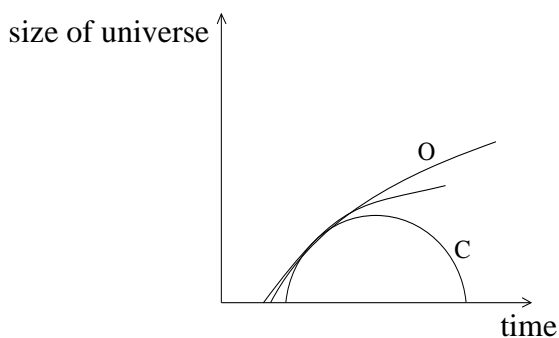


**Option F — Astrophysics**

- F1.** (a) (i) (total) power emitted; [1]
- (ii) mass / temperature / surface area / radius / type of star / composition; [1]
- (b) (i) outer surface expands and contracts;  
changing (surface) temperature / changing any other relevant property of surface; [2]
- (ii)  $L_A$  and  $L_B$  read-offs; (allow 900-1100 and 9000-11000)  
use of  $\frac{L_A}{L_B} = \frac{b_A \times d_A^2}{b_B \times d_B^2}$  **or** clear correct ratio;  
correct substitution into correct equation;  
*e.g.*  $1.6 \times 10^{21} \sqrt{\left(\frac{10 \times 1.2 \times 10^{-14}}{5.3 \times 10^{-16}}\right)}$   
 $2.4 \times 10^{22}$  m; [4]

- F2.** (a) (i) peak higher;  
peak to left; [2]
- In parts (ii) and (iii) allow credit for appearance of marking points in either part (ii) or (iii), but only credit each point once overall.*
- (ii) radiation (approximately) same from all directions;  
radiation has characteristics of black body radiation; [2]
- (iii) radiation characteristic of 3 K / low temperature;  
describes “big bang” as hypothesis that universe is expanding;  
expansion is the result of an energy release at beginning of universe; [3]
- (b) (i) non-coincident starts (not at beginning);  
correct shapes and correctly labelled;  
coincident at appropriate place; [3]



- (ii) density > critical density;  
critical density is density of “flat” universe / gravity acts to contract universe / *OWTTE*; [2]

- F3.** (a) *galaxy*: collection of gravitationally bound stars;  
*galactic supercluster*: cluster is a group of galaxies;  
 super cluster is a collection of clusters; [3]
- (b) age of universe =  $\frac{1}{H_0}$  ;  
 $\frac{1}{H_0} = \left( \frac{d}{v} \right) = \frac{190 \times 10^6 \times 3.1 \times 10^{16}}{1.3 \times 10^7}$  ;  
 =  $14 \times 10^9$  year **or**  $4.2 \times 10^{17}$  s ; [3]
- F4.** (a) mass limit of star above which it cannot become a white dwarf; [1]
- (b) Chandrasekhar limit is exceeded;  
 to yield supernova;  
 resulting in neutron star/black hole; [3]

**Option G — Relativity**

- G1.** (a) (i) length measured by observer at rest with respect to object; [1]
- (ii) time interval between two events measured in a reference frame where the events occur at the same place; [1]
- (b) (i)  $0.99 \times c \times 3.1 \times 10^{-6}$ ;  
 $= 0.92 \text{ km}$ ; [2]
- (ii)  $\gamma = \frac{1}{\sqrt{1 - \left(\frac{v^2}{c^2}\right)}} = 7.1$ ;  
 time  $(= 3.1 \times 10^{-6} \times 7.1) = 2.2 \times 10^{-5} \text{ s}$ ;  
 distance = 6.5 km; [3]
- (c) muon at rest in its reference frame measures the proper time for decay; to observers, because muons are in frame moving with respect to them muons take longer, this is time dilation; [2]  
*Allow [2 max] if answer is correctly stated in terms of length.*

- G2.** (a) initial mass at  $\frac{v}{c} = 0$  non-zero;  
 mass rises to become asymptotic at  $\frac{v}{c} \rightarrow 1$ ;  
 line horizontal for  $\frac{v}{c} < 0.5$ ; [3]
- (b) (i)  $2.5 (\text{MeV } c^{-2})$ ; [1]
- (ii)  $\gamma = \left(\frac{m}{m_0}\right) = 5$ ;  
 $5 = \frac{1}{\sqrt{1 - \left(\frac{v^2}{c^2}\right)}}$ ;  
 $= 0.98c$ ; [3]

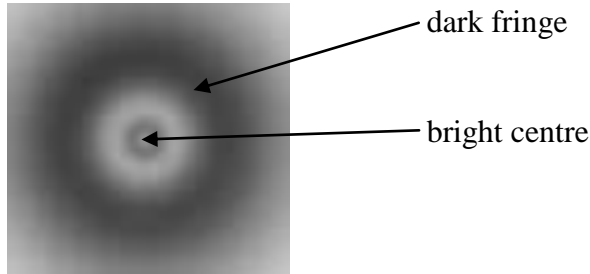
- G3.** speed of light independent of observer;  
as light is reaching B carriage moves forward;  
so B sees light from the left (person X) first;  
not simultaneous; **[4]**  
*Award [0] if invalid or incorrect statements are given.*
- G4.** (a) (i) region of extreme curvature in space-time;  
such that escape speed is  $c$  (or greater) / light cannot escape; **[2]**
- (ii) radius of boundary inside which mass must fit for black hole to be possible; **[1]**
- (iii)  $5.9 \times 10^4$  m ;  
no mass lost; **[2]**
- (b) (i) deflect the path of spacecraft / send into orbit round black hole / “attracted” by  
black hole; **[1]**
- (ii) matter distorts space; (*do not allow “warps”*)  
particles in space-time follow shortest path;  
path curved as mass approaches black hole/matter;  
this is interpreted as a force / *OWTTE*; **[4]**

**Option H — Optics**

- H1.** (a) (i) ray drawn to surface with correct refraction;  
second ray with correct refraction and image location; [2]
- (ii)  $n = \frac{\text{real depth}}{\text{apparent depth}}$ ;  
6.5 m; [2]
- (b) (i) ray drawn to surface with correct reflection by eye;  
second ray with correct reflection by eye;  
construction lines to show image formed above water; [3]
- (ii) disturbed surface leads to many reflections in different directions / diffuse reflection; [1]
- H2.** (a) one correct ray;  
second correct ray;  
image construction lines clear and image drawn in, labelled I; [3]
- (b) (i) point closer than which eye cannot focus; [1]
- (ii) image formed 21 cm from lens  $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ ;  $\left\{ \begin{array}{l} \textit{real is + ve, allow new} \\ \textit{Cartesian solution} \end{array} \right.$   
so  $\frac{1}{u} = \frac{1}{8} + \frac{1}{21}$ ;  
 $u = 5.8 \text{ cm}$ ; [3]  
*Award [2 max] if 25 cm used for v.*
- (c) (i) *chromatic*:  
different amounts of refraction for different colours/wavelengths;  
colour fringing of image;  
*spherical*:  
rays parallel to principal axis at edge of lens brought to different focus from those near centre of lens / *OWTTE*;  
image blurred / *OWTTE*; [4]
- (ii) restrict aperture; [1]

- H3. (a) (i) circular pattern light and dark markings clearly labelled;  $\left\{ \begin{array}{l} \textit{Minimum is centre} \\ \textit{with 2 fringes outside it.} \end{array} \right.$

bright centre to pattern clearly labelled;



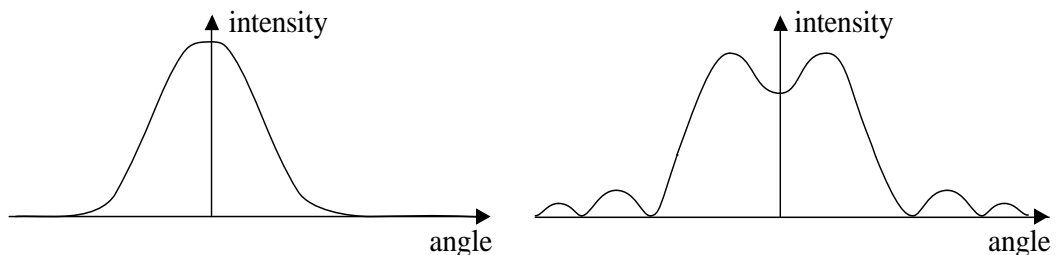
[2]

Award [1 max] for an intensity-position graph if it has a central maximum and is clearly a diffraction pattern (must see central maximum, first minimum, first maximum at least) and award [2 max] if there is a mention of circular symmetry.

- (ii)  $\sin \theta = \frac{1.22\lambda}{d} = \frac{1.22 \times 450 \times 10^{-9}}{0.25} = 2.2 \times 10^{-6}$ ;  $\left\{ \begin{array}{l} \textit{Do not award if} \\ \textit{1.22 factor missing} \end{array} \right.$   
 diameter =  $2 \times 0.75 \times \sin(\textit{or tan})\theta = 3.3 \times 10^{-6}$  m; [2]

- (b) (i) resolution of telescope =  $\left( \frac{1.22 \times 4.5 \times 10^{-7}}{0.25} \right) = 2.2 \times 10^{-6}$ ;  $\left\{ \begin{array}{l} \textit{Allow ECF if 1.22} \\ \textit{is missing in (a)(ii).} \end{array} \right.$   
 $d = 2.2 \times 10^{-6} \times 1.5 \times 10^{17}$ ;  
 $= 3.3 \times 10^{11}$  m; [3]

- (ii) separation  $2d$  shows definite dip between maxima;  $\left\{ \begin{array}{l} \textit{Award these two marking points} \\ \textit{for words or diagram.} \end{array} \right.$   
 separation  $\frac{d}{2}$  shows small or no dip;  
 general shapes of curves good showing 2+ minima, asymmetric higher-order maxima, reducing heights of maxima;  $\left\{ \begin{array}{l} \textit{Award this marking point} \\ \textit{on the basis of a diagram.} \end{array} \right.$



[3]