Lecture #5

Forces & Newtons Laws

→ What makes acceleration ?

Forces ~ mass × acceleration

Examples gravity :

Earth

Weight = mg_E

Weight = $m(9.8\,m/s^2)$

= units = Newton

Moon

$g_{moon} =$

Weight $\simeq m\, g_{moon}$
moon

$= m\ 1.2\,m/s^2$

Mass

	Weight on Earth	Weight on Moon
Feather ~ 1 gram	1 gram × $\frac{10\,m}{s^2}$ = 0.01N	1 gram $\left(\frac{1.2m}{s^2}\right)$
2 liter bottle ~ 2 kg	~ 20N	2N
200 lb body → 100 kg	~ 1000 N	100 N

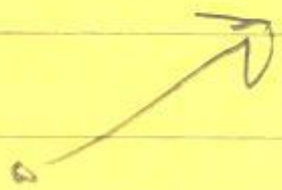
More Examples of Forces

- Electromagnetic ← Chemistry
  ↖ Biology

- Strong Nuclear Force ↙ Nuclear Physics

- Normal Forces:
  - perpendicular to surface
  - molecules are like tiny springs

Forces is a vector:



Newton Laws

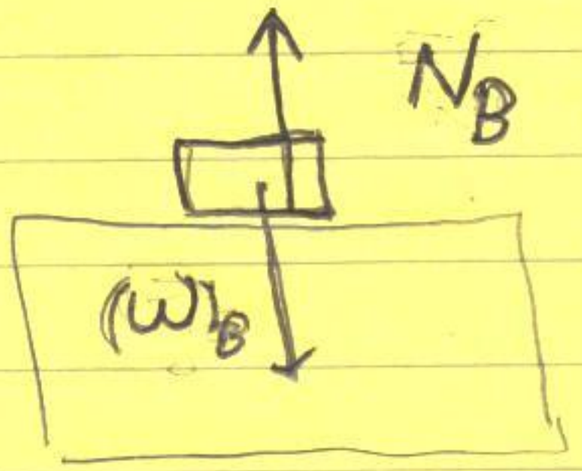
① A Body in motion (or at rest) stays in motion until acted upon by an "external" force

② $\sum \vec{F} = m\vec{a}$

③ For every action there is an opposite and equal reaction

(3)

Book on a table



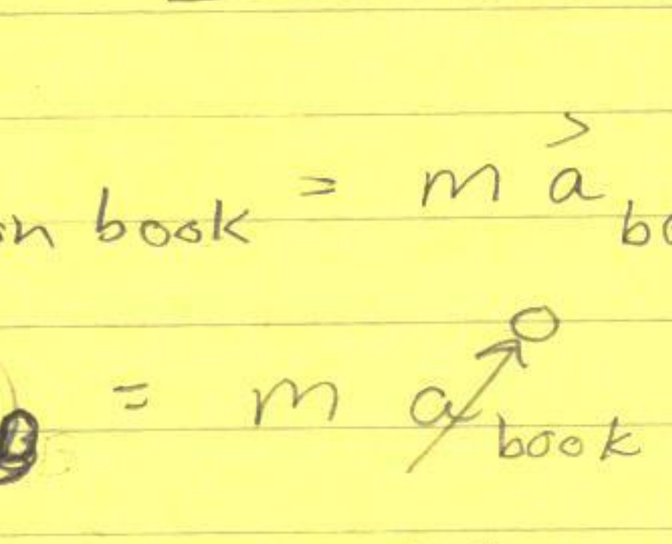
$$\vec{F}_{tot\ on\ book} = m\vec{a}_{book}$$

$$N_B - w_B = m\vec{a}^{\,0}_{book}$$

$$N_B = w_B = m_B g$$

Now:

Look at Table;



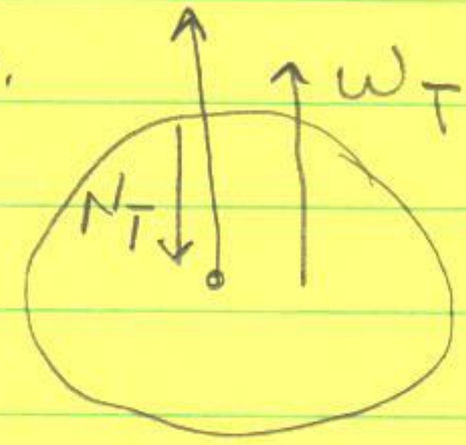
$$-N_B + N_T - w_T = m_{Table}\vec{a}^{\,0}_{Table}$$

$$N_T = w_T + N_B = w_T + w_B$$

Agrees with intuition

Then where is the equal and opposite force to W_B?

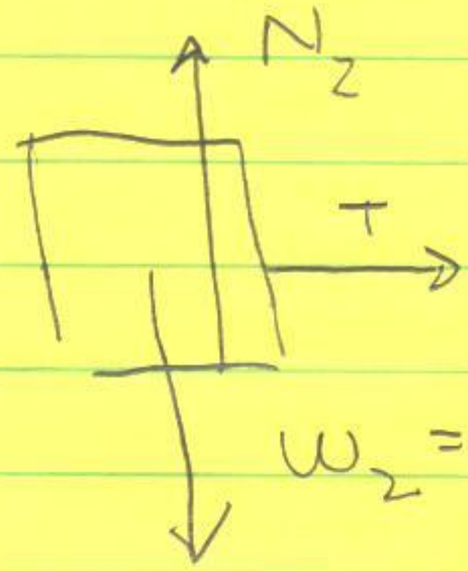
Forces W_B on earth:

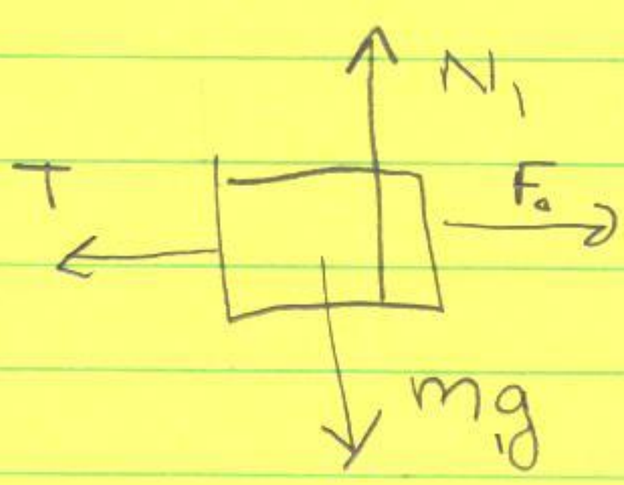


Pulling to blocks

$M = 2kg$ $m = 1kg$

Write Newton Law in all directions





(5)

x] Block 2 Block 1

$$T = M_2 a \qquad -T + F_0 = m_1 a$$

y]

$$N_2 - Mg = \cancel{Ma_y} \qquad N_1 - m_1 g = m_1 \cancel{a_y}$$

$$N_2 = Mg \qquad N_1 = mg$$

Then:

$$\frac{T}{M_2} = a \qquad -T + F_0 = m_1 \frac{T}{M}$$

$$F_0 = \left(\frac{m_1}{M} + 1\right) T$$

$$\frac{F_0}{1 + m_1/M} = T$$

$$a = \frac{1}{M_2} \frac{F_0}{(1 + \frac{m_1}{M})} = \frac{F_0}{M + m_1}$$

$$a = \frac{F_0}{M + m_1}$$

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Why is $a = \frac{F_0}{M+m}$

$$F_{Net} = M_{TOT}\, a_{TOT}$$

$$F_0 = (M+m)\, a$$

$$\boxed{\frac{F_0}{M+m} = a}$$

Dimensionfull analysis

$[F_0] \sim N$

$[M] \sim kg$

$[m] \sim kg$

$T \propto F_0$

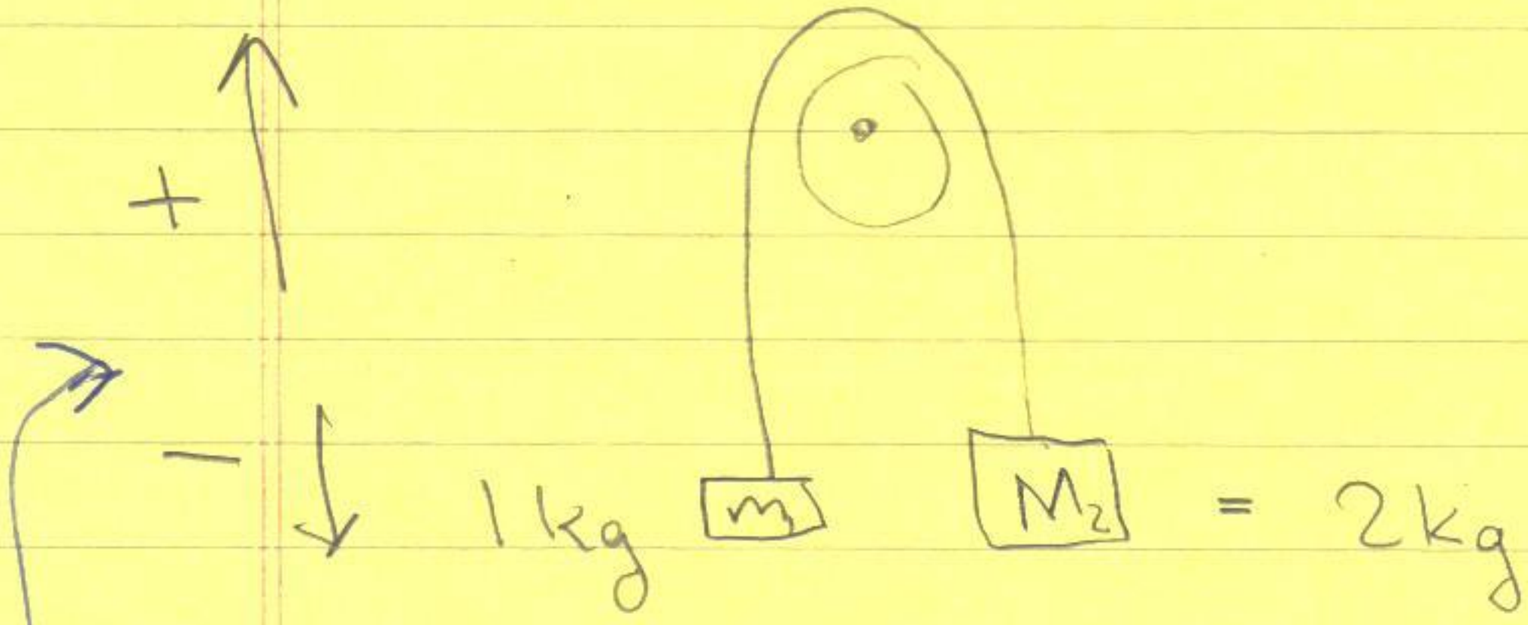
The tension must be proportional to F_0

Dimensionless: $\frac{m}{M}$

$$T = F_0 f\left(\frac{m}{M}\right)$$

(7)

Atwood Machine



Problem

(1) Find The acceleration of the blocks

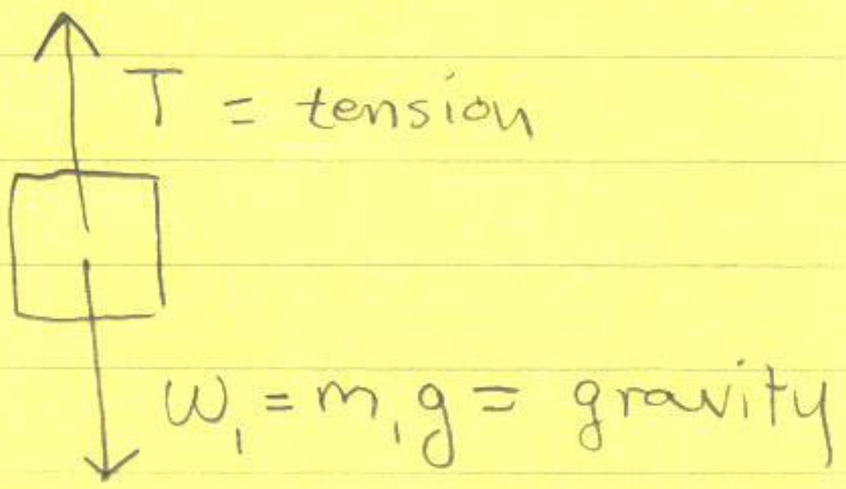
Solution

- Write down Newton's Law for both blocks
- Agree on a coordinate system

Block 1

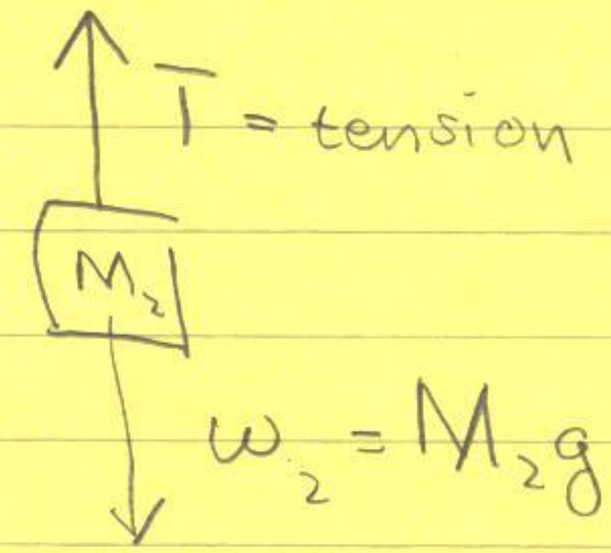
$$\sum F_{net} = m_1 a_1$$

$$T - m_1 g = m_1 a_1 \quad (1)$$



(8)

Block 2



$$+T - M_2 g = M_2 a_2$$

Since they are connected by a rope when block 1 goes up block 2 goes down so

$$\boxed{a_1 = -a_2}$$

We know that block 2 goes down -- a_2 is negative

a_1 = positive

So

Block 2 becomes

$$\boxed{T - M_2 g = -M_2 a_1} \quad (2)$$

We now have two equations and two unknowns T and a_1

From (2) $T = M_2 g - M_2 a_1$

From (1) $M_2 g - M_2 a_1 = m_1 g = m_1 a_1$

$$M_2 g - m_1 g = m_1 a_1 + M_2 a_1$$

$$(M_2 - m_1) g = a (m_1 + M_2)$$

$$\boxed{\left(\frac{M_2 - m_1}{m_1 + m_2}\right) g = a}$$

So then

$$T = M_2 g - M_2 g \left(\frac{M_2 - m_1}{M_2 + m_1} \right)$$

$$T = M_2 g \left(\frac{M_2 + m_1}{M_2 + m_1} - \frac{(M_2 - m_1)}{M_2 + m_1} \right)$$

$$\boxed{T = \frac{2 M_2 m_1}{M_2 + m_1} g}$$

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