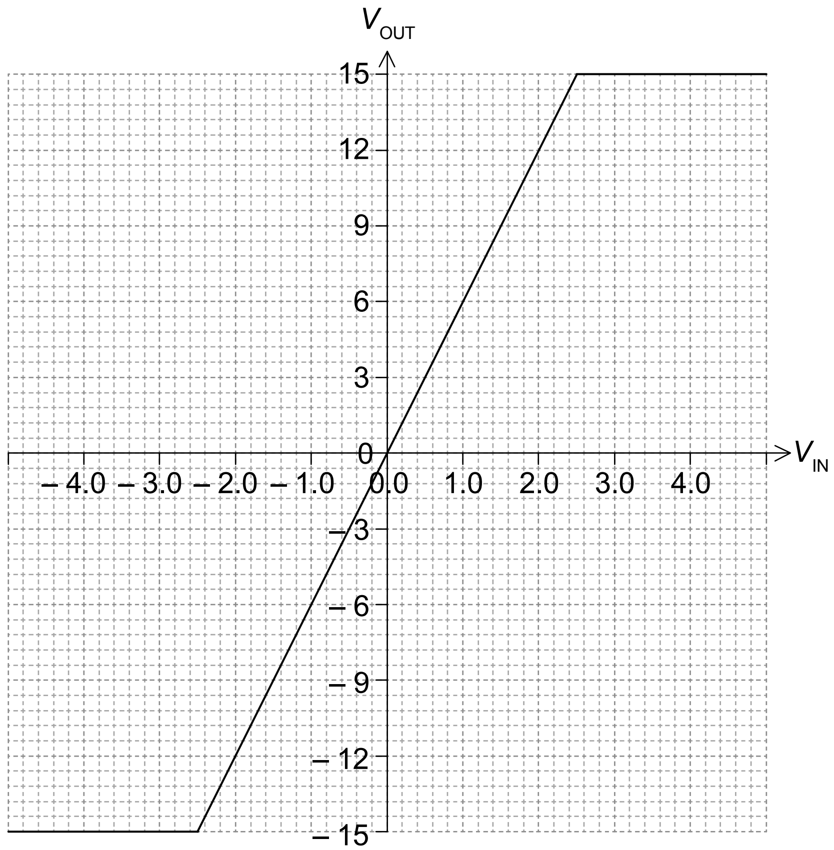
$V = \dfrac{Q}{C} = \dfrac{630 \times 1.6 \times 10^{-19}}{170 \times 10^{-12}}$ ***or*** 5.9×10^{-7} V; **[4]**

(c) digital output 1100; **[1]**

10. (a) (i) $G = 1 + \frac{20}{4}$;

$= 6$; **[2]**

(ii)



general shape of graph correct;
straight line between –2.5 V and 2.5 V;
plateau at –15 V and +15 V beyond this; **[3]**

(b) switch over happens when non-inverting input $\geq 5\text{ V}$;

current through the $20\,\text{k}\Omega = \left(\frac{5-(-15)}{20\times10^3} = \frac{20}{20\times10^3} = \right) 1\,\text{mA}$;

$V_{IN} = (5 + [1\text{ mA} \times 4\text{ k}\Omega] = 5 + 4 =)\ 9\text{ V}$; **[3]**

11. damage caused by mining for precious metals;
high rate of disposal/landfill;
masts detract from beauty in some areas; **[2 max]**

Option D — Relativity and particle physics

12. (a) a coordinate system;
that is not accelerating / where Newton's first law applies; **[2]**

(b) (i) $\gamma = \left[\frac{1}{\sqrt{1-0.8^2}} =\right] 1.67$;

$\Delta t_0 = \left[\frac{3}{1.67} =\right] 1.8\text{ s}$; **[2]**

(ii) 1.6*c*; **[1]**

(iii) (one of the) postulates states that the speed of light in a vacuum is the same for all inertial observers;
Galilean transformation will give a relative speed greater than the speed of light; **[2]**

(iv) $\gamma = \frac{1}{\sqrt{1-0.976^2}} (= 4.59)$;

$l_0 = (4.56 \times 8.00 =)\ 36.7\text{ m}$; **[2]**

(c) $t = \frac{s}{v} = \frac{11.4}{0.8} = 14.25$ years;

$\Delta t_0 = \frac{\Delta t}{\gamma} = \frac{14.25}{1.67} = 8.6$ years; **[2]**

Accept length contraction with the same result.

13. (a) $+\frac{2}{3} - \frac{1}{3} - \frac{1}{3} = 0$ for charge;
any particle containing a strange quark has strangeness of -1; **[2]**

(b) (i) *strangeness*:
the *p* has a strangeness of 0;
the K^- particle has a strangeness of -1;

baryon number:
lambda and protons are baryons each having a baryon number of $+1$;
the K^- meson has a baryon number of 0; **[4]**

(ii) only during the weak interaction strangeness is not conserved (therefore it is a weak interaction); **[1]**

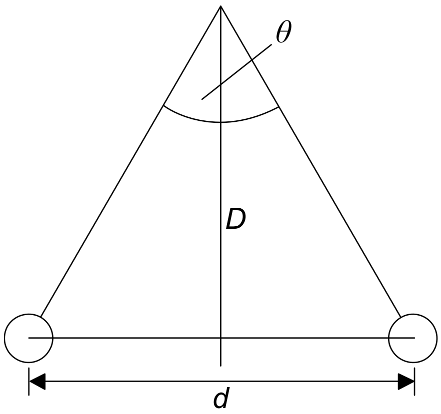
(iii) $m = \left[80.4\text{ GeV c}^{-2} = \frac{80.4 \times 10^9}{931.5 \times 10^6} \times 1.661 \times 10^{-27} =\right] 1.43 \times 10^{-25}\text{ kg}$;

$R \approx \left(\frac{6.63 \times 10^{-34}}{4\pi \times 1.43 \times 10^{-25} \times 3 \times 10^8} =\right) 1.23 \times 10^{-18}\text{ m}$; **[2]**

Option E — Astrophysics

14. (a) the star is (much) closer than the other star (and close enough to Earth) / parallax effect has been observed; **[1]**

(b) (i)



[1]

*Award **[1]** if all three (d, D, θ) are shown correctly.*
Accept D as a line from Earth to the star.

(ii) $\sin\frac{\theta}{2} = \frac{d}{2D}$ ***or*** $\tan\frac{\theta}{2} = \frac{d}{2D}$ ***or*** $\theta = \frac{d}{D}$;

consistent explanation, *eg*: small angle of approximation yields $\theta = \frac{d}{D}$; **[2]**

(iii) any angular unit quoted for θ and any linear unit quoted for *D*; **[1]**

(c) (yes) star is close enough (in local galaxy) to determine spectral characteristics; **[1]**

15. (a) HR diagram refers to real stars / absolute magnitude depends on (inherent) properties of the star / absolute magnitude is a measure of brightness at a distance of 10 pc;
any relevant info about apparent magnitude, *eg*: apparent magnitude depends on distance; **[2]**

(b) to cover a wide range of orders of magnitude;
smaller values would be lost on a linear scale / the logarithmic scale allows more stars to be shown on the diagram (making the diagram more relevant); **[2]**

(c) $\frac{L_V}{L_S} = \left(\frac{\sigma A_V [T_V]^4}{\sigma A_S [T_S]^4} = \right) \frac{\sigma [r_V]^2 [T_V]^4}{\sigma [r_S]^2 [T_S]^4}$;

$\frac{1.54 \times 10^{28}}{3.85 \times 10^{26}} = \frac{[r_V]^2}{[r_S]^2} \times \frac{9600^4}{5800^4}$;

$r_V = \left(\sqrt{\frac{1.54 \times 10^{28}}{3.85 \times 10^{26}} \times \frac{5800^4}{9600^4}} r_S = \right) 2.3\, r_S$; **[3]**

(d) obtain the spectrum of the star;
measure the position of the wavelength corresponding to maximum intensity;
use Wien's law (to determine temperature); *(allow quotation of Wien's equation if symbols defined)* **[3]**

*Award **[3 max]** for referring to identification of temperature via different ionizations of different elements.*

16. (a) $T = \frac{2.90 \times 10^{-3}}{\lambda_{max}} = \frac{2.90 \times 10^{-3}}{1.06 \times 10^{-3}}$;
$= 2.7\,K$; **[2]**

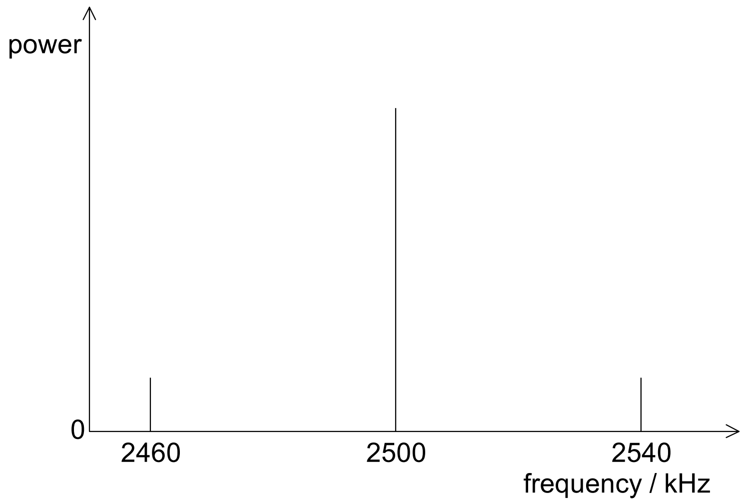
(b) current low temperature observed is a result of expansion;
(expansion) has caused cooling from high temperatures; **[2]**

Option F — Communications

17. (a) the modification/change of a carrier wave by addition of a signal wave/information; **[1]**

(b) (i) (voice signal only requires) low quality;
AM has lower band width requirement than FM;
simpler (more reliable) circuits;
range greater than FM / can bounce off the ionosphere; **[2 max]**

(ii)



central band drawn at correct position;
shorter side bands at correct positions; **[2]**

(iii) $\left(\dfrac{0.4\times10^{6}}{80\times10^{3}}=\right)5$; **[1]**

(c) *geostationary*: **[2 max]**

Allow ***one*** *advantage plus argument*:
always above the same point of the Earth / no tracking dish required / allows for continuous communication / outside Earth's atmosphere so last longer in orbit / can be positioned permanently in sunlight for its power supply;
evidence of the mentioned / any relevant argument;

or

Allow any ***two*** *advantages*:
always above the same point of the Earth;
no tracking dish required;
allows for continuous communication;
outside Earth's atmosphere so last longer in orbit;
can be positioned permanently in sunlight for its power supply;

polar-orbiting: **[2 max]**

Allow ***one*** *advantage plus argument*:
lower orbit / less power required at both ground station and satellite / cheaper to put into orbit / coverage of whole planet over a number of orbits;
evidence of the mentioned / any relevant argument;

or

Allow any ***two*** *advantages*:
lower orbit;
less power required at both ground station and satellite;
cheaper to put into orbit;
coverage of whole planet over a number of orbits; **[4 max]**

18. (a) (i) (a digital) signal is split up for transmission and recombined at the end of the process / the signal is transmitted in pulses;
other signals can be transmitted in the spaces between the pulses; **[2]**

(ii) the bit rate is higher / more data sent per unit time;
faster transmission of data;
making use of empty space between samples; **[1 max]**

(b) time between samples $= \frac{1}{4000} = 250\ \mu\text{s}$;

duration of sample $= 8\ \text{bit} \times 8\ \mu\text{s} = 64\ \mu\text{s}$;

number of samples transmitted $= \frac{250}{64} = 3.9$ signals;

so three signals maximum; **[4]**

(c) attenuation $= 0.08 \times 30.0\ (= 2.4\,\text{dB})$;

$2.4 = 10\log\left(\frac{I_1}{2\,\text{mW}}\right)$;

$I_1 = 3.5\,\text{mW}$; **[3]**

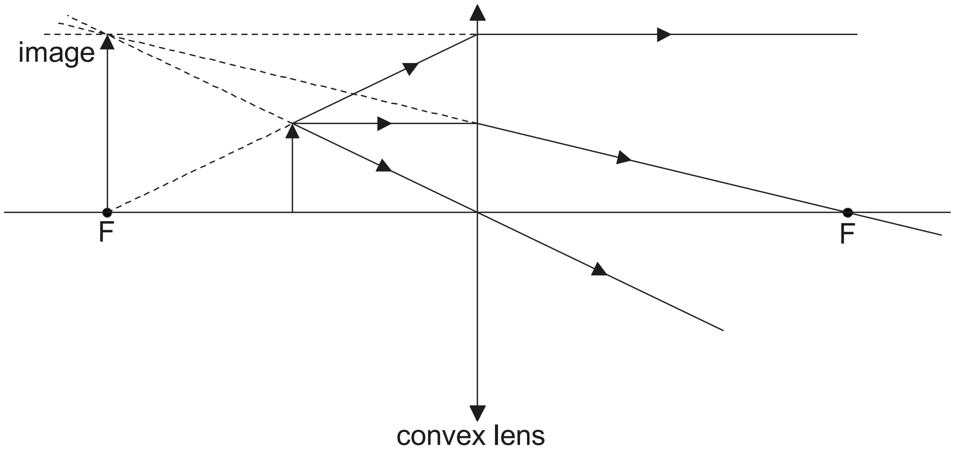
Option G — Electromagnetic waves

19. (a) sky is blue due to scattering of light from Sun (by particles, nitrogen molecules);
blue scatters better / as the atmosphere (becomes) less dense less scattering occurs;
(finally) the sun's light is not scattered and "the sky" is black (meaning no light between point light sources); **[3]**

(b) natural frequency of carbon dioxide $= \left(\frac{1}{5\times10^{-14}} =\right) 2\times10^{13}\,\text{Hz}$;

infrared from the Sun is well outside this value so transmitted;
infrared from the Earth is close to this value so absorbed/scattered/trapped; **[3]**

20. (a) (i)



any correct ray out of the three shown above;
second ray correct;
image correctly located and labelled; **[3]**

(ii) the image is virtual;
no light rays pass through this point; **[2]**

(b) $\frac{1}{u} = \frac{1}{f} - \frac{1}{v}$;

$u = \frac{20}{3}$;

$m = \left(-\frac{v}{u} = -\frac{60}{20} =\right)(-)3$; **[3]**

21. (a) single slit before the double slit / use a laser light / single source; **[1]**

(b) destructive interference;
path lengths from slits differ by half a wavelength;
waves arrive antiphase / 180° out of phase / π out of phase; **[2 max]**

(c) (i) $\theta_{\text{blue}} = \left(\dfrac{\theta_{\text{red}}\lambda_{\text{blue}}}{\lambda_{\text{red}}} = \dfrac{0.0045 \times 440\,\text{nm}}{660\,\text{nm}} = \right) 0.0030\,\text{rad}$;
$\Delta\theta_{\text{blue}} = (0.0045 - 0.0030 =)\ 0.0015\,\text{rad}$; **[2]**

(ii) marking direction of shift on the diagram; **[1]**