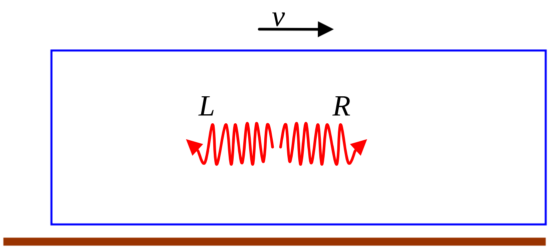
Extension Worksheet – Option H, Worksheet 2

1 Einstein considered a thought experiment in which a fast train moves past observers on the platform. Light signals from the middle of the train are emitted simultaneously towards the front and back of the train. The light signals will be received by the front and the back of the train simultaneously according to the observers on the train. In the theory of relativity, the observers on the ground will measure that the back of the train will receive light first. In Galilean relativity all observers agree that the light signals reach the ends of the train at the same time. In this exercise you will try to explain this quantitatively in both Einstein relativity and Galilean relativity.



Part 1 Einstein relativity

a State the speed of the light signals *L* and *R* according to the observers on the ground. [1]

b State the **relative** speed of each signal with respect to the end of the train it is travelling towards, according to the observers on the ground. [2]

c Explain why the answers that you found in **b** are nothing to worry about! [2]

d Use the answers to the previous parts to deduce that the left end of the train will receive the light a time $\frac{Lv}{c^2 - v^2}$ **before** the light arrives at the right end where *L* is the length of the train according to the ground observers. [3]

e Show that the time interval in **d** can be rewritten as $\frac{\gamma L_0 v}{c^2}$ where L_0 is the proper length of the train. [2]

Part 2 Galilean relativity

a State the speed of the light signals *L* and *R* according to the observers on the ground. [2]

b State the **relative** speed of each signal with respect to the end of the train it is travelling towards, according to the observers on the ground. [2]

c Use the answers to parts **a** and **b** to deduce that the light signals will arrive at the ends of the train at the same time. [2]

2 The distance between the Earth and the nearest star (other than our Sun) is about 4.00 ly as measured by observers on Earth. A spaceship moving at 0.600 *c* relative to the Earth leaves Earth on its way to the star.

a Show that the time taken for the spaceship to get to this star is 5.33 years according to clocks in the spaceship. [2]

b An observer on the spaceship claims that she is at rest and it is the star that is approaching her spaceship. She claims that the star is approaching at a speed that she estimates as $\frac{4.00\text{ ly}}{5.33\text{ y}} = 0.750c$. Explain what is correct with her argument and correct what is wrong with her argument. [2]

3 A spaceship moving at 0.80 *c* relative to the Earth leaves Earth on its way to a very distant planet. On its way the spaceship moves past a space station whose distance from Earth is 60 ly according to Earth measurements.

a Calculate the time for the spaceship to get to the space station according to clocks on Earth. [1]

b Determine the time taken for this trip according to clocks in the spaceship. [2]

c The spaceship sends a light signal to Earth as it goes past the space station. Calculate how long it takes the light signal to arrive on Earth according to (i) the Earth and (ii) spaceship clocks. [4]

4 Describe the purpose of the Michelson–Morley experiment, explaining why the apparatus was rotated by 90°. [3]

5 A rocket moves with velocity 0.80 *c* relative to the ground. The exhaust gases of the rocket have velocity –0.40 *c* relative to the rocket. Determine the velocity of the gases relative to the ground. [3]

6 Calculate the momentum of a photon of total energy 220 MeV. [2]

7 An electron is accelerated from rest by a potential difference of 2.8 MV. Calculate the de Broglie wavelength of the accelerated electron. [4]