

Option F — Astrophysics

F1. This question is about comets and stars.

- (a) State **one** difference (other than size) between the orbit of a typical comet and the orbit of the Earth around the Sun. [1]

.....

.....

- (b) The average distance between the stars in a galaxy is about 2 pc. A typical galaxy has a volume of 10^{12} pc³. Estimate the number of stars in the galaxy. [2]

.....

.....

.....

F2. This question is about magnitude and apparent brightness.

- (a) Define *apparent brightness* and *apparent magnitude*. [2]

Apparent brightness:

.....

Apparent magnitude:

.....

(This question continues on the following page)



(Question F2 continued)

- (b) The table gives information on the peak absolute magnitude and the peak apparent brightness of two Cepheid stars.

star	(peak) absolute magnitude	(peak) apparent brightness
Delta Cephei	-3.47	$9.0 \times 10^{-10} \text{ Wm}^{-2}$
Zeta Geminorum	-4.13	$7.2 \times 10^{-10} \text{ Wm}^{-2}$

State and explain whether Delta Cephei or Zeta Geminorum

- (i) appears brighter from Earth. [1]

.....

.....

.....

- (ii) is closer to Earth. [2]

.....

.....

.....

- (c) The luminosity of a Cepheid star is variable. Outline the reason for this variation. [2]

.....

.....

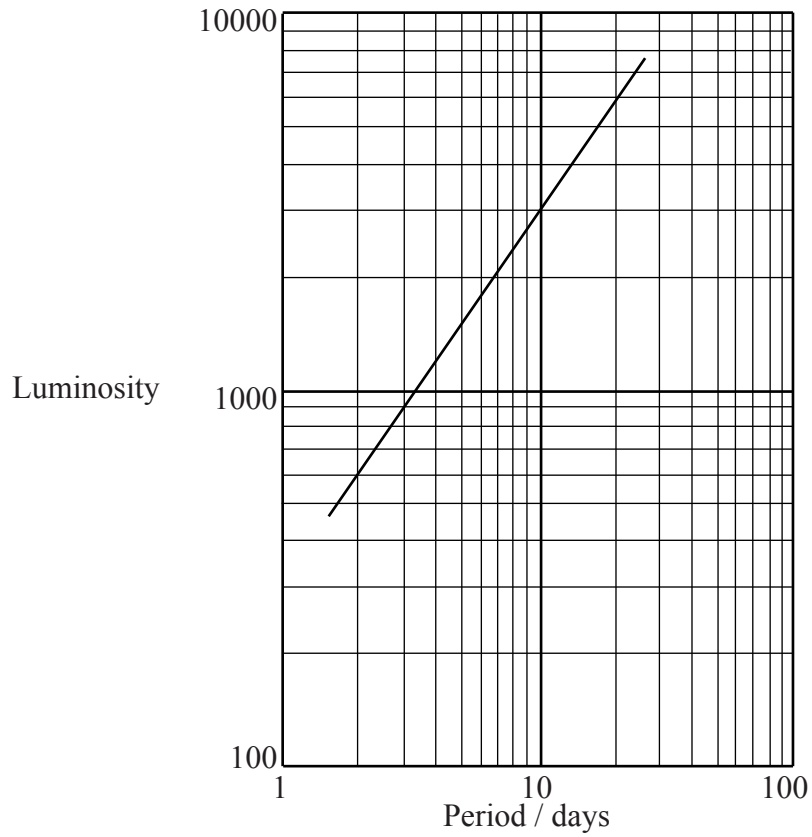
.....

(This question continues on the following page)



(Question F2 continued)

The graph shows the variation with period of the peak luminosity of Cepheid stars.



The luminosity is given in terms of the solar luminosity of 3.9×10^{26} W.

(This question continues on the following page)



(Question F2 continued)

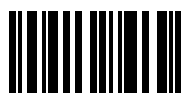
- (d) (i) Outline how data from the graph may be used to determine the distance of a galaxy from Earth. [3]

.....
.....
.....
.....
.....

- (ii) The peak apparent brightness of Zeta Geminorum is $7.2 \times 10^{-10} \text{ Wm}^{-2}$ and the period of variation of luminosity is approximately 10 days.

Use data from the graph on previous page to deduce that the distance to Zeta Geminorum from Earth is about $1.1 \times 10^{19} \text{ m}$. [2]

.....
.....
.....
.....



F3. This question is about cosmic microwave background radiation.

(a) State what is meant by cosmic microwave background radiation. [2]

.....
.....
.....

(b) Describe how the cosmic microwave background radiation provides evidence for the expanding universe. [3]

.....
.....
.....
.....
.....

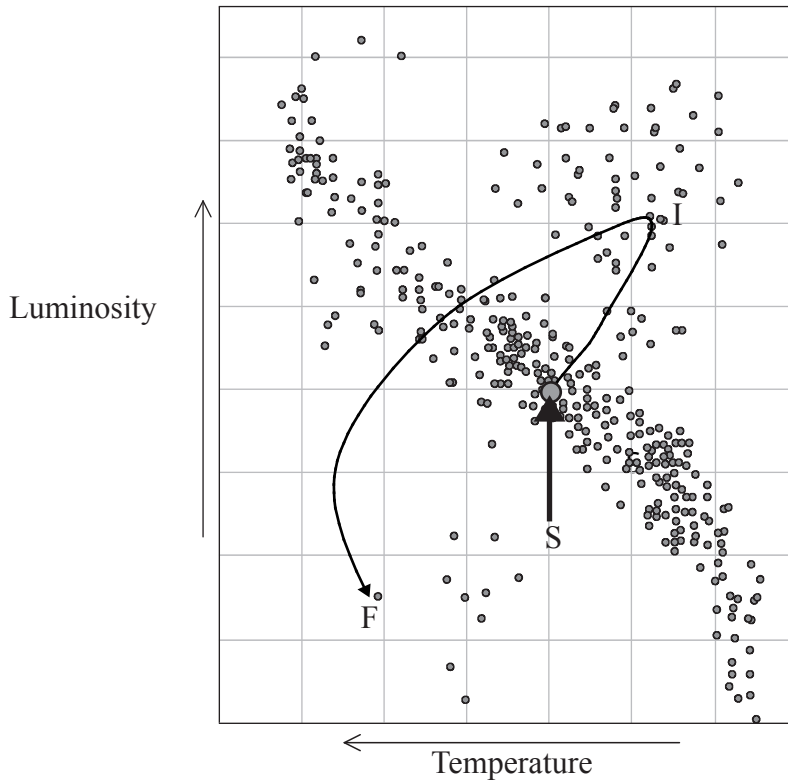


Blank page



F4. This question is about stellar evolution.

A partially completed Hertzsprung-Russel (H-R) diagram is shown below.



The line indicates the evolutionary path of the Sun from its present position, S, to its final position, F. An intermediate stage in the Sun's evolution is labelled by I.

(a) State the condition for the Sun to move from position S. [1]

.....
.....

(b) State and explain the change in the luminosity of the Sun that occurs between positions S and I. [2]

.....
.....

(This question continues on the following page)



(Question F4 continued)

- (c) Explain, by reference to the Chandrasekhar limit, why the final stage of the evolutionary path of the Sun is at F. [2]

.....

.....

.....

.....

- (d) On the diagram on the previous page, draw the evolutionary path of a main sequence star that has a mass of 30 solar masses. [1]

F5. This question is about Hubble’s law.

- (a) State Hubble’s law. [1]

.....

.....

- (b) Deduce an expression for the age T of the Universe in terms of the Hubble constant H . [3]

.....

.....

.....

.....



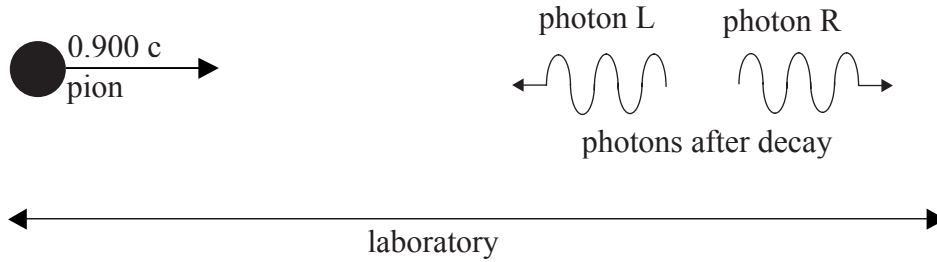
Blank page



Option G — Relativity

G1. This question is about the speed of light.

A pion is an unstable particle that decays into two photons. A particular pion, travelling at $0.900 c$ with respect to an observer at rest in a laboratory, decays into two photons, L and R, travelling in opposite directions as shown in the diagram.



The speed of both photons as measured by the observer at rest with respect to the pion is c .

(a) Calculate the velocity of photon R with respect to the observer in the laboratory using

(i) Galilean kinematics. [1]

.....

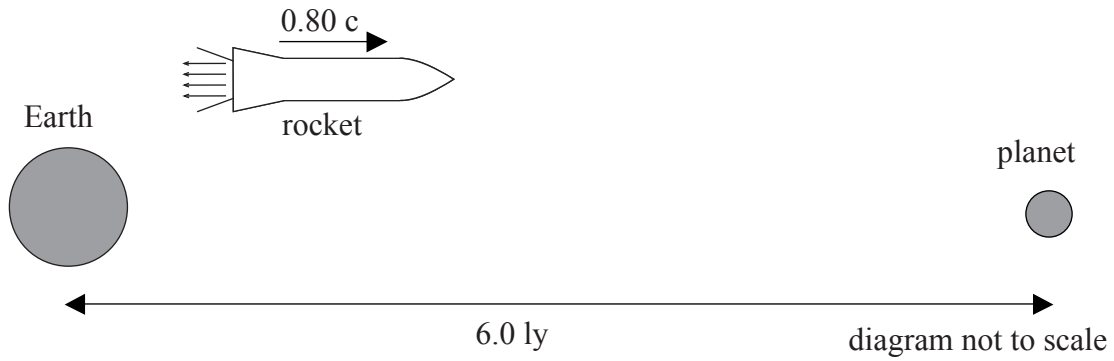
(ii) relativistic kinematics. [3]

.....
.....
.....
.....



G2. This question is about relativistic kinematics.

A rocket moving at $0.80c$, relative to Earth, passes the Earth on its way to a distant planet. As measured by an observer on Earth the distance between Earth and the planet is 6.0 ly .



(a) Calculate the duration of the journey from Earth to the planet according to the observer

(i) on Earth. [1]

.....

.....

(ii) in the rocket. [2]

.....

.....

.....

.....

(This question continues on the following page)



(Question G2 continued)

(b) The rocket passes a space station that is at rest with respect to the Earth. The proper length of the rocket and the proper length of the space station are both 40 m.

(i) Define *proper length*. [1]

.....
.....

(ii) Determine the length of the space station according to the observer in the rocket. [2]

.....
.....
.....

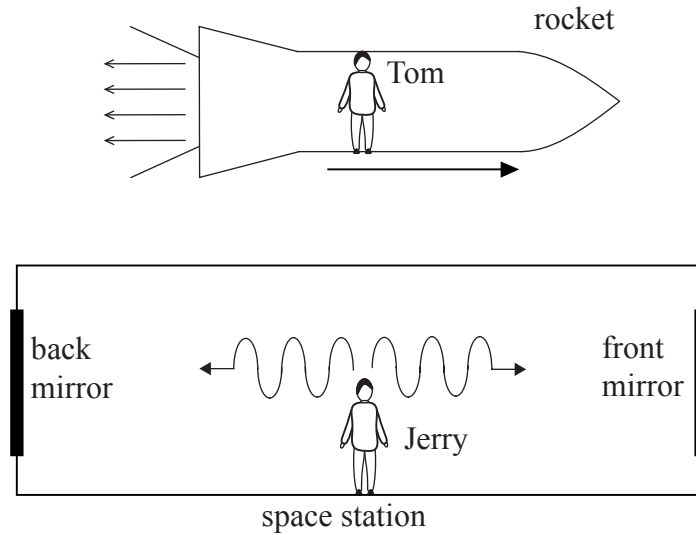
(This question continues on the following page)



(Question G2 continued)

- (c) Tom is an observer in a rocket that moves past a space station. Jerry is an observer in the middle of the space station. Jerry sends two light signals towards mirrors at the front and the back of the space station. The signals are emitted simultaneously according to Tom and according to Jerry.

The signals are reflected off the mirrors and are received by Jerry.



Determine, **according to Tom**, whether

- (i) the front or the back of the space station receives the signal first or whether the signals arrive simultaneously. [2]

.....

.....

.....

- (ii) the reflected signals arrive at Jerry simultaneously. [2]

.....

.....

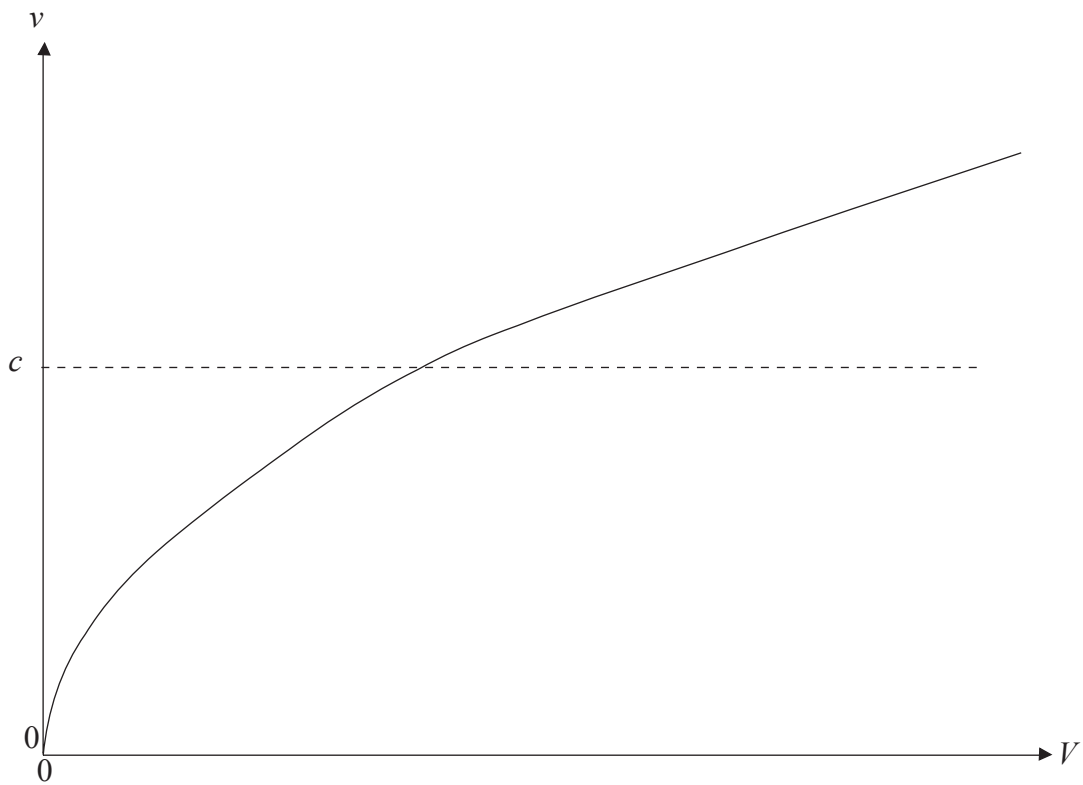
.....

G3. This question is about relativistic mechanics.

- (a) A proton of rest mass 938 MeVc^{-2} is accelerated from rest through a potential difference V . With respect to an observer in the laboratory the speed of the proton after acceleration is $0.998 c$. Calculate the value of the accelerating potential difference as measured by the observer. [4]

.....
.....
.....
.....

- (b) The graph below shows the variation with accelerating potential difference V of the speed v of a proton after acceleration, according to Newtonian mechanics.

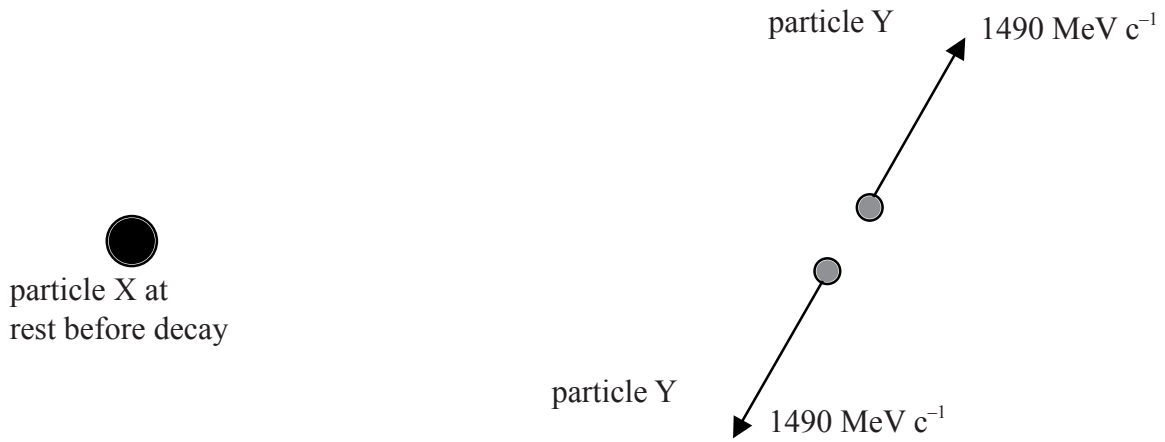


On the graph, draw a line to show the variation with accelerating potential difference V of the speed v of a proton according to relativistic mechanics. [2]



G4. This question is about a relativistic decay.

Particle X has rest mass $3520 \text{ MeV } c^{-2}$. It decays at rest in a laboratory, into two identical particles Y. The two particles move in opposite directions with momentum $1490 \text{ MeV } c^{-1}$ with respect to the laboratory as shown in the diagram.



Determine the rest energy, in units of MeV, of particle Y.

[4]

.....
.....
.....
.....

G5. This question is about black holes.

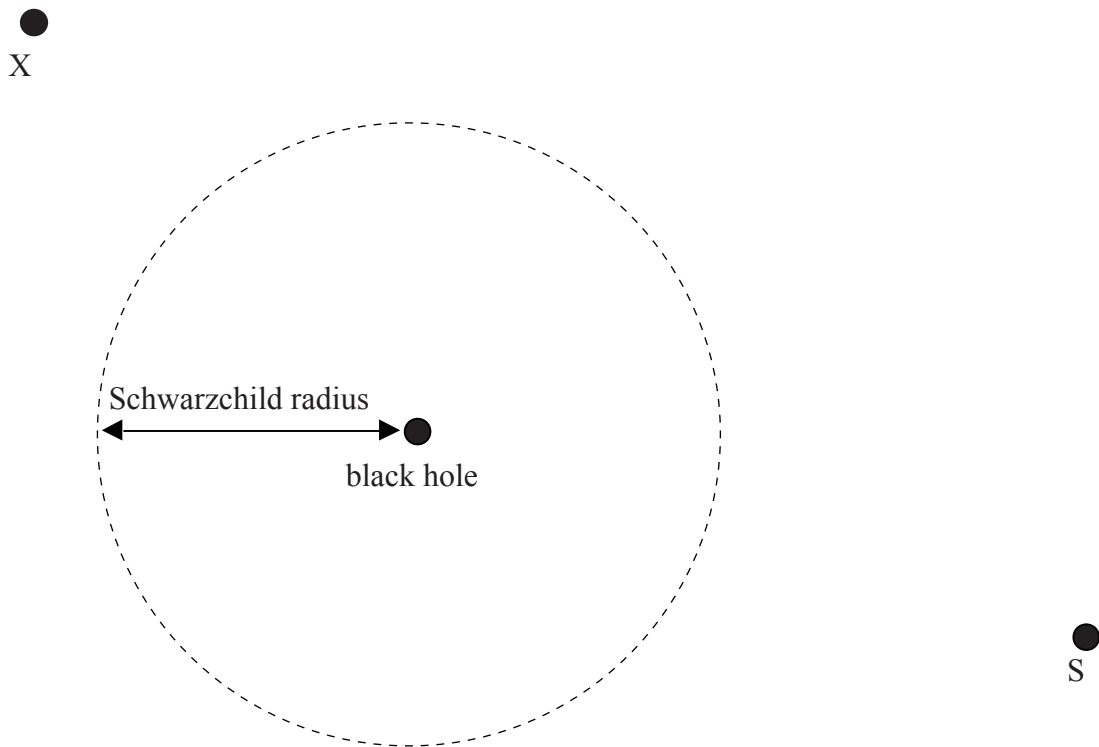
(a) Define the *Schwarzschild radius* of a black hole. [1]

.....
.....

(b) Suggest why the Schwarzschild radius of a black hole is likely to increase with time. [2]

.....
.....

(c) The diagram shows a black hole with Schwarzschild radius R .



An observer at X sends a signal that is received by the spacecraft S.

(i) On the diagram, draw a line to indicate a possible path of the radio signal. [1]

(ii) Explain the path you have drawn. [2]

.....
.....

