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*** $\lambda_{\max} = \dfrac{2.90\times10^{-3}}{T}$ to find temperature; ***[3]***

(c) (i) $4.93\times10^{5}\ \text{AU} = 2.39\,\text{pc}$ ***or*** distance less than $100\,\text{pc}$;
(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) $L = 4\pi d^2 b$;
$d = (4.93\times10^{5}\times1.50\times10^{11}) = 7.40\times10^{16}\ \text{m}$;
$L = 4\times3.14\times7.40^2\times10^{32}\times1.97\times10^{-12}$;
$= 1.35\times10^{23}\ \text{W}$ ***[3]***

Carefully verify the correct use of numerical values to reach the answer.

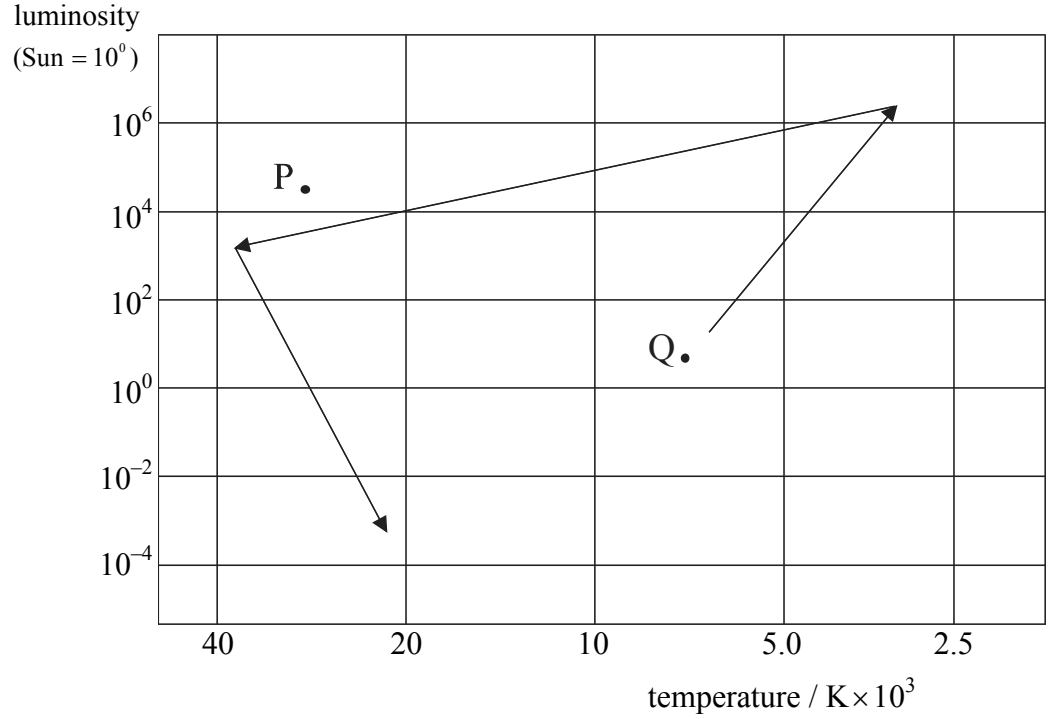
(d) $A = \dfrac{L}{\sigma T^4}$;

$= \left(\dfrac{1.35\times10^{23}}{5.67\times10^{-8}\times(4.00\times10^{3})^4}\right) = 9.30\times10^{15}\ \text{m}^2$; ***[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; ***[2]***
Paths do not need to be straight and be generous with regions.

(b) P becomes a neutron star/black hole as opposed to white dwarf; ***[1]***

(c) the maximum mass for a white dwarf is $1.4\,M_{sun}$;
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; ***[1]***
All three needed to receive the mark.

(b) the universe is expanding;
due to Doppler shift (observed) light is red shifted; ***[2]***
Do not accept "galaxies are moving away from us".

(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 $\gamma = \dfrac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}}$ 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) $\gamma = \dfrac{1.20}{0.800} = 1.5$;

$1.5 = \dfrac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}}$;

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*;