Practice – Mechanical Equilibrium

Read through the example below, then answer the questions that follow showing all work as taught in class.

Example: A painter stands off center towards a board's right end. The board is suspended at the ends by two vertical ropes. The painter and the board are in mechanical equilibrium. The tension in the left rope is 250 N, the painter weighs 500 N, and the board weighs 100 N. What is the tension in the right rope?

Step 1: Read and Understand

What information is given? Drawing a picture here can be helpful.

Tension in rope 1 = T_1 = 250 N
Weight of painter = W_1 = 500N
Weight of board = W_2 = 100 N

Step 2: Plan and Solve

What unknown are you trying to calculate?

Tension in rope 2 = T_2 = ?

What mathematical equation can you use to calculate the unknown?

$\Sigma F = 0$

Determine the directions of all force and consider the signs ("+" or "-") you will give each value.

T_1 is up T_2 is up W_1 is down W_2 is down

Calculate the sum of the forces, being careful to use the correct signs.

$\Sigma F = 0$
$T_1 + T_2 + W_1 + W_2 = 0$
$T_2 = -W_1 - W_2 - T_1$
$T_2 = -(-500\ N) - (-100\ N) - 250\ N$
$T_2 = 350$

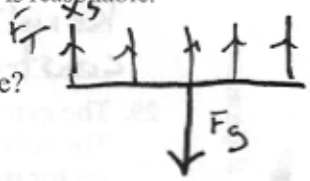
Step 3: Look Back and Check

Is you answer reasonable?

The sum of the upward forces is 600 N and the sum of the downward forces is 600 N. The answer is reasonable.

Answer the following, showing all work.

1. Five vertical ropes hold up a board that weighs 300 N. What is the tension in each rope?

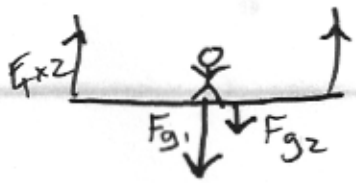


$\Sigma F = 0$
$5F_T + F_g = 0$
$\frac{5F_T}{5} = \frac{-F_g}{5}$
$F_T = \frac{-F_g}{5}$

$F_T = ?$
$F_g = -300N$

$F_T = \frac{-F_g}{5}$
$= \frac{-(-300N)}{5} = \boxed{60N}$

2. Suppose a painter weighing 800 N stands in the center of a board suspended by two vertical ropes. If the weight of the board is 180 N, what is the tension in each rope?



$\Sigma F = 0$
$2F_T + F_{g1} + F_{g2} = 0$
$\frac{2F_T}{2} = \frac{-F_{g1} - F_{g2}}{2}$
$F_T = \frac{-F_{g1} - F_{g2}}{2}$

$F_T = ?$
$F_{g1} = -800N$
$F_{g2} = -180N$

$F_T = \frac{-(-800N) - (-180N)}{2} = \frac{980}{2} = \boxed{490N}$

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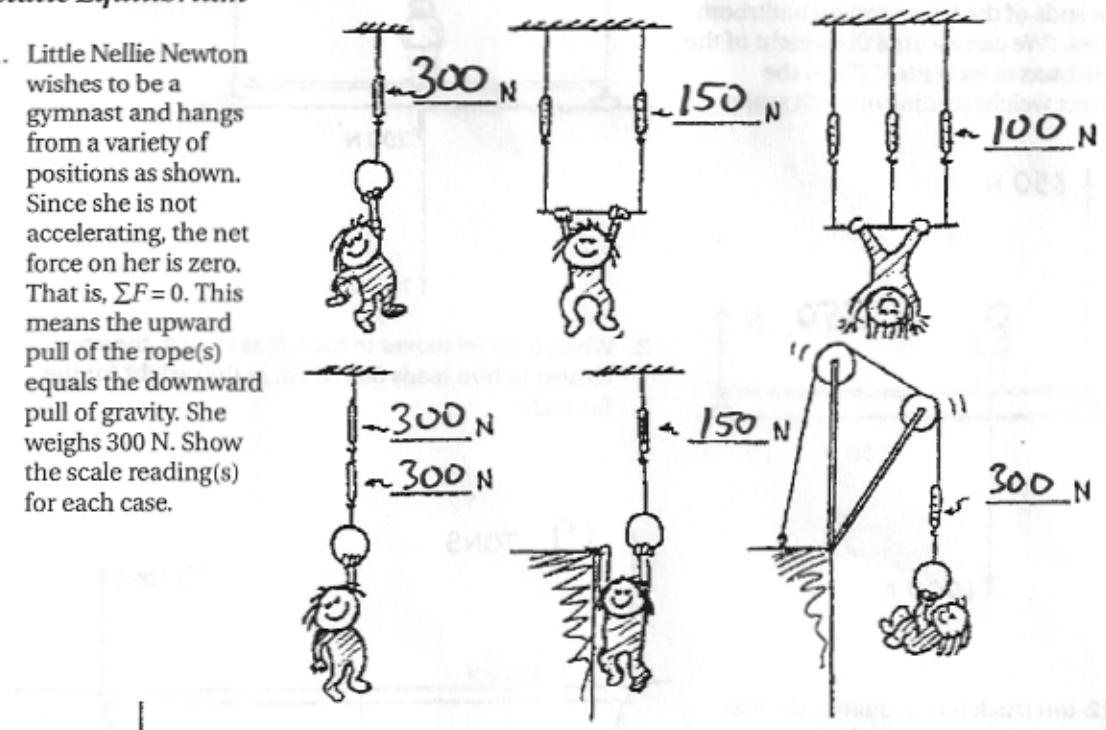
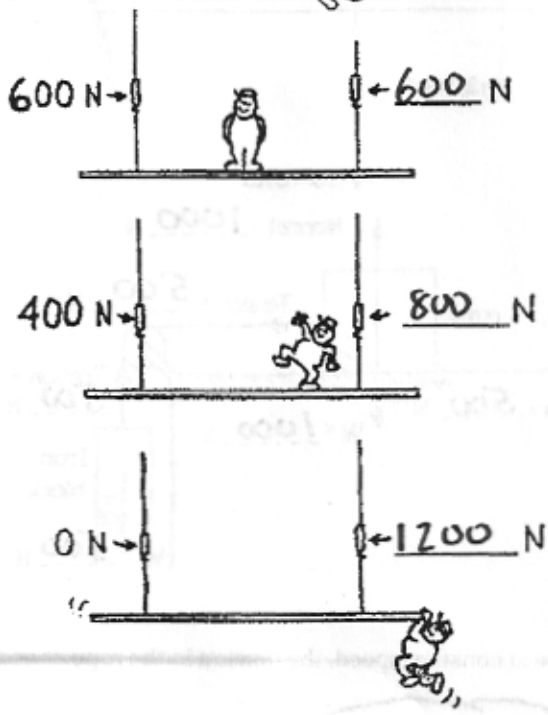
Static Equilibrium

1. Little Nellie Newton wishes to be a gymnast and hangs from a variety of positions as shown. Since she is not accelerating, the net force on her is zero. That is, $\Sigma F = 0$. This means the upward pull of the rope(s) equals the downward pull of gravity. She weighs 300 N. Show the scale reading(s) for each case.





2. When Burl the painter stands in the exact middle of his staging, the left scale reads 600 N. Fill in the reading on the right scale. The total weight of Burl and staging must be 1200 N.

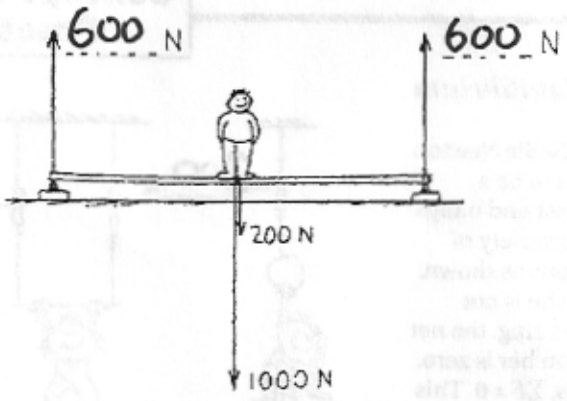
3. Burl stands farther from the left. Fill in the reading on the right scale.

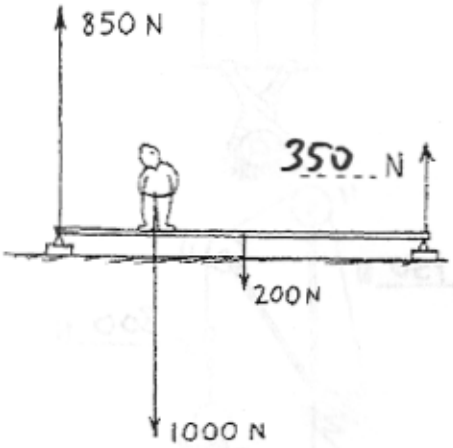
4. In a silly mood, Burl dangles from the right end. Fill in the reading on the right scale.

CONCEPTUAL PHYSICS

The Equilibrium Rule: $\Sigma F = 0$

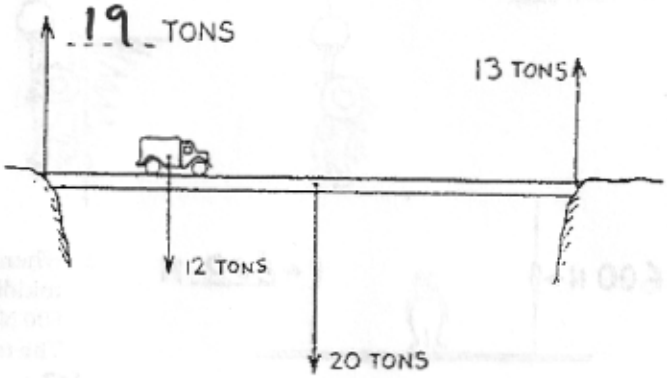
1. Manuel weighs 1000 N and stands in the middle of a board that weighs 200 N. The ends of the board rest on bathroom scales. (We can assume the weight of the board acts at its center.) Fill in the correct weight reading on each scale.



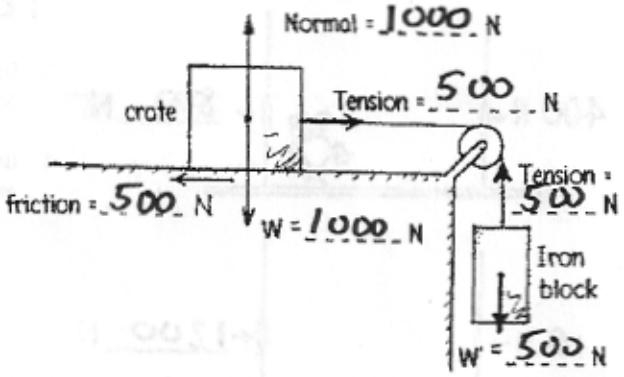


2. When Manuel moves to the left as shown, the scale closest to him reads 850 N. Fill in the weight for the far scale.

3. A 12-ton truck is one-quarter the way across a bridge that weighs 20 tons. A 13-ton force supports the right side of the bridge as shown. How much support force is on the left side?



4. A 1000-N crate resting on a surface is connected to a 500-N block through a frictionless pulley as shown. Friction between the crate and surface is enough to keep the system at rest. The arrows show the forces that act on the crate and the block. Fill in the magnitude of each force.



5. If the crate and block in the preceding question move at constant speed, the tension in the rope (is the same) (increases) (decreases).
The sliding system is then in (static equilibrium) (dynamic equilibrium)

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Vectors and Equilibrium

1. Nellie Newton dangles from a vertical rope in equilibrium: $\Sigma F = 0$. The tension in the rope (upward vector) has the same magnitude as the downward pull of gravity (downward vector).

2. Nellie is supported by two vertical ropes. Draw tension vectors to scale along the direction of each rope.

3. This time the vertical ropes have different lengths. Draw tension vectors to scale for each of the two ropes.

4. Nellie is supported by three vertical ropes that are equally taut but have different lengths. Again, draw tension vectors to scale for each of the three ropes.

Circle the correct answers.

5. We see that tension in a rope is (dependent on) (independent of) the length of the rope. So the length of a vector representing rope tension is (dependent on) (independent of) the length of the rope.

CONCEPTUAL PHYSICS