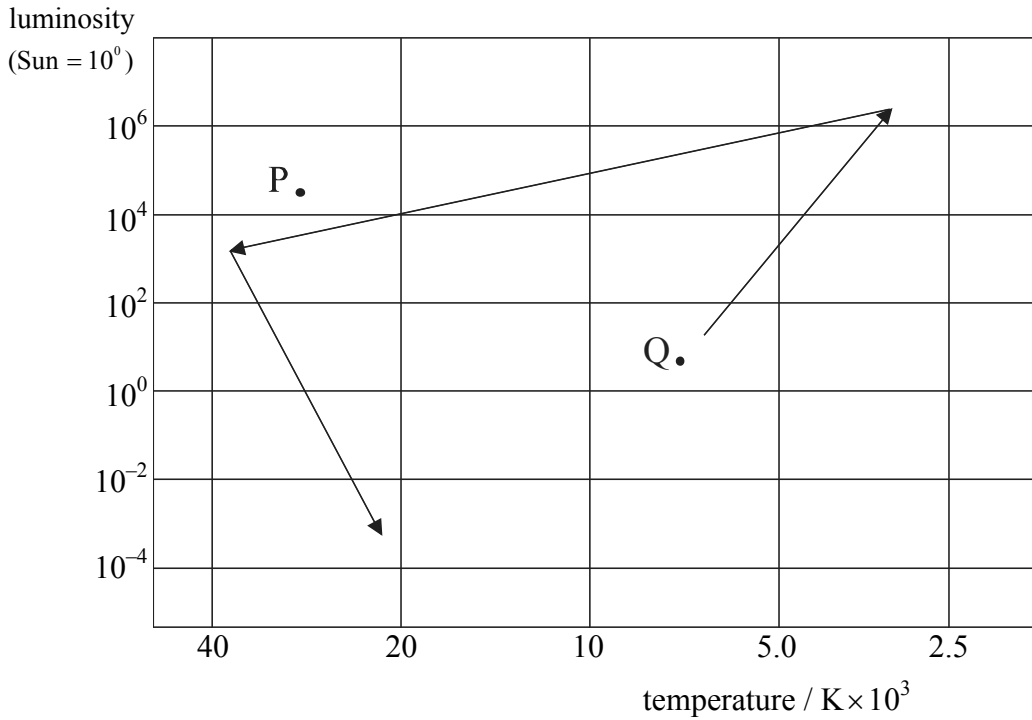


Option F — Astrophysics

- F1.** (a) *stellar cluster*: a group of stars (with gas and dust) held together by gravity/ forming a globular/open arrangement;
galaxy: a large-scale collection/large number of stars/star clusters, gas, and dust; [2]
- (b) 10^{-6} ; [1]
Accept interval within 10^{-5} and 10^{-7} .
- F2.** (a) *apparent brightness*: power incident per square metre of surface of Earth;
apparent magnitude: a measure of how bright a star appears (to the eye) viewed from Earth; [2]
- (b) measure the blackbody spectrum (of the star) / analysis of intensity-wavelength graph;
to find the wavelength at which the emitted energy is a maximum; *Accept statements in terms of peak wavelength.*
use Wien's displacement law *or* $\lambda_{\max} = \frac{2.90 \times 10^{-3}}{T}$ to find temperature; [3]
- (c) (i) $4.93 \times 10^5 \text{ AU} = 2.39 \text{ pc}$ *or* distance less than 100 pc;
(which is easily) measured by (stellar) parallax; [2]
- (ii) lower temperature than the Sun and further away from the Sun;
therefore less bright so apparent magnitude is greater; [2]
- (iii) $L = 4\pi d^2 b$;
 $d = (4.93 \times 10^5 \times 1.50 \times 10^{11}) = 7.40 \times 10^{16} \text{ m}$;
 $L = 4 \times 3.14 \times 7.40^2 \times 10^{32} \times 1.97 \times 10^{-12}$;
 $= 1.35 \times 10^{23} \text{ W}$ [3]
Carefully verify the correct use of numerical values to reach the answer.
- (d) $A = \frac{L}{\sigma T^4}$;
 $= \left(\frac{1.35 \times 10^{23}}{5.67 \times 10^{-8} \times (4.00 \times 10^3)^4} \right) = 9.30 \times 10^{15} \text{ m}^2$; [2]
- F3.** (a) that it is uniform / stars are uniformly distributed; [1]
Accept also homogenous or isotropic.
- (b) in every direction that one looked one would see a star;
hence the sky should never be dark; [2]
Accept reasoning based on intensity $\propto r^{-2}$ but number $\propto r^2$.

F4. (a)



to red giant region;

ends in white dwarf region;

Paths do not need to be straight and be generous with regions.

[2]

(b) P becomes a neutron star/black hole as opposed to white dwarf;

[1]

(c) the maximum mass for a white dwarf is $1.4 M_{\text{sun}}$;

star P has much more than this;

star could lose enough mass to bring it within the Chandrasekhar limit / *OWTTE*;

[3]

F5. (a) spiral, elliptical, irregular;

All three needed to receive the mark.

[1]

(b) the universe is expanding;

due to Doppler shift (observed) light is red shifted;

Do not accept "galaxies are moving away from us".

[2]

(c) the further away the greater the recessional speed of the galaxies / *OWTTE*;

[1]

Option G — Relativity

G1. (a) a system of coordinates;
that enables the position of various objects to be specified / that enables measurements to be made / *OWTTE*; [2]

(b) (i) Myron: $L' = x_2' - x_1'$;
Linda: $L = x_2 - x_1 = (x_2' + vt) - (x_1' + vt)$
 $L = x_2' - x_1' = L'$; [2]

(ii) $\gamma(x_1 - x_2) = x_1' - x_2'$;
where $\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$ with c being the free space speed of light / speed of light
in a vacuum; [2]

(iii) Linda and Myron are inertial observers;
if not measured simultaneously the distance between the ends of the rod can have different values;
(because one of the postulates of relativity states) the speed of light in a vacuum is the same for all inertial observers; [3]

(iv) Michelson and Morley could detect no difference in the time it takes light to travel equal path lengths that are perpendicular to each other / *OWTTE*;
this indicates that the speed of light is constant for all inertial observers; [2]

(c) (i) Myron
(since this is) the time interval between two events measured in the reference frame;
in which the events occur at the same place; [2]

(ii) $\gamma = \frac{1.20}{0.800} = 1.5$;
 $1.5 = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$;
to give $v = 0.75c$; [3]

G2. (a) same up to about 0.3;
then curve asymptotic to 1.0; [2]

(b) calculation of $\gamma = 2.3$;
 $E = (\gamma m_0 c^2) = 1.2 \text{ MeV}$; [2]

G3. $E_{\text{tot}} = Ve + m_0c^2$;
 $= (500 + 938) = 1438 \text{ MeV}$;
 $(E_{\text{tot}}^2 = p^2c^2 + m_0^2c^4) p^2c^2 = 1438^2 - 938^2$;
 $p = 1090 \text{ MeV c}^{-1}$; **[4]**

G4. (a) a coordinate system in which a time axis is constructed at right angles to the x -axis / *OWTTE*;
the motion of the particle is plotted as a series of points in this system / is described
by a line in this system / *OWTTE*; **[2]**

(b) (i) all particles/objects take the shortest path between two points in spacetime;
Earth warps spacetime;
the satellite follows the shortest path in this warped spacetime; **[3]**

(ii) the closer to Earth the greater the degree of warping of spacetime / *OWTTE*; **[1]**

or

the further from Earth the less the degree of warping of spacetime / *OWTTE*;

Option H — Optics

H1.	<i>Name of associated region</i>	<i>Frequency / Hz</i>	<i>Possible source</i>
	<i>gamma radiation</i>	10^{18}	<i>radioactive decay</i>
	infra red;	10^{13}	hot objects / laser / remote control device;
	radio waves;	10^6	(accelerated) motion of electrons in conductors/aerials/electric currents;

[4]

Do not apply ECF from region to possible source.

- H2. (a) (i) when the (transmitted) ray/light in medium 2 is along the boundary/refracted at 90° ;
the angle of incidence in medium 1 is the critical angle;

[2]

or

when a ray/light is incident on the boundary at an angle greater than the critical angle;
the ray is not transmitted / no light is transmitted but is totally reflected at the boundary / is totally internally reflected;

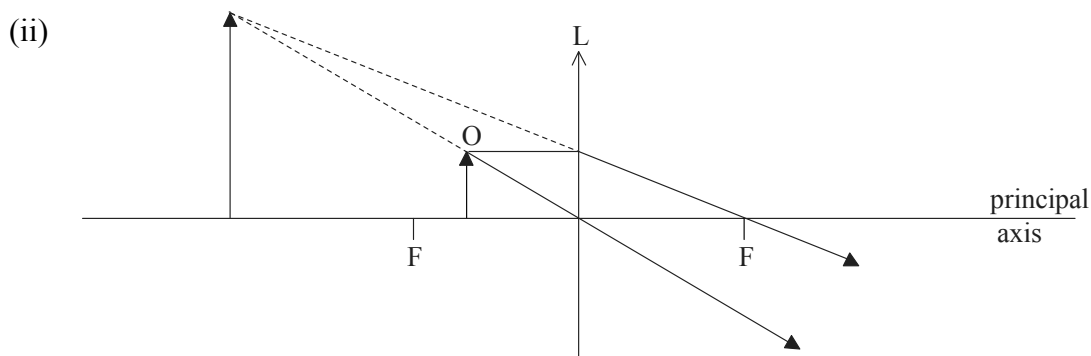
- (ii) reflected ray with angle of reflection = angle of incidence;
transmitted ray with angle of refraction greater than angle of incidence;
Judge both by eye.

[2]

- (b) $n_1 \sin \theta_1 = n_2 \sin \theta_2$
 $\theta_1 = \phi_c$ and $\theta_2 = 90^\circ$;
 $n_1 \sin \phi_c = n_2$;

[2]

- H3.** (a) (i) *principal axis*: a line at right angles to the plane of the lens and that passes through the (optical) centre of the lens / *OWTTE*;
principal focus: a point on the principal axis to which rays parallel to the principal axis pass after refraction (through the lens) / *OWTTE*; [2]



two rays as shown; { *Do not penalise if rays do not have extrapolated back to locate image;* *arrows.* [2]

- (iii) virtual
the rays diverge after passing through the lens;
cannot be focused onto a screen / appear to come from a point / *OWTTE*;
Award [1 max] for an explanation based on the image on the same side of the lens. [2]

(b) (i) $M = \left(\frac{\theta_i}{\theta_o} \right) = \frac{h_i}{h_o}$;
 $6 = \left(\frac{h_i}{h_o} = \frac{v}{u} \right) = \frac{25}{u}$;
 $u = \left(\frac{25}{6.0} \right) = 4.2 \text{ cm}$; [3]

- (ii) maximum magnification; [1]

- H4.** (a) each element of the slit acts as a secondary source of waves;
the interference between these waves produces the diffraction pattern; [2]

(b) (i) half width of central maximum = $3.1 (\pm 0.1) \text{ mm}$;
slit width = $\frac{2.4 \times 6.3 \times 10^{-7}}{3.1 \times 10^{-3}}$;
= 0.50 mm ; [3]
Award [1 max] for use of 4.5×10^{-3} followed by use of $\sin(\text{max}) = n\lambda$.

- (ii) greater intensity;
decrease in width of central maximum; [2]

- H5.** light reflected from bottom surface (that emerges from top surface);
interferes with light reflected from top surface;
for a particular thickness of oil;
certain colours/wavelengths are removed by destructive interference;
white light less this colour/wavelengths is observed; [3 max]