MOMENTUM

IB Physics HL

Relativity - Set 1

A.5 | First assessment 2025 | Higher Level

Independent examination-style practice material

10 original problems

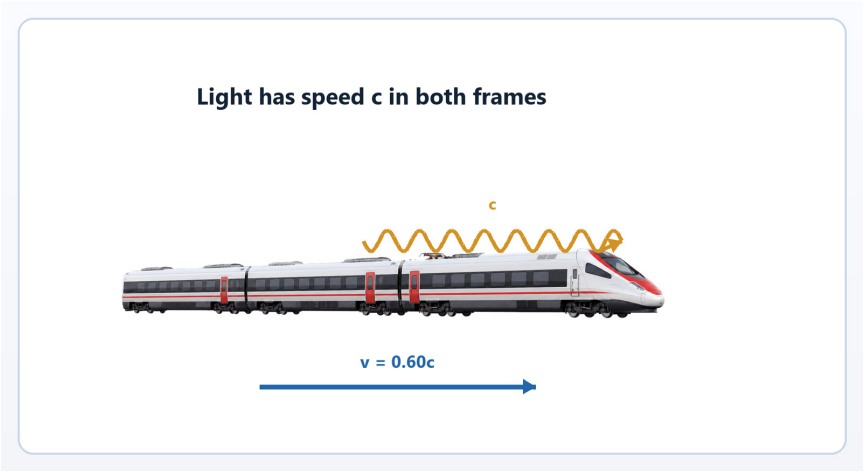
TASK 01

[7]

Light emitted inside a moving train

Paper 2 style | IB code A.5

A laboratory train moves at 0.600c relative to a platform. A pulse of light is emitted forwards from its centre. The proper length of the train is 300 m.



(a) State the speed of the pulse measured in the train and on the platform. [2]

(b) Determine the train length on the platform. [2]

(c) Determine the platform time for the pulse to reach the front wall. [3]

TASK 02

[6]

Lightning strikes a moving train

Paper 2 style | IB code A.5

A 600 m proper-length train moves at 0.600c. In the platform frame, lightning strikes its front and rear ends simultaneously.

(a) Determine the separation of the strikes in the platform frame. [2]

(b) Determine their time separation in the train frame. [3]

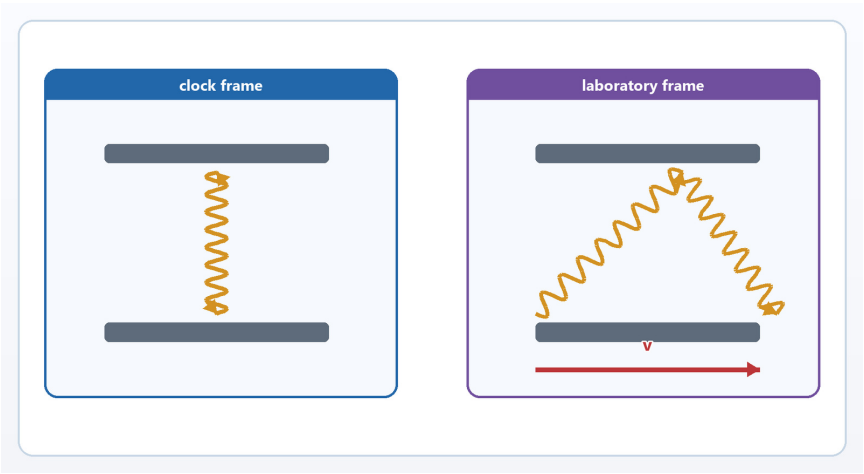
(c) State which strike occurs first in the train frame. [1]

TASK 03
[6]

A moving light clock

Paper 2 style | IB code A.5

The mirrors of a light clock are separated by 1.20 m. The clock moves horizontally at 0.800c relative to a laboratory.



(a) Determine the proper period of one complete cycle. [2]

(b) Determine the period measured in the laboratory. [2]

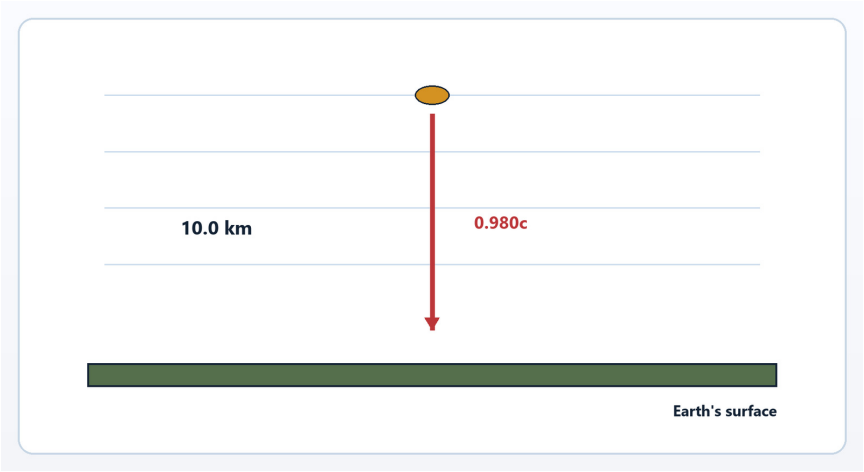
(c) Determine the diagonal distance travelled by light between mirrors in the laboratory. [2]

TASK 04
[8]

Cosmic-ray muons

Paper 2 style | IB code A.5

Muon proper mean lifetime is 2.20 microseconds. Muons travel towards Earth at 0.980c from altitude 10.0 km.



(a) Determine their mean distance travelled in Earth's frame. [3]

(b) Determine the surviving fraction after 10.0 km. [3]

(c) Explain the observation in the muon frame. [2]

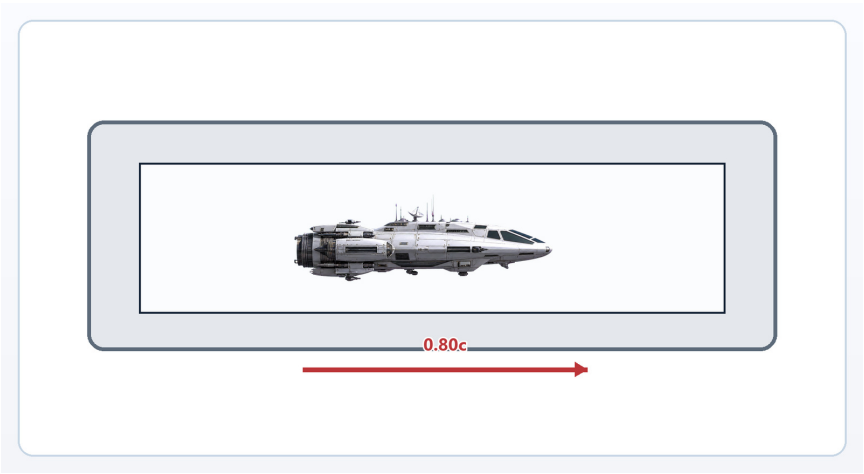
TASK 05

[6]

A spacecraft and a tunnel

Paper 2 style | IB code A.5

A spacecraft has proper length 120 m and a tunnel has proper length 100 m. The spacecraft moves at 0.800c relative to the tunnel.



(a) Determine the spacecraft length in the tunnel frame. [2]

(b) Decide whether both tunnel doors can close simultaneously in the tunnel frame. [1]

(c) Explain why there is no contradiction in the spacecraft frame. [3]

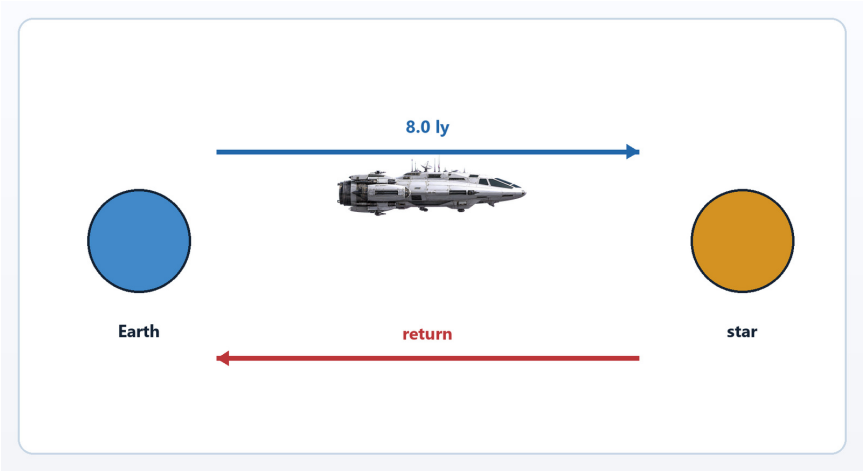
TASK 06

[5]

A relativistic journey to a star

Paper 2 style | IB code A.5

A star is 8.00 light-years from Earth in the Earth frame. A spacecraft travels at 0.800c, ignoring acceleration phases.



(a) Determine the journey time in the Earth frame. [1]

(b) Determine the elapsed proper time on the spacecraft. [2]

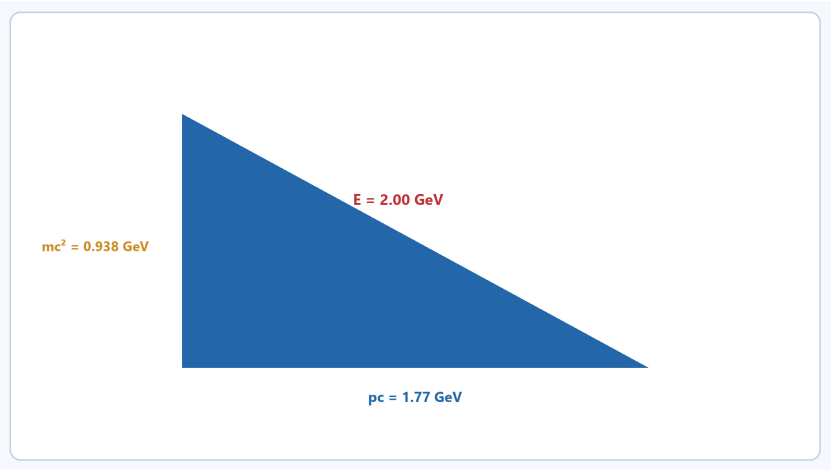
(c) Determine the Earth-star distance measured by the travellers. [2]

TASK 07
[6]

Energy and momentum of a proton

Paper 2 style | IB code A.5

A proton has total energy 2.00 GeV. Its rest energy is 0.938 GeV.



(a) Determine its Lorentz factor and speed. [3]

(b) Determine its momentum in GeV/c. [2]

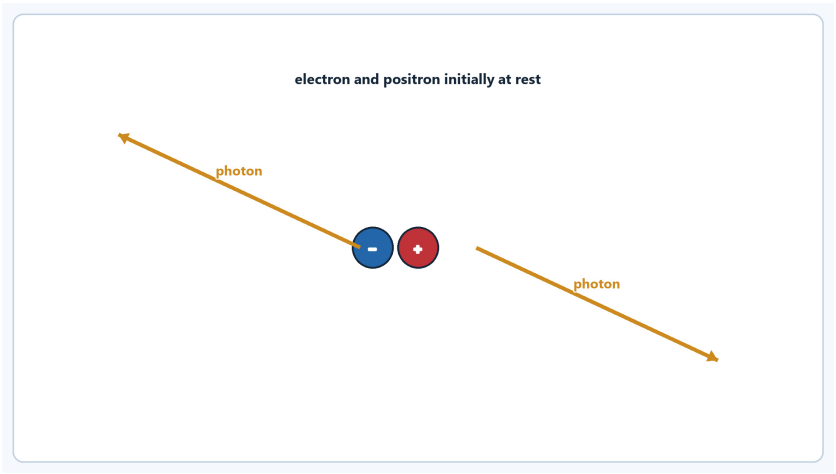
(c) Determine its kinetic energy. [1]

TASK 08
[5]

Electron-positron annihilation

Paper 2 style | IB code A.5

An electron and a positron are initially at rest and annihilate into two photons.



(a) Explain why at least two photons are required. [2]

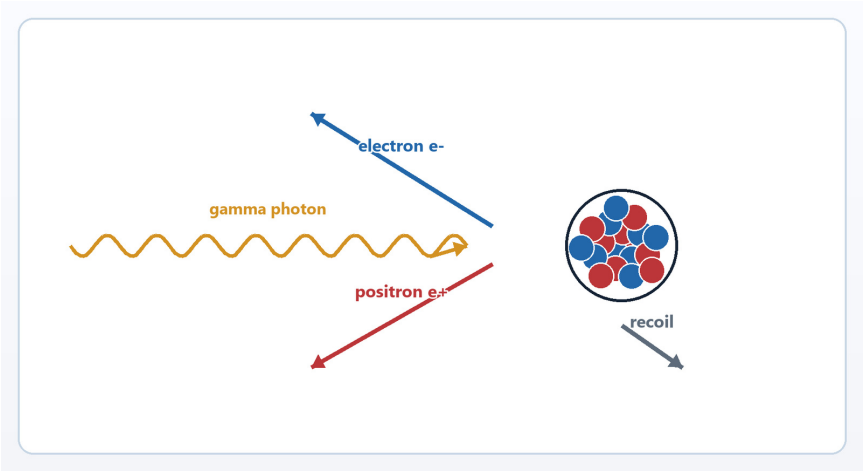
(b) Determine the energy and wavelength of each photon. [3]

TASK 09
[4]

Threshold for pair production

Paper 2 style | IB code A.5

A high-energy photon creates an electron-positron pair near a nucleus.



(a) Determine the minimum photon energy if nuclear recoil is neglected. [1]

(b) Explain why pair production cannot occur for a single photon in empty space. [2]

(c) State the role of the nearby nucleus. [1]

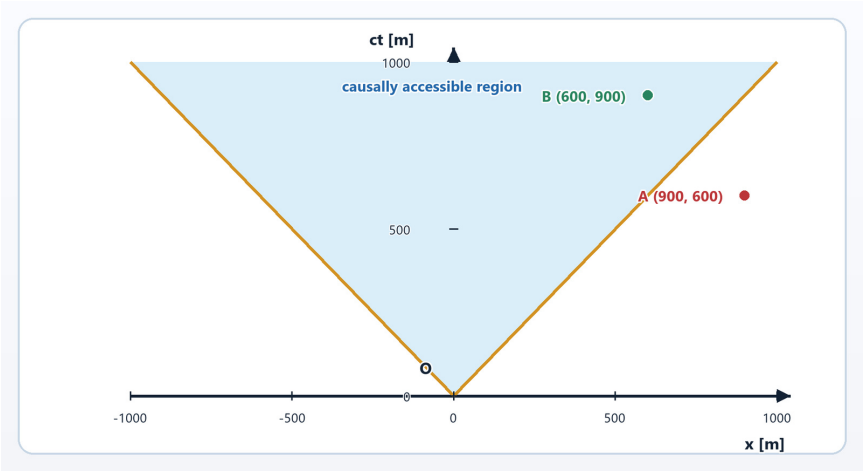
TASK 10

[6]

Events on a spacetime diagram

Paper 2 style | IB code A.5

Two events have separations Delta x = 900 m and Delta t = 2.00 microseconds in one inertial frame.



(a) Classify the interval as timelike, lightlike or spacelike. [2]

(b) Determine whether one event can causally influence the other. [1]

(c) Determine the speed of a frame in which the events are simultaneous, if such a frame exists. [3]