Measurement of ‘g’

Atwood’s Machine

Outline

- Measurement of ‘g’,
  - Early attempts,
  - ‘Dilution’ of Gravity,
  - Atwood’s Machine.
- Present Day equipment,
  - Correction terms,
  - Expressed as a straight line graph.
- Procedure,
  - Starting mechanism,
  - Electrical Connections,
  - Timing Mechanism.

Early attempts

- Galileo 1564-1642
  - born and studied in Pisa
  - professor of mathematics at Padua
  - reputed to have dropped objects off the Leaning Tower.
  - establishing acceleration is independent of the mass.
  - but could not measure it accurately
  - 55m tall $\rightarrow$3.5 seconds to drop

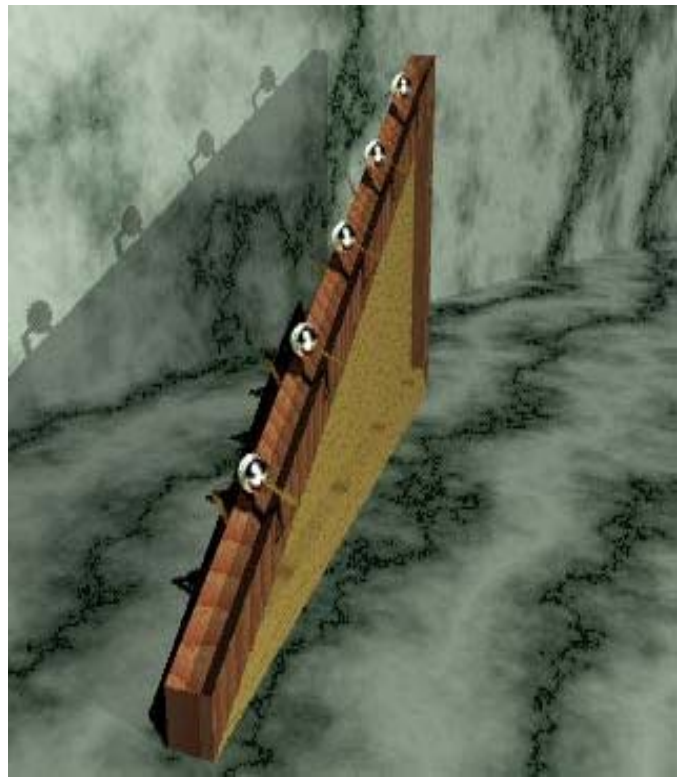
Atwood's Machine

‘Diluting’ Gravity

- To slow down the rate of descent
  - Galileo used an inclined plane,
    - Could then get reasonable accuracy
  - using a ‘water clock’
    - water pouring out of a beaker into a graduated flask.
- Showed that the distance a ball rolls,

$$d = \tfrac{1}{2} a t^2$$

- Still difficult to measure ‘a’ accurately



Atwood's Machine

Atwood's Machine 'dilutes' gravity

- Rev. George Atwood (1746-1807)
  - tutor at Trinity College, Cambridge
- set-up the demonstration experiment that today bears his name.
- used a very light pulley on a light axle
- supported each end of the axle
  - on the rim of two other wheels
  - to reduce friction in the bearings.

$$a = \frac{(m_1 - m_2)}{(m_1 + m_2)} g$$

Dilution factor

Atwood's Machine

Present –day experiment

- Two unequal weights joined by a light inextensible string
- Solenoid magnet and micro-switch used to time the fall (or rise) of the masses.
- Two differences
  - 1) Uses a ‘heavy’ pulley wheel.
  - 2) With friction in the bearings.
- Have to correct for these effects.

Atwood's Machine

Including the correction factors

Correction factors

$$(m_1 - m_2)g - (m_1 + m_2)a = \frac{Ia}{r^2} + \Gamma / r$$

Acceleration found by $a = \frac{2h}{t^2}$

Inertia (I) of heavy pulley,
r is radius of pulley

Friction in the bearings Γ
Expressed as a torque (r x F_f)

Equation of a straight line…..

Plot Δm against $1/t^2$

$$\Delta m = \frac{2h}{g}\left(M + \frac{I}{r^2}\right)\frac{1}{t^2} + \frac{\Gamma}{gr}$$

y = a x + b

a: gradient

b: intercept

Measure t (secs) for different values of Δm

$\Delta m = m_1 - m_2$ (grams)

$M = m_1 + m_2$ (grams)
n.b. hold constant

h is measured (metres) and held constant

$I/r^2 = 80$grams

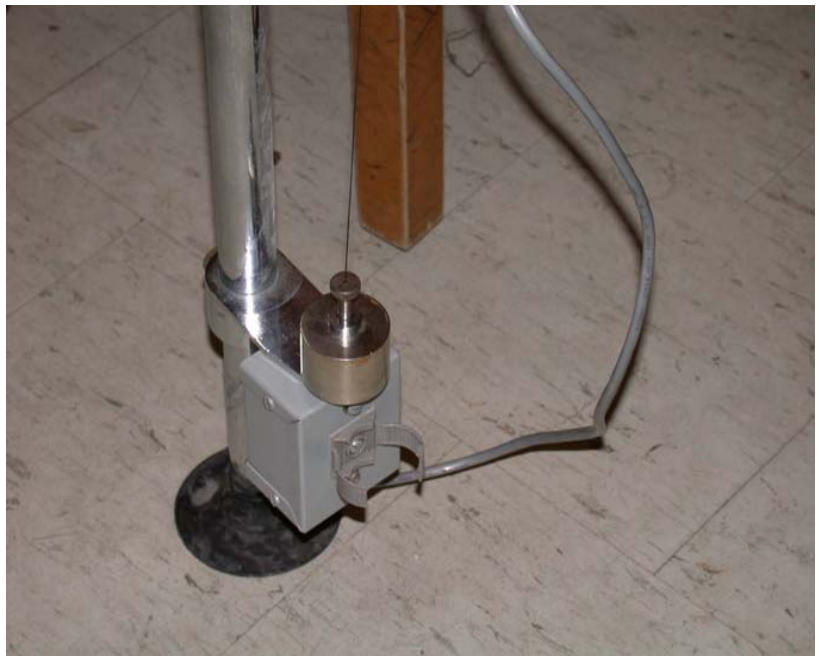
Γ can be found from the intercept

Procedure

- Start by weighing the washers and the weights,
  - all washers plus weights together = M,
  - weigh 10 washers and divide by ten to find average
  - the change, Δm, is twice the weight of one washer.
- Assemble onto the line and fit over pulley,
  - Measure height - h, that mass will rise,
  - Measure radius – r, of pulley (half diameter).
- N.B. when adding or removing washers, rest the other mass on the bench

Starting mechanism

- Electromagnet restrains the weights
  - until you are ready to start timing
  - Press switch to release weights and start the timer.
- N.B. One weight has an iron insert.
  - Make sure it's over the electromagnet,
  - Set this one to be the lighter of the two



Electrical connections

- Plug electromagnet cable (grey) into MAGNET socket of electronic clock,
- N.B. beware of Mains (110v) voltage
  - Don't touch bare wires……
- Connect the brown cable between the micro-switch terminal at the base of the pole, and the EXT.STOP of the electronic clock.
- Solenoid platform should be as low as possible,
- Plug in the micro-switch lead at the top of the pole

Atwood's Machine

Electronic Timing

- Set the clock as follows
  - Set the leftmost switch to ON
  - Set the rightmost switch to EXT.STOP
  - Set the power switch (at side) to ON
  - Reset the clock (electromagnet will be activated)
  - Press the remote switch to start the timer and release the weights
  - Reset clock after each cycle
- N.B. make sure string and weights don't touch the bench or the supports during the movement.

Go to it……..

- Start weighing the masses,
- Assemble the string and pulley
- Make sure the string is long enough
- Measure the distance to rise
- Connect the electrical wires
- Switch on and take a sample measurement,
- Make sure the pulley system doesn’t snag on the bench-top or support pole.

- **The end**