How can you determine the mass of a meter stick using only a known mass and your fingers?

Chapter 12 – Rotation of a Rigid Body

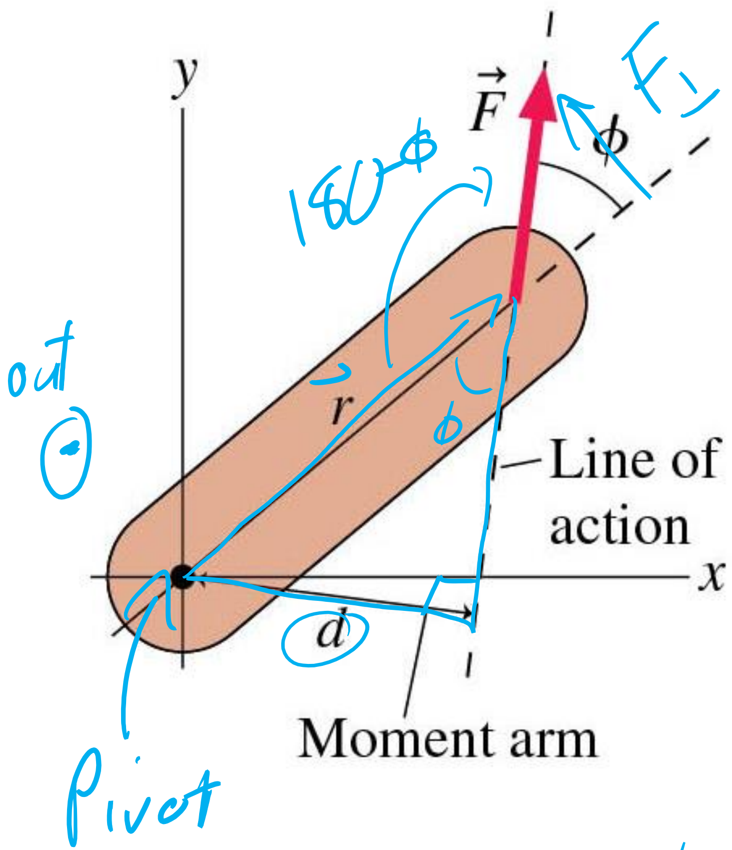
- Centre of mass and moment of inertia
- Torque and cross product
- Rolling motion and rotational energy
- Angular momentum

Torque is the rotational equivalent of force:

$$|\tau| = rF\sin\phi = rF_t = dF$$

The vector description of torque is

$$\vec{\tau} = \vec{r} \times \vec{F}$$



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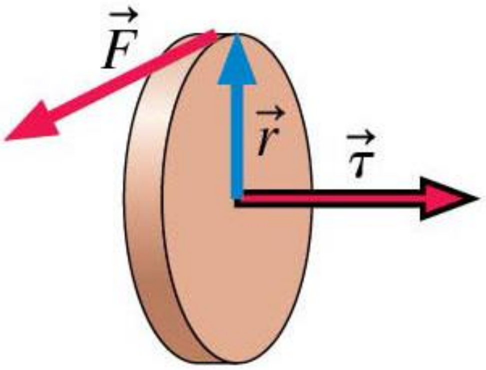


$$\sin\phi = \sin(180-\phi)$$

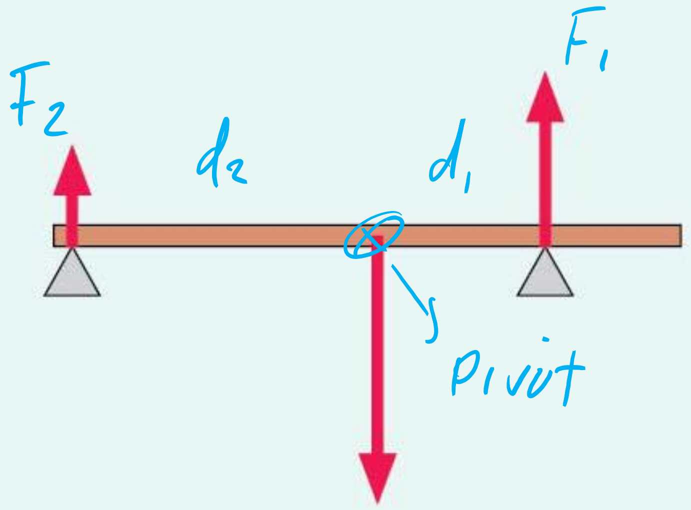
MODEL 12.3

Static equilibrium

For extended objects at rest.

- Model the object as a rigid body with no acceleration.
- Mathematically:
  - No net force: $\vec{F}_{\text{net}} = \sum \vec{F}_i = \vec{0}$, and
  - No net torque: $\tau_{\text{net}} = \sum \tau_i = 0$
- The torque is zero about *every* point, so use any point that is convenient for the pivot point.
- Limitations: Model fails if either the forces or the torques aren't balanced.

$F_2 d_2 = F_1 d_1$



$\vec{a} = \vec{0} \quad \alpha = 0$

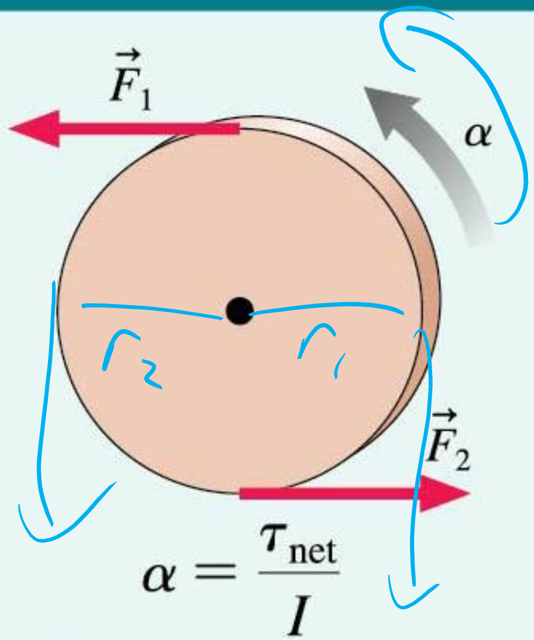
The object is at rest.

MODEL 12.2

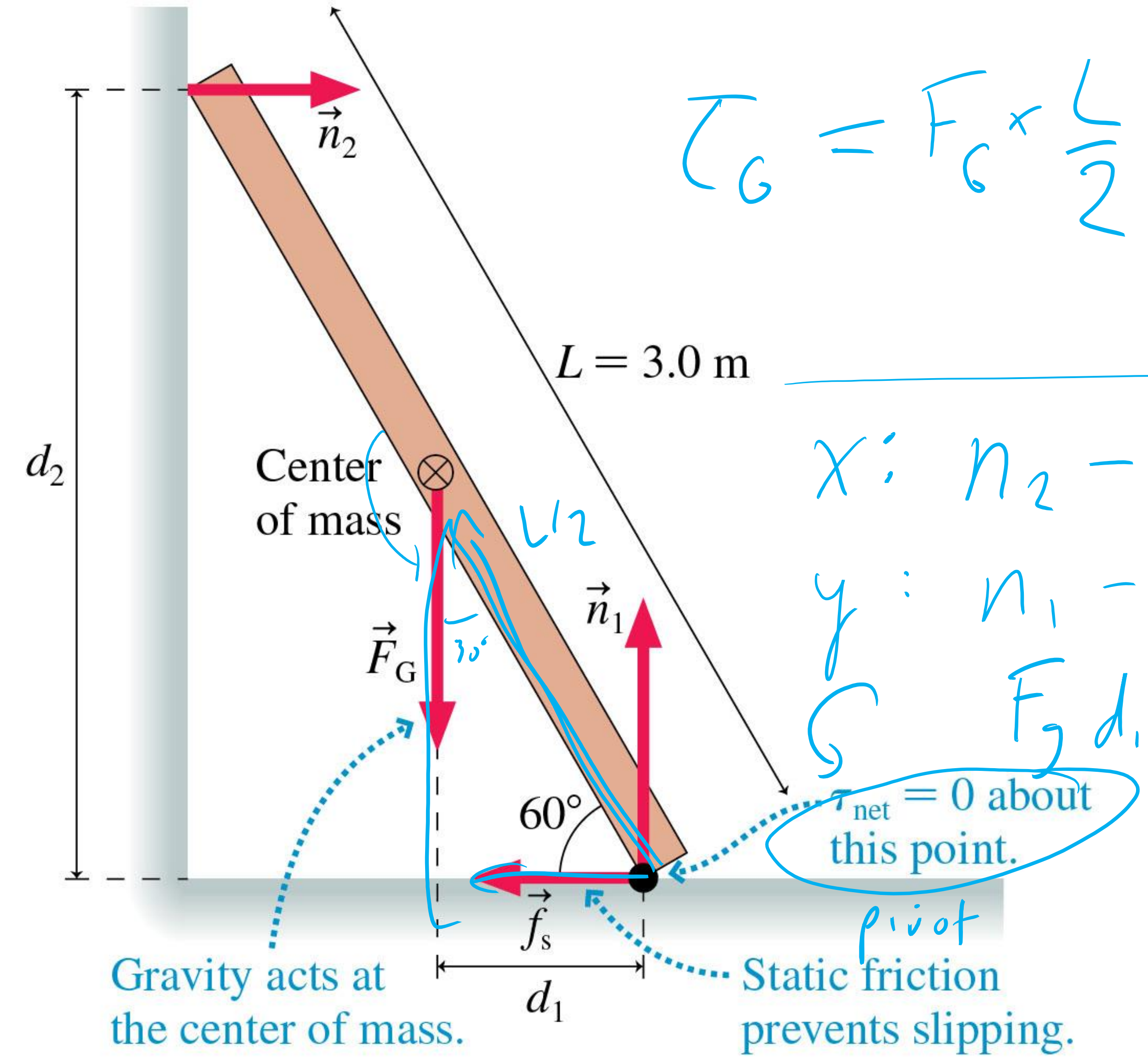
Constant torque

For objects on which the net torque is constant.

- Model the object as a rigid body with constant angular acceleration.
- Take into account constraints due to ropes and pulleys.
- Mathematically: $F = ma$
  - **Newton's second law** is $\tau_{net} = I\alpha$.
  - Use the kinematics of constant angular acceleration.
- Limitations: Model fails if the torque isn't constant.



The object has constant angular acceleration.



$$\tau_G = F_G \times \frac{L}{2} \times \sin(150) = F_G d_1$$

$$d_1 = \frac{L}{2} \cos 60$$

$$x: \quad n_2 - f_s = 0$$

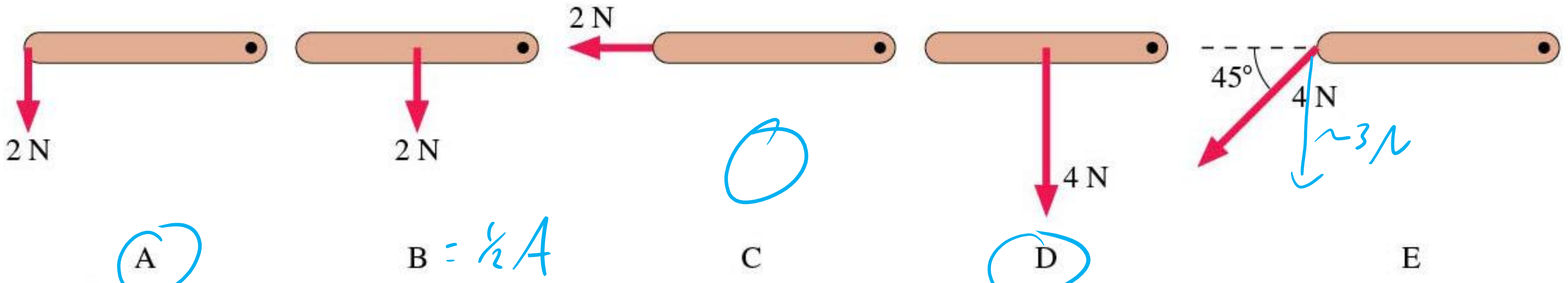
$$y: \quad n_1 - mg = 0$$

$$\circlearrowleft \quad F_g d_1 - n_2 d_2 = 0$$

$$f_s \le \mu n_1$$

Team Up Questions

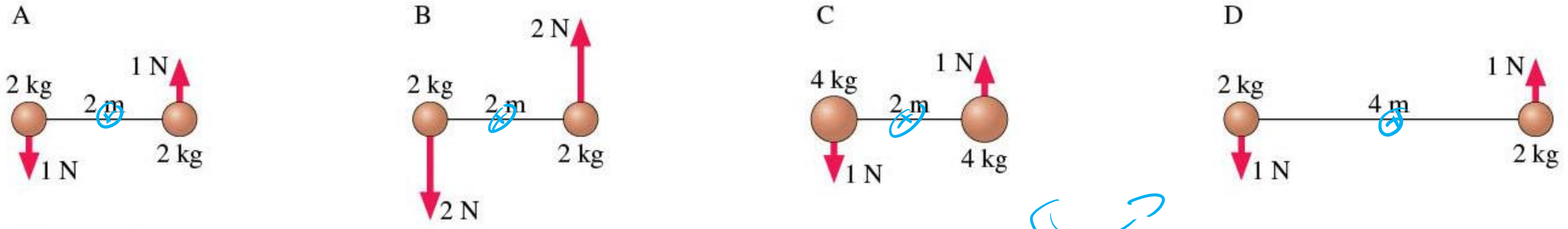
STOP TO THINK 12.4 Rank in order, from largest to smallest, the five torques τ_A to τ_E. The rods all have the same length and are pivoted at the dot.



same

Team Up Questions

STOP TO THINK 12.5 Rank in order, from largest to smallest, the angular accelerations α_A to α_D.



same

Point mass: $I = mr^2$

$2^{kg} \times 2 \times (1)^2$ | same | $4^{kg} \times 2 \times (1)^2$ | $2^{kg} \times 2 \times (2)^2$

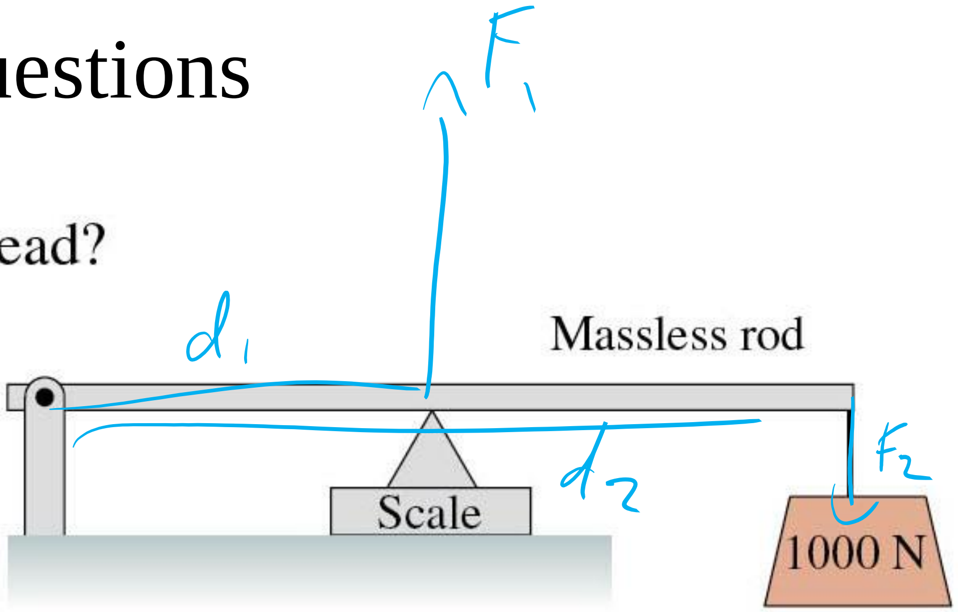
$1N \times 2 \times 1$ | $2N \times 2 \times 1$ | $1N \times 2 \times 1$ | $1N \times 2 \times 2$

$2/4$ | $4/4$ | $2/8 = 1/4$ | $4/16 = 1/4$

Team Up Questions

STOP TO THINK 12.6 What does the scale read?

a. 500 N
b. 1000 N
c. 2000 N
d. 4000 N



$$F_1 d_1 = F_2 d_2$$

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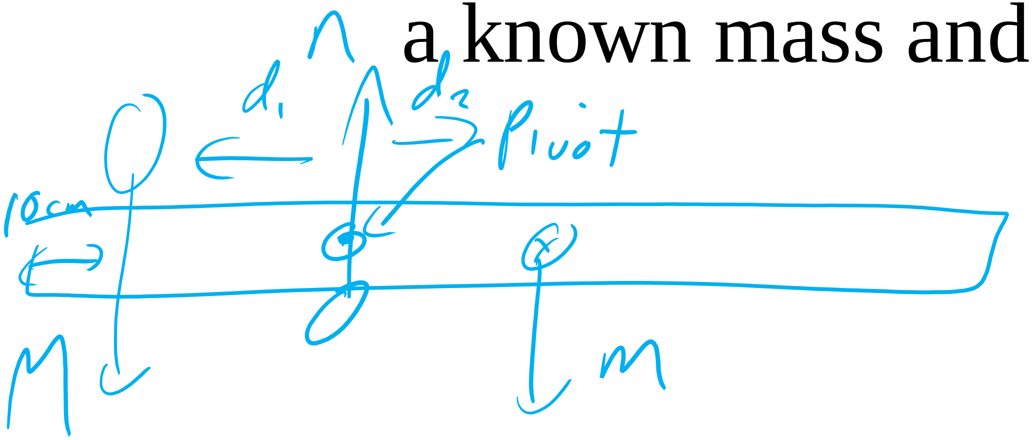


$$d_1 Mg = d_2 mg$$

$$n = (m+M)g$$

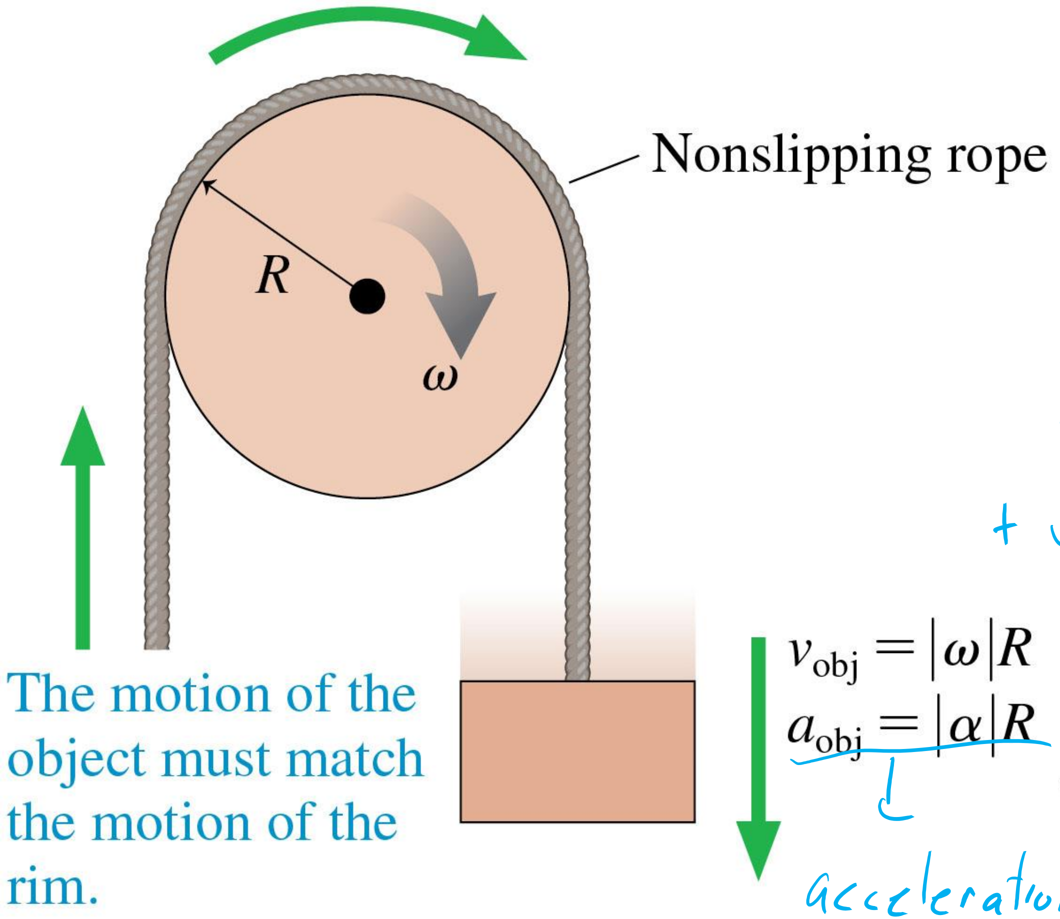
$d_1 = 15cm$

$d_2 = 25cm$

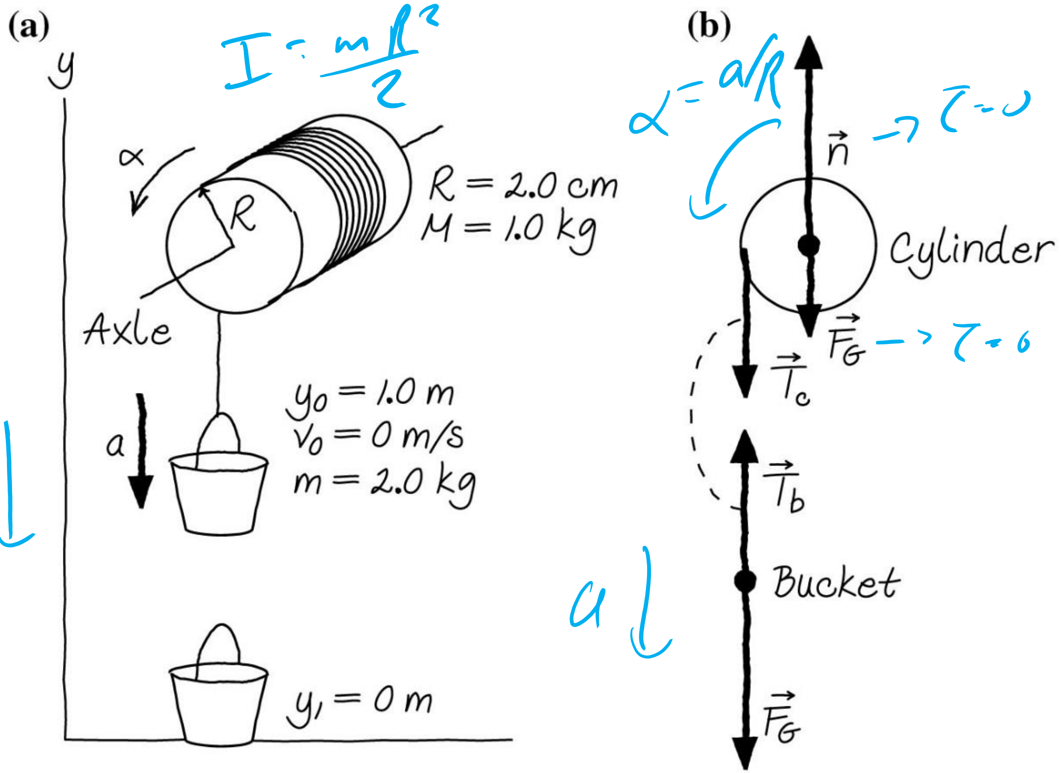
$M = 200g$

$$m = 200g \frac{15}{25}$$

$$m = 120g$$



acceleration constraint



$I = \frac{mR^2}{2}$

$\alpha = a/R$

$+ \downarrow$

$\vec{n} \rightarrow \tau = 0$

$\vec{F}_G \rightarrow \tau = 0$

$a \downarrow$

cylinder $Tr = \tau = I\alpha$

$I = \frac{1}{2} mR^2$

$\alpha = a/R$

bucket $mg - T = ma$