N15/4/PHYSI/SP3/ENG/TZ0/XX/M

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 <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.

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) $E_{max} = (1.75 \times 1.60 \times 10^{-19} =)\ 2.80 \times 10^{-19}\ \text{J}$;
$\phi = \left(hf - E_{max} = 6.63 \times 10^{-34} \times \frac{3.00 \times 10^{8}}{620 \times 10^{-9}} - 2.80 \times 10^{-19} = \right) 4.1 \times 10^{-20}\ \text{J}$; **[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: *ν*/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 $= 3000 \times 16 (= 48000)$;

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 $= 0.6 \times 1050 \, (= 630)$;

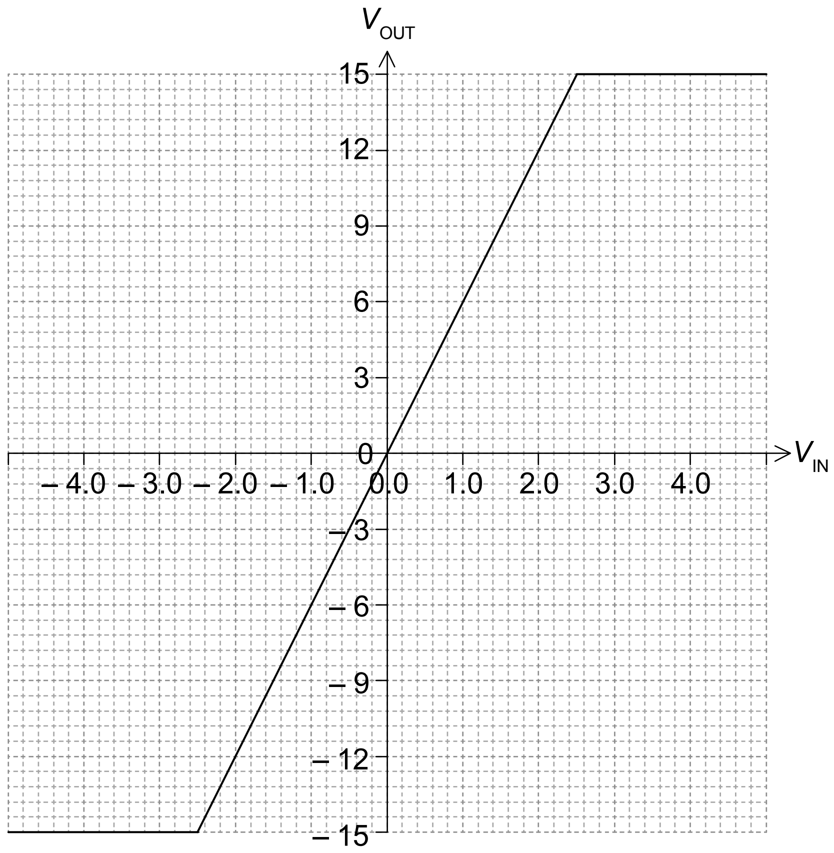
$V = \dfrac{Q}{C} = \dfrac{630 \times 1.6 \times 10^{-19}}{170 \times 10^{-12}}$ ***or*** 5.9×10^{-7} V; **[4]**

(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]**

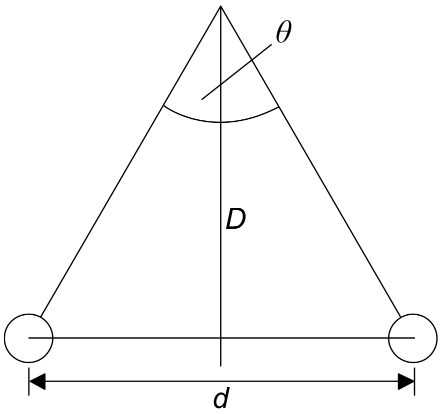
(ii) only during the weak interaction strangeness is not conserved (therefore it is a weak interaction); **[1]**

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

$$\frac{1.54\times10^{28}}{3.85\times10^{26}} = \frac{[r_V]^2}{[r_S]^2}\times\frac{9600^4}{5800^4};$$

$$r_V = \left(\sqrt{\frac{1.54\times10^{28}}{3.85\times10^{26}}\times\frac{5800^4}{9600^4}}\, r_S = \right) 2.3\, r_S;$$ **[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) $$T = \frac{2.90\times10^{-3}}{\lambda_{max}} = \frac{2.90\times10^{-3}}{1.06\times10^{-3}};$$
$= 2.7\,\text{K}$; **[2]**

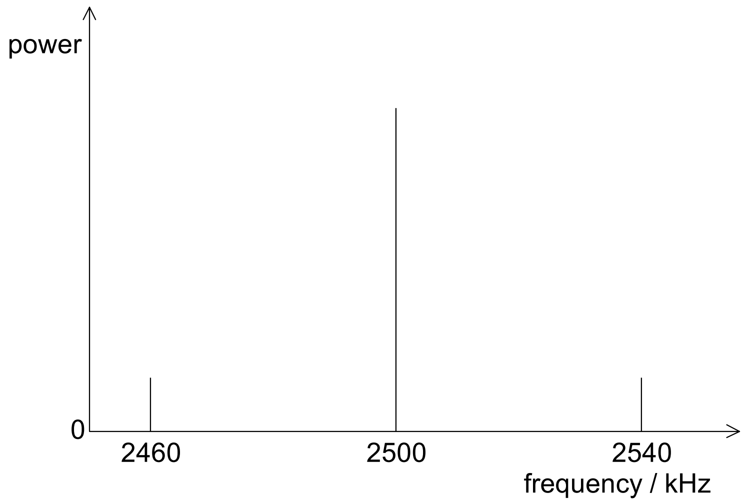
(b) current low temperature observed is a result of expansion;
(expansion) has caused cooling from high temperatures; **[2]**

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

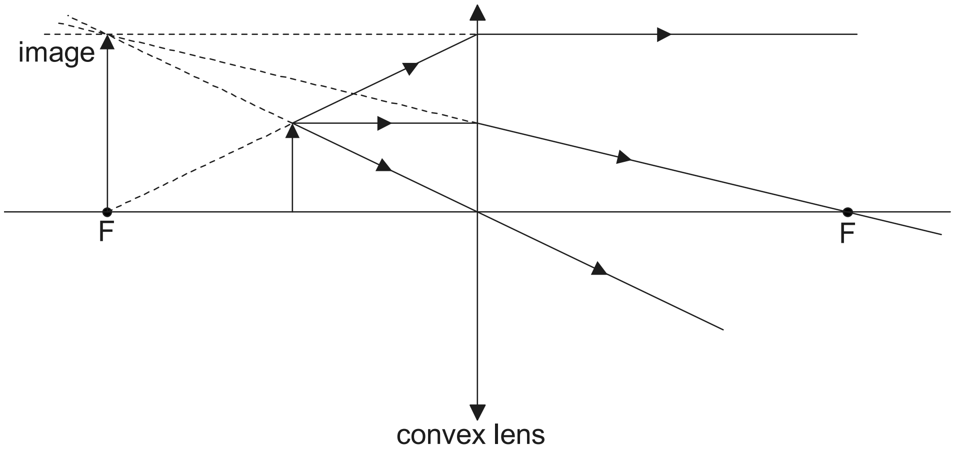
Option G — Electromagnetic waves

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]**