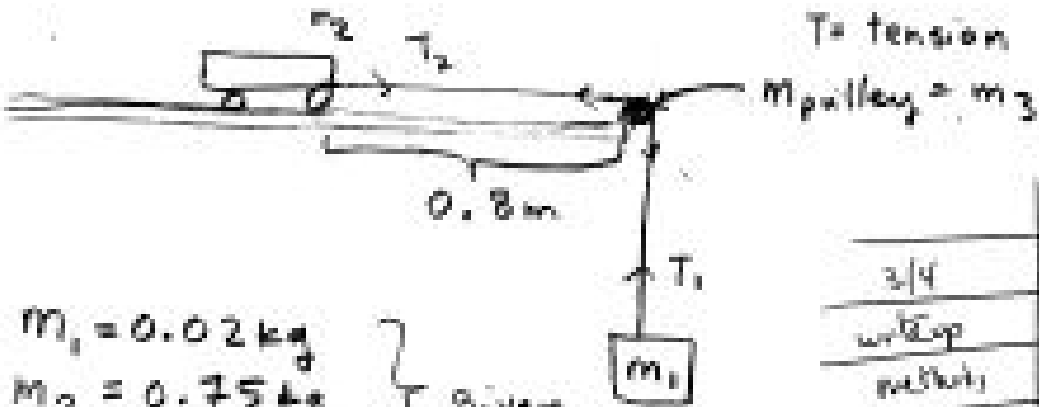
Station 1

Jack Kamm



$m_1 = 0.02\,kg$
$m_2 = 0.75\,kg$
$m_3 = 0.1\,kg$
} given

3/4	10
wrEp	10
results	10
prec	10
conc	9

59/60

distance from cart to pulley = distance m_1 falls = 0.8 m
(found with ruler)

Can I have back?

radius of pulley = r = 0.0525 m

Find a

Experimental

We used a stopwatch to find the time it takes for the system to travel 0.8 m.
Our five times were: 2.69 s, 2.65 s, 2.65 s, 2.68 s, 2.71 s
Our average t was: 2.68 s

$\Delta x = v_0 t + \frac{1}{2} a t^2$

$v_0 = 0$ so

$\frac{2\Delta x}{t^2} = a$

$a = 0.223 \frac{m}{s^2}$

Theoretical

$\alpha = \frac{a}{r}$

$I = \frac{1}{2} m_3 r^2$ (because pulley is in the shape of a disc)

$m_2 a = T_2$ (because T_2 is only force acting on m_2)

$m_1 a = m_1 g - T_1$ (because F_w and T_1 are two opposing forces acting on m_1; it has no other forces)

$\Sigma \tau = T_1 r - T_2 r = I \alpha$

$m_1 g r - m_1 a r - m_2 a r = \left(\frac{1}{2} m_3 r^2\right) \cdot \left(\frac{a}{r}\right)$

$m_1 g = m_1 a + m_2 a + \left(\frac{1}{2} m_3\right) a$

$\frac{m_1 g}{m_1 + m_2 + \frac{1}{2} m_3} = a$

$\boxed{0.239 \frac{m}{s^2} = a}$

Conclusion

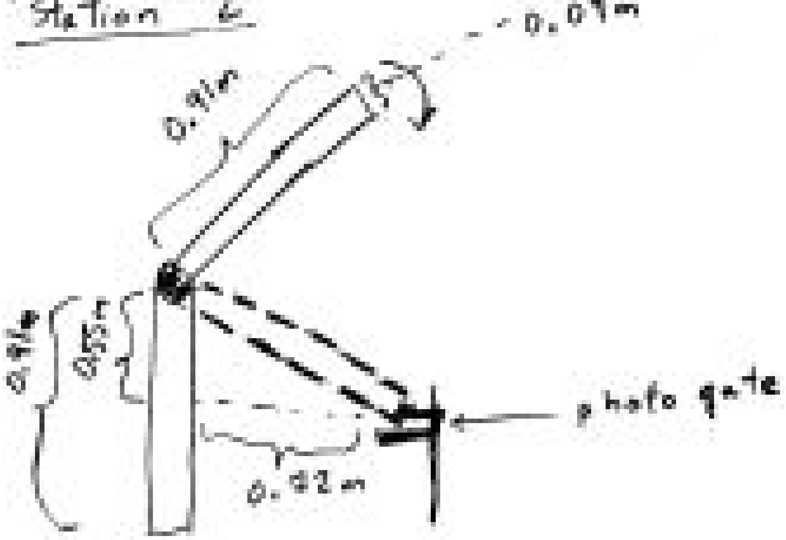
$\% \text{ error} = \frac{\text{theoretical} - \text{actual}}{\text{theoretical}} = \frac{0.239 \frac{m}{s^2} - 0.223 \frac{m}{s^2}}{0.239 \frac{m}{s^2}}$

$\boxed{\% \text{ error} = 6.695 \%}$

There were two inaccuries we had in our experiment. Firstly, we didn't measure the friction between the cart and the track. Secondly, we could not get the motion detector to work, so we had to rely on a stopwatch and imperfect human reflexes to find the time it took the system to move 0.8 m.

→ can you estimate this error by your measurement scatter

Station 2 Jack Kamm



Find ω of swinging wooden board when it crosses the photogate.

Experimental

To find ω, we found v when the board crossed the photogate and multiplied that by r (the length of the board).

To find v, we found the time the plank took to cross the photogate (using the photo gate). We then took the width of the plank and divided it by t.

We used a ruler to measure all the lengths in the diagram. Finally, we started the plank as straight up at a 90° angle from the horizontal, then let it drop forward.

Our measurements were:

width: 0.09 m

time: 0.0119 s, 0.0121 s, 0.0126 s

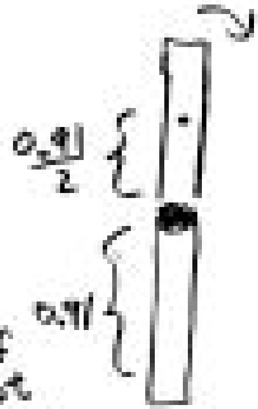
average time = 0.0122 s

$$\omega = \frac{\text{width}}{\text{time} \cdot r} = 8.086 \frac{\text{rad}}{\text{sec}}$$

Theoretical

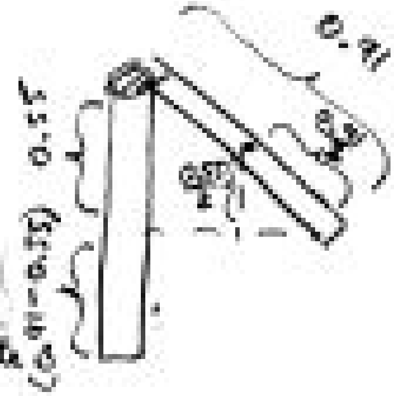
$E_i = E_f$

$E_i = mgh_1$



$h_1 = \underbrace{0.91m}_{\text{height of pivot off table}} + \underbrace{\frac{0.91m}{2}}_{\text{height of center of mass of plank off pivot}}$

$E_f = mgh_2 + \frac{1}{2}mv^2 + I\omega^2$



$h_2 = \underbrace{(0.96 - 0.55m)}_{\text{height of photogate off table}} + \underbrace{\frac{0.55}{2}m}_{\text{height of center of mass off photo gate}}$

(because corresponding parts of corresponding triangles are proportional)

$I_{plank} = \frac{m(a^2+b^2)}{12}$ where a = width = 0.09 m, b = length of plank = 0.91 m

$I_{pivot} = I_{plank} + m\left(\frac{b}{2}\right)^2$ because $\frac{b}{2}$ is distance from center of mass of plank to the pivot point

$v = 0$ at pivot point

$\cancel{m}gh_1 = \cancel{m}gh_2 + \cancel{\frac{1}{2}mv^2} + \left[\frac{\cancel{m}(a^2+b^2)}{12} + \cancel{m}\left(\frac{b}{2}\right)^2\right]\omega^2$

$$\boxed{\omega = 7.194 \ \frac{\text{rad}}{\text{sec}}}$$

Station 2

Jack Keenan

Conclusion

$$\% \text{ error} = \frac{|\text{theoretical} - \text{actual}|}{\text{theoretical}}$$

$$\% \text{ error} = \frac{|7.194 - 8.086|}{7.194}$$

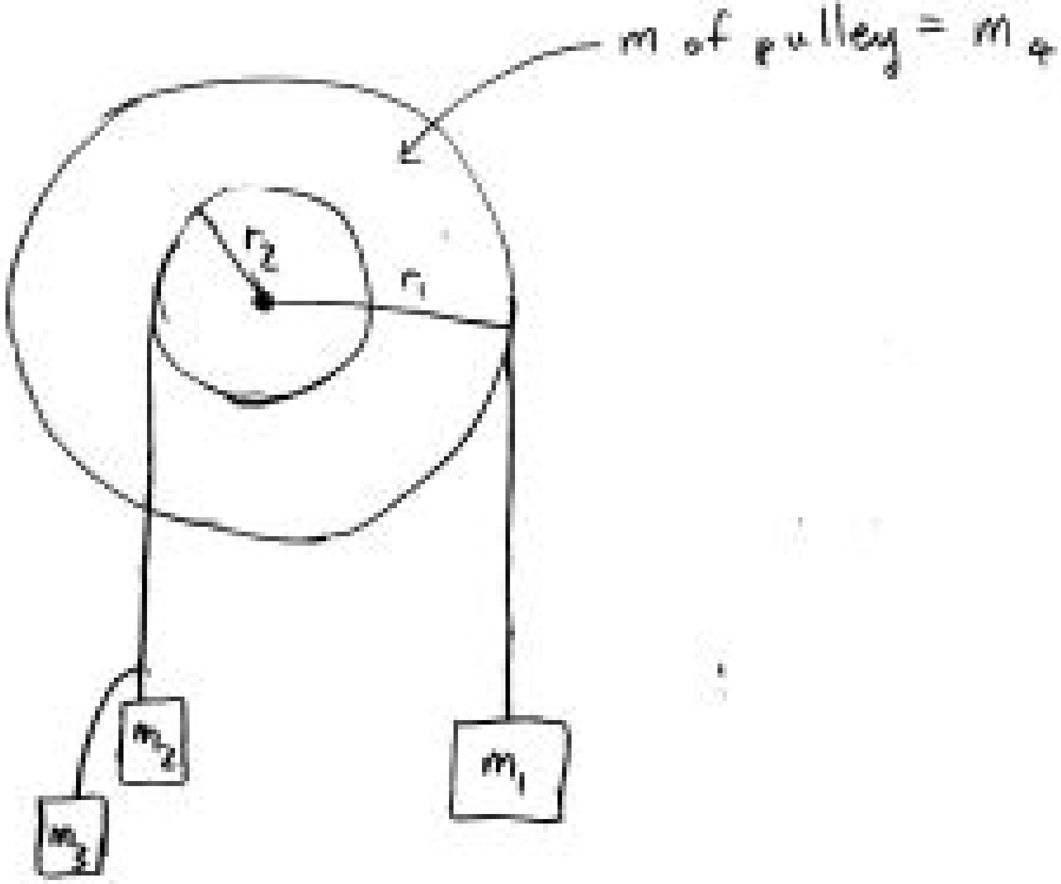
$$\boxed{\% \text{ error} = 12.40\%}$$

I can't think of any major errors. Some energy is probably lost to the air particles hitting the plank, and if the hinge isn't properly oiled a little energy will be dissipated there as well.

Also velocity is not $\frac{\Delta x}{\Delta t}$ but the Δt is so small here that the error should be negligible.

Station 4

Jack



$m_1 = 0.02\,kg$
$m_2 = 0.05\,kg$
$m_3 = 0.01\,kg$
$m_4 = 0.1\,kg$

These masses were all given.

$r_1 = 0.00525\,m$
$r_2 = 0.00175\,m$

Therefore $\left(\frac{r_1}{r_2}\right) = 3$

We found r_1 and r_2 with a ruler.

Part 1

Show why the two sides are balanced.

The two sides are balanced iff $\Sigma\tau = 0$.

$\Sigma\tau = \tau_1 - \tau_{23}$

$\tau_1 = F_{t1} \cdot r_1$

$\tau_2 = F_{t23} \cdot r_2$

$F_{t1} = -F_{w1}$, because m_1 is not moving

$F_{t23} = -F_{w23}$

$\tau_1 = m_1 g \cdot r_1 = 0.001029$ Nm

$\tau_2 = (m_2 + m_3) g \cdot r_2 = 0.001029$ N·m

$\therefore \tau_1 = \tau_2$

$\therefore \tau_1 - \tau_2 = 0$

$\therefore \sum \tau = 0$ QED.

Part 2

Find the acceleration of m_1 if m_3 is removed.

Experimental

We measured the distance from m_1 to the table and found a height of 0.53 m.

Using a timer, we timed how long it took for m_1 to fall a distance of 0.53m. Our times were: 1.68s, 1.63s, 1.56s, 1.65s, 1.63s

The average time was 1.63s.

Since $\Delta x = v_0 t + \frac{1}{2} a t^2$, and $v_0 = 0$ and $\Delta x = h$,

$a_1 = \frac{2(-h)}{t^2}$. Therefore, the measure of a_1 we found was $-0.399 \frac{m}{s^2}$.

Theoretical

① $\sum F_1 = m_1 a_1 = m_1 g + F_{t_1}$

② $\sum F_2 = m_2 a_2 = m_2 g + F_{t2}$

$\alpha = -\frac{a_1}{r_1} = \frac{a_2}{r_2}$ (the two pulleys have the same ω and α; also, a_1 is negative because m_1 falls).

$a_1 = -\left(\frac{r_1}{r_2}\right) a_2$

③ $a_1 = -3 a_2$

$I_{pulleys} = \frac{1}{2} m_4 r_1^2$ (I of a disc is $\frac{1}{2} m r^2$.
We only know the I's of a limited number of shapes; the shape of the pulley is closest to the disc.
We cannot take the I of each part of the pulley and add because the pulley is hollowed out.)

$\tau_1 = F_{t1} r_1$

$\tau_2 = F_{t2} r_2$

$\sum \tau = \tau_1 - \tau_2 = I \alpha$

There fore

(4) $F_{t1} r_1 - F_{t2} r_2 = (\frac{1}{2} m_4 r_1)^2 (-\frac{a_1}{r_1})$

We have four equations and four unknowns (a_1, a_2, F_{t1}, F_{t2}). Solving for all 4 equations in my calculator's simultaneous equation solver gives me:

$a_1 = -0.432 \frac{m}{s^2}$

$a_2 = 0.144 \frac{m}{s^2}$

$F_{t1} = 0.187$ N

$F_{t2} = 0.497$ N

Conclusion

$\%\ error = \frac{|theoretical - actual|}{|theoretical|} = \frac{|-0.432 - (-0.399)|}{|-0.432|}$

% error = 7.64 %

Some inaccuracies in our experimental result came about because we could not measure exactly how long it took the mass to fall, given our human reflexes. Unfortunately, the probe/sensor we were given did not work, so we had no alternative.
We also could not find the exact theoretical value of a_1 because we have not learned how to find "I" for any object.