

Option F — Astrophysics

F1. (a) wavelength peak = 500 nm ;

$$T = \frac{2.90 \times 10^{-3}}{5 \times 10^{-7}} ;$$

$$= 5800 \text{ K}$$

[2]

(b) the dark lines are due to absorption of light/photons;
by electrons within atoms/molecules;
the wavelengths (of the light absorbed) are characteristic of the element associated
with the atom/molecule / *OWTTE*;

or

wavelengths of lines;
are compared to emission spectra of elements / *OWTTE*;
since all elements have a characteristic (line) spectrum;

[3]

F2. (a) luminosity is the total power emitted (by a star);

[1]

(b) use of $L = \sigma AT^4$ to recognize that $\frac{L_A}{L_B} = \frac{R_A^2 T_A^4}{R_B^2 T_B^4}$;

$$\frac{L_A}{L_B} = \frac{(8.7 \times 10^{11})^2 \times (3.0 \times 10^3)^4}{(6.8 \times 10^7)^2 \times (2.0 \times 10^4)^4} ;$$

$$= 8.3 \times 10^4 ;$$

[3]

F3. (a) the greater the apparent magnitude the less bright a star appears;
Sirius does not appear as bright as the Sun so has greater apparent magnitude /
OWTTE;

[2]

(b) $d = \sqrt{\frac{L}{4\pi b}}$;

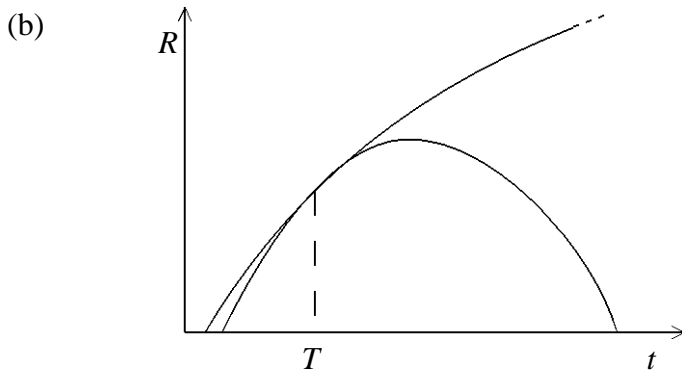
$$\frac{d_{\text{sir}}}{d_{\text{sun}}} = \sqrt{\frac{L_{\text{sir}} b_{\text{sun}}}{L_{\text{sun}} b_{\text{sir}}}} ;$$

$$d_{\text{sir}} = \sqrt{\frac{23 \times 1.4 \times 10^3}{1.1 \times 10^{-7}}} ;$$

$$= 5.4 \times 10^5 \text{ AU}$$

[3]

- F4.** (a) a closed universe is one which will stop expanding at some future time, and begin contracting (due to gravity) / *OWTTE*; [1]



a line starting to left of drawn curve;
 touches at present time;
 overall shape curved (showing reducing rate of increase); [3]

- (c) the only known data point is at the present time;
 extrapolation of curves for different models gives different ages / *OWTTE*; [2]

- F5.** (a) 1. (the gas cloud must be) sufficiently dense / high temperature;
 2. (the gas cloud must be) sufficiently massive / high pressure; [2]

- (b) (i) mass; [1]

(ii) in a red giant helium is fused;
 if mass is between about four and eight stellar masses / red giants of large mass, then carbon is fused;
 in a red supergiant successively heavier elements than helium are fused *e.g.* neon, oxygen, silicon;
 until iron core is finally reached and core is stable / *OWTTE*; [3 max]

- F6.** (a) from Hubble's law relative recession speed is Hd ;

$$T = \frac{d}{v} = \frac{d}{Hd} = \frac{1}{H};$$
 [2]

(b)
$$T = \frac{1}{H} = 0.013 \text{ km}^{-1} \text{ s Mpc};$$

$$= \frac{3.9 \times 10^{17}}{3.2 \times 10^7};$$

$$\approx 10^{10} \text{ yrs}$$
 [2]

Option G — Relativity

G1. no;

when the light from end B reaches Lucinda it will not have reached Simon / light from end A will reach Lucinda after it has reached Simon;

Simon will see the bird land at B before he sees the one land at A;

because the speed of light is independent of the speed of source / Simon and Lucinda both measure the same value of c /speed of light;

Award [0] for incorrect reasoning or no reasoning.

[4]

G2. (a) (i) time interval for Earth observer = $\left(\frac{d}{v}\right) = \frac{5.0 \times 10^{16}}{0.60 \times 3.0 \times 10^8}$;
 $= 2.8 \times 10^8$ s ;

[2]

(ii) $\gamma = 1.25$;

time = $\frac{2.8 \times 10^8}{1.25} = 2.2 \times 10^8$ s ;

or

distance in astronaut frame = 4.0×10^{16} m ;

time = $\frac{4.0 \times 10^{16}}{0.60c} = 2.2 \times 10^8$ s ;

[2 max]

(b) astronaut;

the events of leaving the Earth and arriving at the star occur at the same point according to astronaut;

Award [0] if no explanation or the wrong explanation is given.

[2]

(c) the (biological) age of the astronaut is less than the Earth observer;

because of time dilation;

the situation is not symmetric;

the astronaut experiences forces / accelerations during trip;

[3 max]

G3. (a) mass increases with increasing speed/velocity;
 mass is infinite when $v = c$;
 infinite force/energy needed; [3]

(b) (i) 6.51MeV (includes rest mass); [1]

(ii) $(E = \gamma m_0 c^2)6.51 = \gamma \times 0.511$;
 $\gamma = 12.7$;

$$12.7 = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \quad v^2 = 0.994c^2;$$

$$v = 0.997c$$

[3]

G4. use of $E^2 = p^2c^2 + m_0^2c^4$

$$E = mc^2 = Ve + m_0c^2 = 2.511(\text{MeV});$$

$$(2.511)^2(\text{MeV})^2 = p^2c^2 + (0.511)^2(\text{MeV})^2;$$

$$p^2c^2 = 6.04(\text{MeV})^2;$$

$$p = 2.46(\text{MeV c}^{-1});$$

To award [4] intermediate and/or final units are not required.

or

calculation of γ from $(\gamma - 1)m_0c^2 = Ve$;

$$\gamma = 4.91;$$

use of γ to calculate

$$v = 0.979c;$$

$$p = \gamma m_0 v = (4.91 \times 0.511 \times 0.979) = 2.46(\text{MeV c}^{-1});$$

[4]

To award [4] intermediate and/or final units are not required.

G5. (a) curved line (striking the wall) below Rosemary;

[1]

(b) Einstein's principle states that it is impossible to distinguish between a system that is accelerating and one that is at rest in a gravitational field / *OWTTE*;

{ (do not accept "gravity and acceleration are the same/indistinguishable")

if the spaceship were at rest on the surface of a planet for example / *OWTTE*;
the ball would follow the same path / *OWTTE*;

[3]

(c) (i) the frequency of Tony's light will (be seen to) be lower (than Rosemary's);

[1]

(ii) gravitational redshift;

[1]

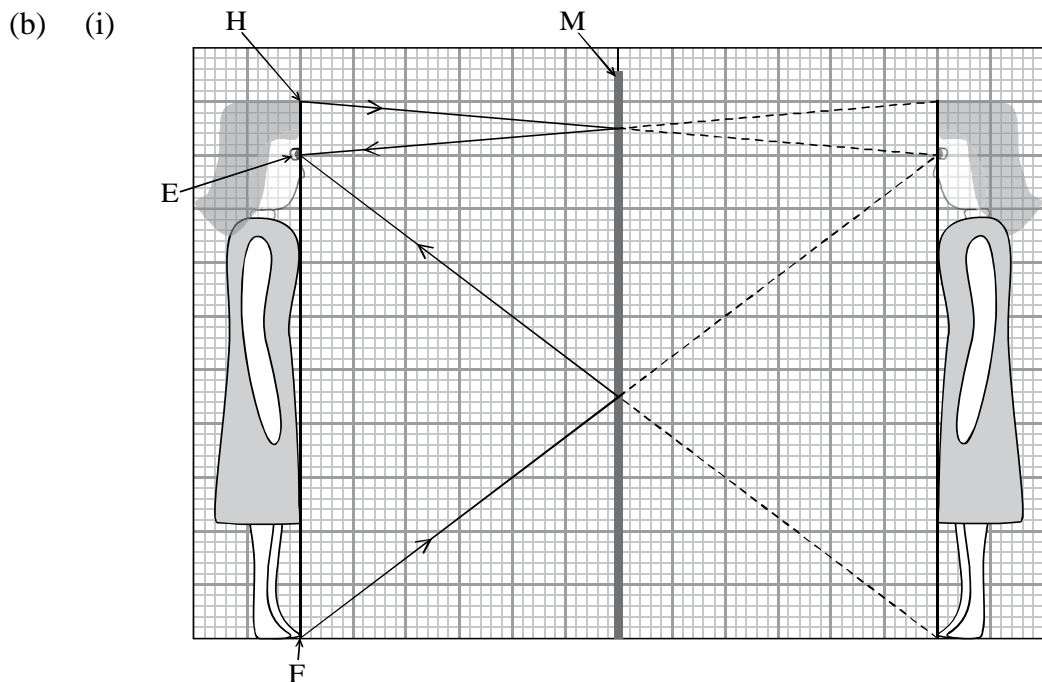
Option H — Optics

H1. (a) $\frac{\sin i}{\sin r}$ *or* $\frac{c}{v}$ with terms for each expression defined; [1]

(b) $= \frac{3.0 \times 10^8}{2.1 \times 10^8}$;
 = 1.4; [2]

(c) speed of light in a medium depends on frequency;
 the refractive index depends on frequency;
 light of different frequencies refracted by different amounts / *OWTTE*; [3]

H2. (a) 1. the angle of incidence is equal to the angle of reflection;
 2. incident ray, reflected ray and normal are coplanar/in the same plane; [2]



same height;
 image distance equal object distance; [2]

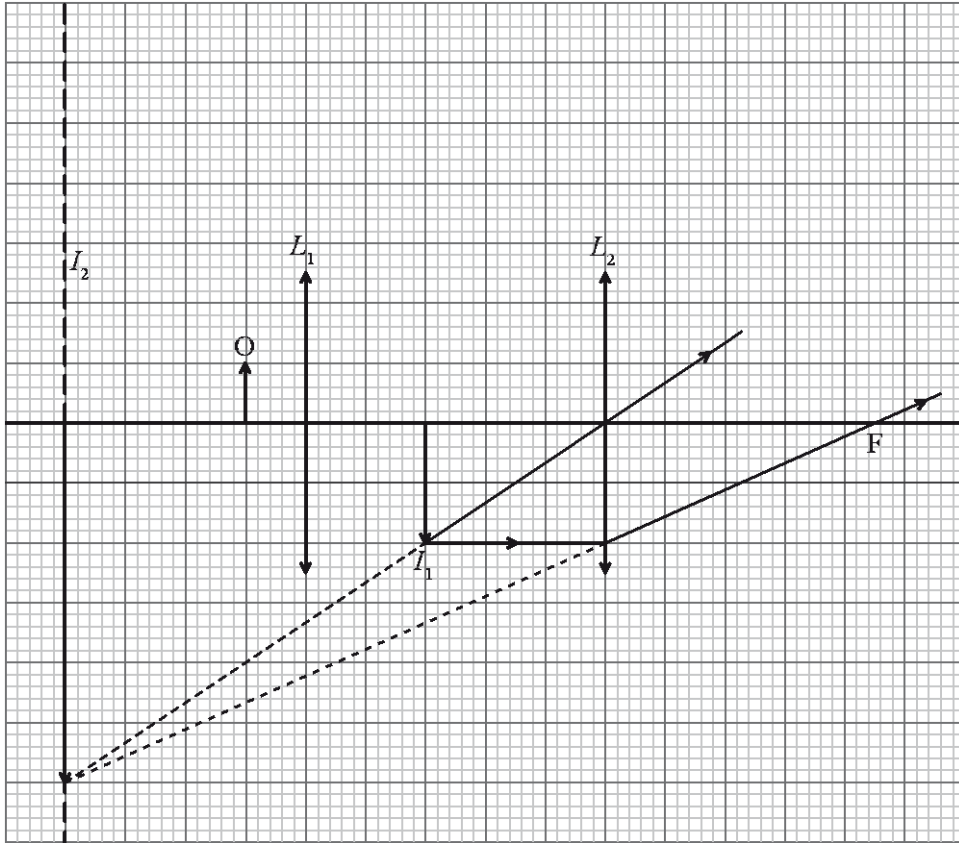
(ii) correct ray construction for F;
 correct ray construction for H;
*The rays should be shown with equal angles at mirror judged by eye.
 Arrows on rays are not required.* [2]

(c) (i) 0.75 (± 0.03) m; [1]

(ii) 0.68 (± 0.03) m; [1]

(d) no effect; [1]

H3. (a)



two correct construction rays;

dotted lines back to I_2 to give F, $4.5(\pm 1)$ cm from L_2 ;

[2]

(b) (i) 2;

[1]

(ii) 3;

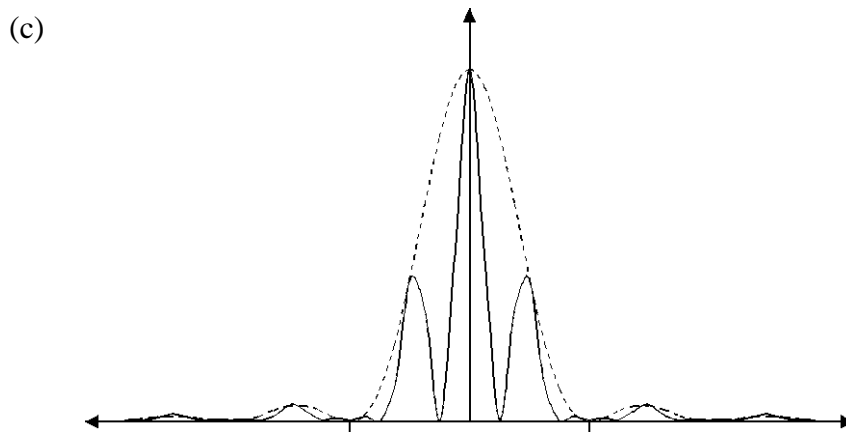
[1]

(c) 6;

[1]

- H4.** (a) each element of the slit acts as a point source of light;
 the light from these sources interfere;
 there will be a zero of intensity (on the screen) when the sum of the path differences
 between the sources is an integral number of half wavelengths / a maximum when
 an integral number of wavelengths; [3]

(b) $\theta = \frac{d}{D} = \frac{\lambda}{b}$;
 rearrange to get $d = \frac{D\lambda}{b}$; [2]



central maximum same intensity as single slit maximum;
 two other maximum either side about half-intensity of central maximum; [2]
Award [1 max] if lines do not touch x-axis.
There is no need to show maxima within secondary maxima. Do not penalize responses if more than two maxima are shown but they must be symmetrical and with realistic relative intensities.

- H5.** (a) changes by $\pi/180^\circ$; [1]

(b) use of $2nd \cos \phi = m + \frac{1}{2} \lambda$
 $n = 1 \cos \phi = 1$ and m changes by 1;
 therefore $d = \frac{\lambda}{2} = 280 \text{ nm}$; [2]