

Inertia, resultant force and reaction pairs

Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Lab

Name: _____ Date: _____ Class: _____

How is the acceleration of a trolley related to the pulling force? This lab keeps the total mass constant and uses falling masses to pull the trolley. You measure a time over a fixed distance, calculate acceleration and look for a pattern. It is a classic way to test the second law at school level.

Level: Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** HS-PS2-1, GCSE P5

Aim

To investigate how the acceleration of a trolley depends on the resultant force when the total mass is kept constant.

Equipment

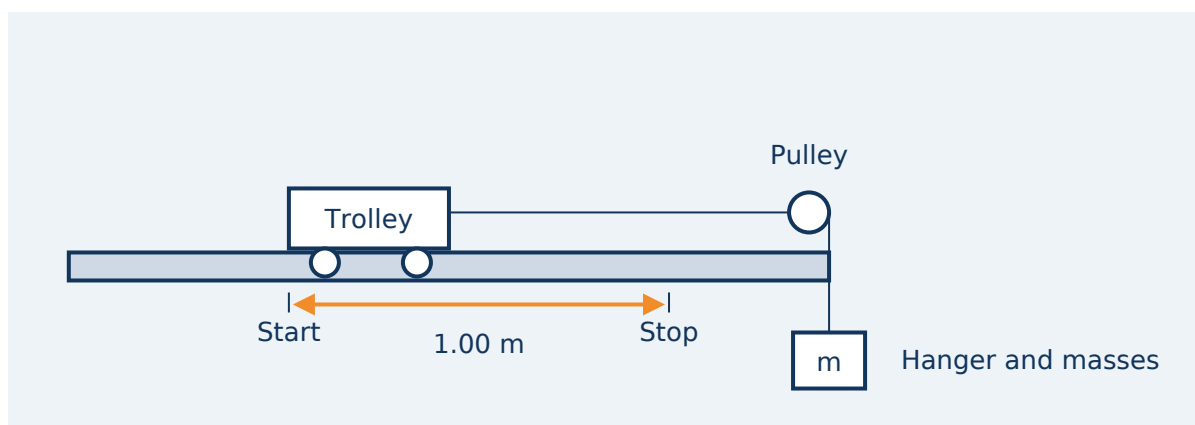
- Trolley, smooth bench or runway and a pulley clamped at the end
- String, mass hanger and ten slotted masses of 10 g
- Metre rule, stopwatch, balance
- Soft landing pad (a folded towel)

Safety

Safety

Stop the trolley with a pad so it cannot fall off the bench onto your feet. Keep feet away from the falling masses and tie the string firmly.

Method



Trolley, string, pulley and hanger arranged on a bench; the trolley starts from rest.

1. Set the total mass of trolley, string, hanger and slotted masses to 0.600 kg. Keep the slotted masses on the trolley at the start.
2. Mark a start line and a stop line 1.00 m apart. Hold the trolley at rest on the start line.
3. Move 20 g from the trolley to the hanger. Release the trolley and time it from release to the stop line. Repeat three times and take the mean time t .
4. Move another 20 g from the trolley to the hanger, so the hanging mass becomes 0.040 kg. Repeat the timing. Continue until the hanging mass is 0.100 kg, always keeping the total mass at 0.600 kg.
5. Calculate the pulling force $F = m \times g$, with $g = 9.8 \text{ N/kg}$, and the acceleration $a = 2d \div t^2$ for each trial.

Results

Sample results for $d = 1.00 \text{ m}$. The force is the weight of the hanging mass.

Hanging mass m (kg)	Force F (N)	Mean time t (s)	Acceleration a (m/s^2)
0.020	0.196	2.62	0.29
0.040	0.392	1.84	0.59
0.060	0.588	1.50	0.89
0.080	0.784	1.30	1.18
0.100	0.980	1.16	1.49

Analysis questions

Question 1 Calculate an acceleration

Use the third row of the table: show that $a = 2d \div t^2$ gives 0.89 m/s^2 .

Question 2 Why $a = 2d \div t^2$

The trolley starts from rest and accelerates uniformly. Starting from $d = \frac{1}{2} a t^2$, derive the equation used to find a .

Question 3 Plot and describe

Plot a graph of acceleration (y-axis) against force (x-axis). Describe the shape of the line and state what it shows.

Question 4 Gradient and mass

Find the gradient of the line using the first and last rows. Use it to calculate the mass that the force accelerates and compare it with 0.600 kg.

Question 5 Why the total mass stays fixed

Explain why slotted masses are moved from the trolley to the hanger rather than added to the hanger.

Question 6 Is the force really $m \times g$?

The hanger also accelerates. For the last row, calculate the tension in the string and compare it with the weight of the hanging mass.

Question 7 Timing uncertainty

The mean time in the last row is 1.16 s with an uncertainty of ± 0.05 s. Calculate the percentage uncertainty in t and in a .

Question 8 Improve the investigation

Suggest two improvements that would give more reliable results.