Option F — Astrophysics

F1. This question is about stellar clusters and galaxies.

(a) Distinguish between a stellar cluster and a galaxy. *[2]*

Stellar cluster: . . . . . .

. . . . . .

Galaxy: . . . . . .

. . . . . .

(b) State the value of the ratio

$$\frac{\text{order of magnitude of distance between stars in a galaxy}}{\text{order of magnitude of distance between galaxies}}.$$ *[1]*

. . . . . .

F2. This question is about determining the surface area of the star Wolf-359.

(a) Distinguish between apparent brightness and apparent magnitude. *[2]*

Apparent brightness: . . . . . .

Apparent magnitude: . . . . . .

(b) Outline how the surface temperature of a star is determined. *[3]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(Question F2 continued)

(c) The following data are available for the star Wolf-359 and the Sun.

Apparent brightness of Wolf-359 $= 1.97 \times 10^{-12}\,\text{W m}^{-2}$
Distance of Wolf-359 from Earth $= 4.93 \times 10^{5}\,\text{AU}$
Surface temperature of Wolf-359 $= 4.00 \times 10^{3}\,\text{K}$
Surface temperature of Sun $= 6.00 \times 10^{3}\,\text{K}$

For Wolf-359, use the data to,

(i) suggest which method is used to measure its distance from Earth. *[2]*

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

(ii) explain whether its apparent magnitude is greater **or** less than the apparent magnitude of the Sun. *[2]*

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

(iii) deduce that its luminosity is $1.35 \times 10^{23}\,\text{W}$. *[3]*

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

(d) Determine the surface area of Wolf-359. *[2]*

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

F3. This question is about Olbers' paradox.

Newton made three assumptions about the nature of the universe. Two of these were that the universe is infinite and that it is static.

(a) State Newton's other assumption about the nature of the universe. *[1]*

. . . . . .

(b) Outline how Newton's model of the universe leads to Olbers' paradox. *[2]*

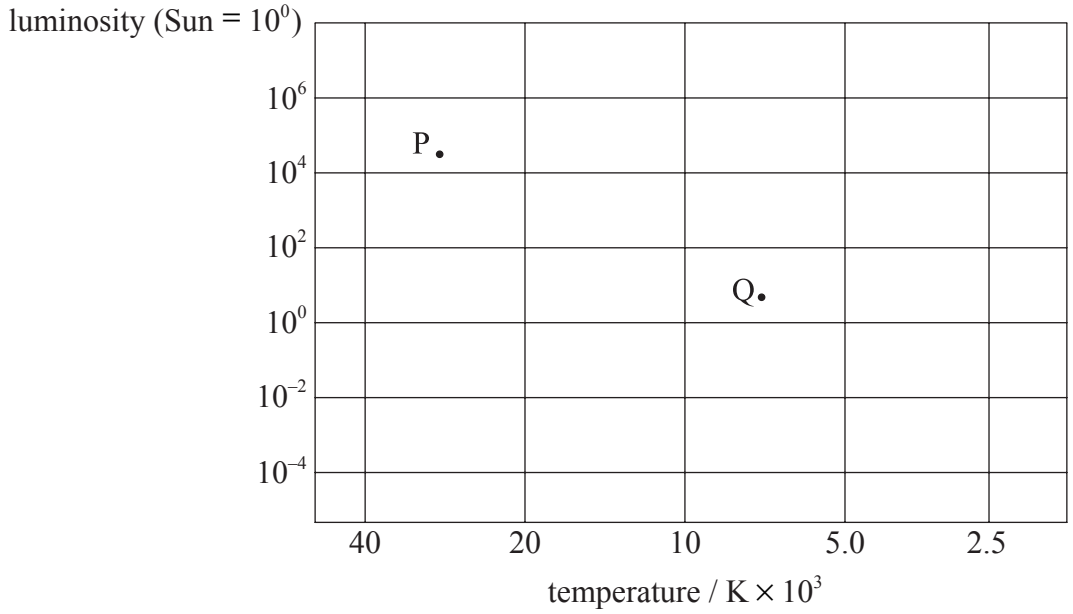
. . . . . .

. . . . . .

. . . . . .

F4. This question is about Main Sequence stars.

Below is a grid of a Hertzsprung-Russell diagram.



The points labelled P and Q are two stars on the main sequence.

(a) On the diagram above, draw the evolutionary path of star Q. *[2]*

(b) State the difference in the likely fate of star P to that of the fate of the star Q. *[1]*

. . . . . .

(c) Explain, with reference to the Chandrasekhar limit, how it might be possible for star P to have the same fate as star Q. *[3]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

F5. This question is about galaxies and red shift.

(a) State the names of **three** types of observed galaxy. *[1]*

. . . . . .

(b) Suggest why the light observed from galaxies shows red shift. *[2]*

. . . . . .

. . . . . .

. . . . . .

(c) State the reason why, the greater the observed red shift the greater the distance of the galaxy from Earth. *[1]*

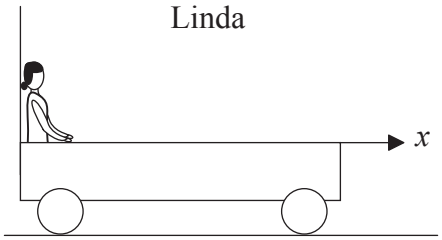
. . . . . .

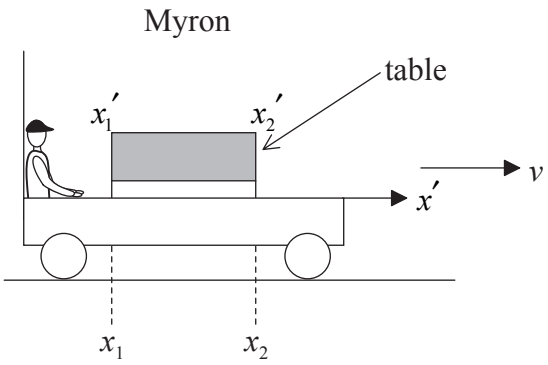
Option G — Relativity

G1. This question is about reference frames and concepts of relativity.

Two railway trucks are on level horizontal tracks parallel to each other. There is an observer in each truck. Linda's truck is stationary relative to the tracks and Myron's truck is moving with constant speed v relative to, and in a direction parallel to, the tracks.

The diagram below represents the positions of the trucks at a time $t = T$ later.





Linda considers herself to be at the origin of her frame of reference and chooses her x-axis to be parallel to the tracks. Myron considers himself to be at the origin of his frame of reference and chooses his x'-axis also to be parallel to the tracks.

(a) Explain what is meant by a frame of reference. *[2]*

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(Question G1 continued)

(b) There is a table at rest with respect to Myron's frame of reference. There is a clock in each truck that is at rest relative to the truck. Myron measures one end of the table to be at x_1' and the other end to be at x_2'. As measured by Linda, at a time $t=0$ the trucks are directly opposite each other, and at a time $t = T$, the corresponding positions are x_1 and x_2 respectively.

(i) Use a Galilean transformation, to deduce that both Linda and Myron will measure the length of the table to be the same. *[2]*

. . . . . .

. . . . . .

. . . . . .

(ii) Use a relativistic transformation, to state the relation between $(x_1' - x_2')$ and $(x_1 - x_2)$. Define any other quantities used. *[2]*

. . . . . .

. . . . . .

. . . . . .

(iii) With reference to the postulates of special relativity, explain why it is important that the measurements are made simultaneously. *[3]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(iv) Outline how the result of the Michelson-Morley experiment supports your explanation in (b)(iii). *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(Question G1 continued)

(c) On the table, there is a lamp that Myron can turn on or off using a remote control. He switches the lamp on and then off. He measures the time interval on his clock between the lamp being turned on and then off as 0.800 s. Linda measures the time interval on her clock as 1.20 s.

(i) State and explain which observer measures the proper time. *[2]*

. . . . . .

. . . . . .

(ii) Calculate the speed v of Myron's truck. *[3]*

. . . . . .

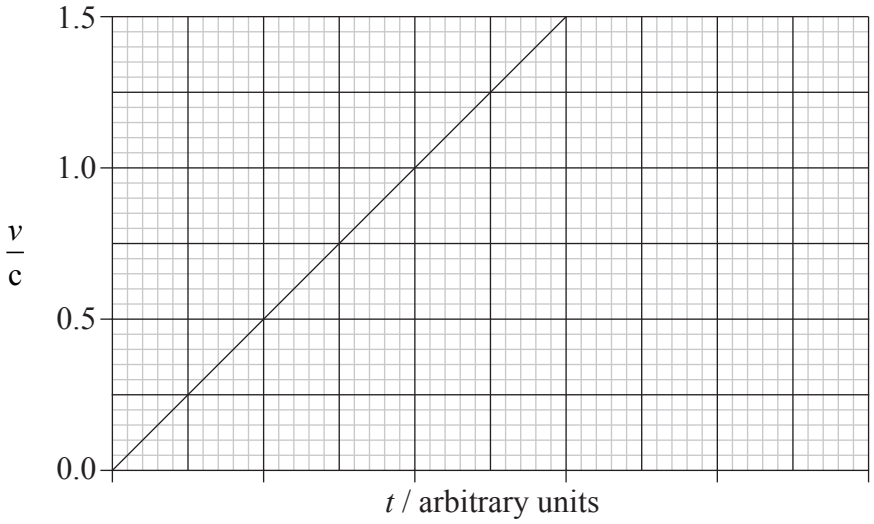
. . . . . .

. . . . . .

. . . . . .

. . . . . .

G2. A particle is accelerated from rest by a constant force. The graph below shows the variation with time t of the ratio $\frac{v}{c}$ where v is the speed of the particle and c is the free space speed of light, as calculated using Newtonian mechanics.



(a) On the graph above, draw the variation with time t of the speed v as calculated using relativistic mechanics. *[2]*

(b) A particle has rest mass $0.51\,\text{MeV}\,c^{-2}$ and it is moving at speed 0.90c. Calculate the total energy of this particle. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

G3. This question is about relativistic momentum.

A proton is accelerated from rest through a potential difference of $5.00 \times 10^2\,\text{MV}$. Determine the momentum of the proton after acceleration. *[4]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

G4. This question is about spacetime.

(a) By reference to a particle moving along the *x*-axis of a coordinate system, describe the concept of spacetime. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) A satellite is in orbit about Earth.

(i) Outline how the concept of spacetime is used to account for the orbital motion of the satellite. *[3]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(ii) State the reason why the gravitational force of attraction between the satellite and Earth decreases with distance from Earth. *[1]*

. . . . . .

. . . . . .