

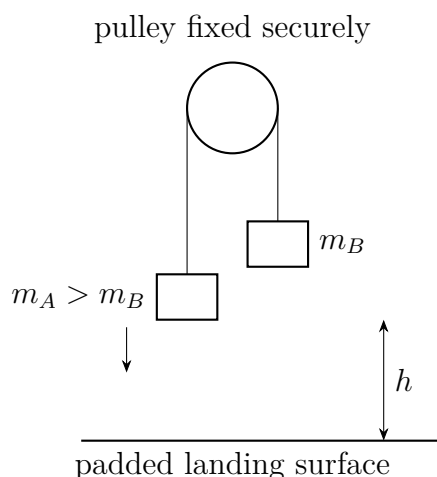
Free fall with connected masses

Name: _____ Class: _____ Date: _____

Aim Estimate g with two connected masses, keeping their total mass constant. Allow 60–75 minutes.

Key ideas For an ideal light string and frictionless pulley, $(m_A - m_B)g = (m_A + m_B)a$. Release from rest so $h = \frac{1}{2}at^2$. Include hanger masses in m_A and m_B .

Apparatus Clamped low-friction pulley, stand, string, two mass hangers, transferable 5 g or 10 g masses, ruler, balance, stopwatch and padded catch tray.



Safety Secure the pulley and stand. Keep feet and fingers out of the fall path. Catch the masses in the tray; stop before a hanger reaches the pulley. Do not stand under a suspended mass.

1 Collect fair measurements

1. Start with each side approximately 0.100 kg. Measure the actual masses. Set a safe fall distance h near 1 m to the landing surface.
2. Transfer a small mass from B to A. Record both totals. Transferring 5 g changes $m_A - m_B$ by 10 g.
3. Release A from the marked start position without a push. Time its fall to the landing surface. Reset and take three readings.
4. Transfer another small mass and repeat. Aim for six useful differences, using small transfers. Do not add fast, unreliable runs merely to reach six points.
5. Check that $m_A + m_B$ and h stay constant. Use smaller transferable masses to spread readings in the slower range.

2 Results and controls

$h =$ _____ m $S = m_A + m_B =$ _____ kg.

$d = m_A - m_B$. Estimate $\Delta h =$ _____ m and justify it.

m_A/kg	m_B/kg	d/kg	t_1/s	t_2/s	t_3/s

d/kg	$\bar{t}/\text{s}$	$1/\bar{t}^2/\text{s}^{-2}$	$K = d\bar{t}^2/\text{kg s}^2$

Record the instrument resolutions and the shortest time you considered reliable. Explain the choice.

3 Graph

Plot mass difference $d = m_A - m_B$ against $1/t^2$. Fit a line without forcing it through the origin.



Choose scales and label both axes with quantities and units. Mark a large gradient triangle on the best-fit line where appropriate.

4 Estimate free-fall acceleration

The ideal model predicts

$$d = K \frac{1}{t^2}, \quad K = \frac{2hS}{g}, \quad g = \frac{2hS}{K}.$$

1. Determine the graph gradient K and its unit. Use it to calculate g . Show your working.

2. For one row, calculate $K_i = d\bar{t}^2$ and $g_i = 2hS/K_i$. Estimate $\Delta g_i/g_i \simeq \Delta h/h + \Delta S/S + \Delta d/d + 2\Delta t/t$. Justify uncertainties; for $d = m_A - m_B$, conservatively use $\Delta d = \Delta m_A + \Delta m_B$.

3. Calculate the percentage difference from 9.81 ms^{-2} . Is your estimate consistent within its uncertainty? Distinguish your one-row uncertainty from the uncertainty of the graph gradient.

4. Explain how pulley inertia changes the gradient and how approximately constant friction can give a positive intercept. Match two limitations to improvements.

Conclusion State what your data support, including whether the fitted intercept is close to zero.

Before you leave Return the apparatus, clear the bench and submit your recorded data.