

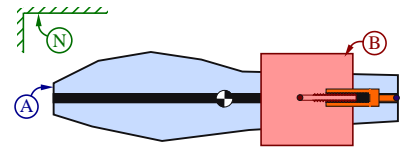
$\vec{F} = m\vec{a}$ FBD, MG road-maps, and concepts for translating mechanical systems.

18.1 Concept: Translational motion? (free-body diagrams)

A rigid body B is connected to a rigid body A with a force actuator (pushes B apart from A). Initially, A and B are **at rest** (stationary) in deep empty space in a Newtonian (inertial) reference frame N .

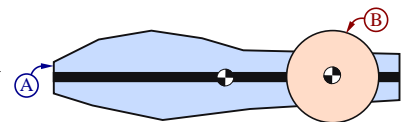
Using physical intuition, guess if the force actuator can move:

• A 's mass center in N ?	Yes/No	<input type="text"/>
• B 's mass center in N ?	Yes/No	<input type="text"/>
• System mass center in N ?	Yes/No	<input type="text"/>

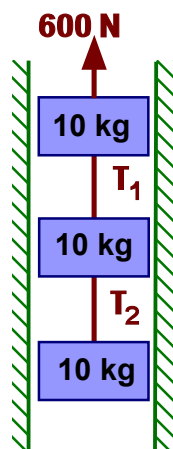


Verify each guess with an equation of motion (3^{rd} -column above).

The previous 3 answers are the **same/different** if B is connected to A with a torque/rotational motor (instead of a force actuator).



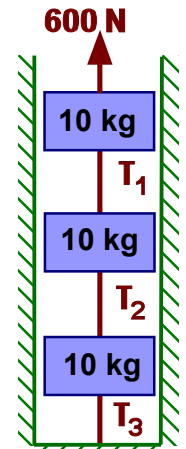
18.2 FE/EIT Review – Tension in vertical ropes (free-body diagrams). $\vec{F} = m\vec{a}$



The figure to the left shows three 10 kg rigid blocks that are in a smooth (**frictionless**) vertical slot. The set of interconnected blocks is pulled vertically-upward with a 600 N force.

Under the figure to the left, circle **True** if the tensions T_i ($i=1, 2$) in the light (massless) inextensible ropes are equal. Otherwise, circle **False** and report numerical values for T_1 and T_2 below. Approximate Earth's gravitational acceleration as $g = 10 \frac{m}{s^2}$.

Repeat this analysis when the same set blocks has its bottom-most block fastened to a rigid floor (shown to the right).



$T_1 = T_2$
True/False

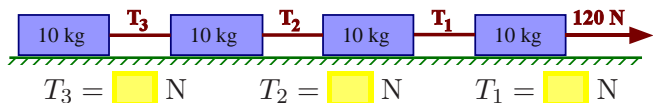
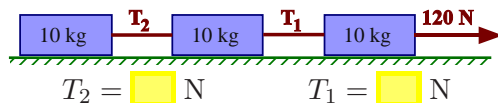
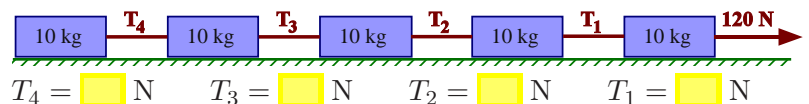
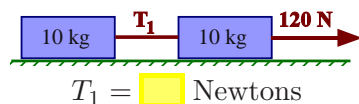
If False for left system:
 $T_1 = \text{[]} \text{ N}$ $T_2 = \text{[]} \text{ N}$

If False for right system:
 $T_1 = \text{[]} \text{ N}$ $T_2 = \text{[]} \text{ N}$

$T_1 = T_2 = T_3$
True/False

18.3 FE/EIT Review – Tension in horizontal ropes (free-body diagrams). $\vec{F} = m\vec{a}$

The following figures show rigid blocks, each of mass 10 kg, that are in contact with a smooth (**frictionless**) flat horizontal Newtonian reference frame. Each set of interconnected blocks is pulled horizontally-right with 120 Newtons. Using **free-body diagrams**, determine the tension T_i ($i = 1, 2, \dots$) in each light inextensible ropes connecting the blocks.



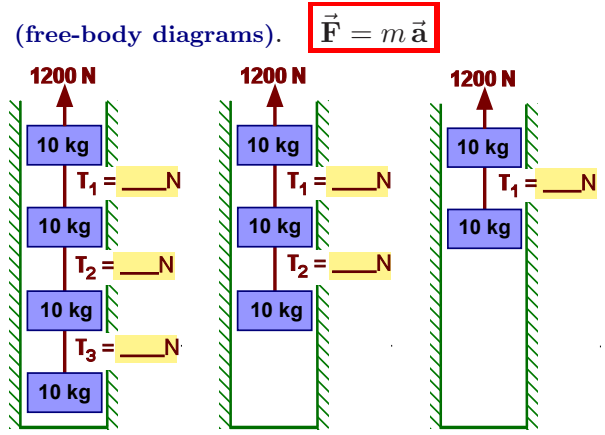
Hint: Consider **MG road-maps** and first calculate system center of mass acceleration, then T_1 , then T_2 , etc.

18.4 FE/EIT Review – Tension in vertical ropes (free-body diagrams). $\vec{F} = m\vec{a}$

The figures to the right show 10 kg rigid blocks that are in smooth vertical slots on Earth (a Newtonian reference frame) whose gravity $g \approx 10 \frac{m}{s^2}$.

Each set of interconnected blocks is pulled vertically-upward with 1200 Newtons.

Using *free-body diagrams*,^a determine the tension T_i ($i = 1, 2, 3$) in the light inextensible ropes connecting the blocks.



^aThe **choice** of *free-body diagrams* is non-unique. Certain **choices** are computationally advantageous. *Free-body diagrams* (also called *free-system diagrams*) may be a collection of bodies/objects (not just one body).

Using **your free-body diagrams** for the left-most set of blocks, cast your equations into matrix form.

Note: The result depends on your **choice** of *free-body diagrams*. The results shown right used *MG road-maps*.

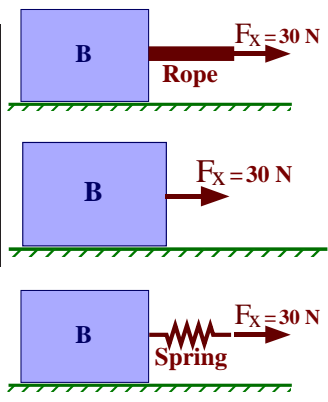
$$\begin{bmatrix} 40 & 0 & 0 & 0 \\ 30 & -1 & 0 & 0 \\ 20 & 0 & -1 & 0 \\ 10 & 0 & 0 & -1 \end{bmatrix} \begin{bmatrix} \ddot{y} \\ T_1 \\ T_2 \\ T_3 \end{bmatrix} = \begin{bmatrix} 800 \\ -300 \\ -200 \\ -100 \end{bmatrix}$$

18.5 † Force transmitted through a rope or spring (free-body diagrams). $\vec{F} = m\vec{a}$

The following figure shows an inextensible rope attached to a metallic particle B that is in contact with a **rough** flat horizontal magnetic table (a Newtonian reference frame). A horizontal force with measure $F_x = 30$ Newtons is applied to the distal end of the rope. **Ignore gravity** in this analysis.

For each analysis, below decide whether it makes a difference to the block's motion or forces if F_x acts through the rope (top-right figure) or directly on B (bottom-right figure). **CIRCLE** Yes or No.

Mass of rope	Static/dynamic analysis	Makes a difference?
Massless	B and rope are stationary (statics)	Yes/No
Massive	B and rope are stationary (statics)	Yes/No
Massless	B and rope translate right at same constant speed	Yes/No
Massive	B and rope translate right at same constant speed	Yes/No
Massless	B and rope translate right at variable speeds	Yes/No
Massive	B and rope translate right at variable speeds	Yes/No



Shown right is a similar system, with the rope replaced by a **spring**.

Reconsider the previous question, except now **BOX** Yes or No.

Draw free-body diagram(s) and explain your spring answer.

Explain:

Draw Free Body Diagrams (FBD) with:

- Physical object(s) in system
- Forces (contact & distance)

Knowing the block's mass is 5 kg, the rope's mass is 1 kg, $F_x = 30$ N, and the block is initially at rest, calculate the magnitude of the block's velocity relative to the table at $t = 4$ seconds.

Result: $|\vec{v}(t = 4)| = \text{[]} \frac{m}{s}$ (For this result only, assume the surface is frictionless).