a place of mind

FACULTY OF EDUCATION

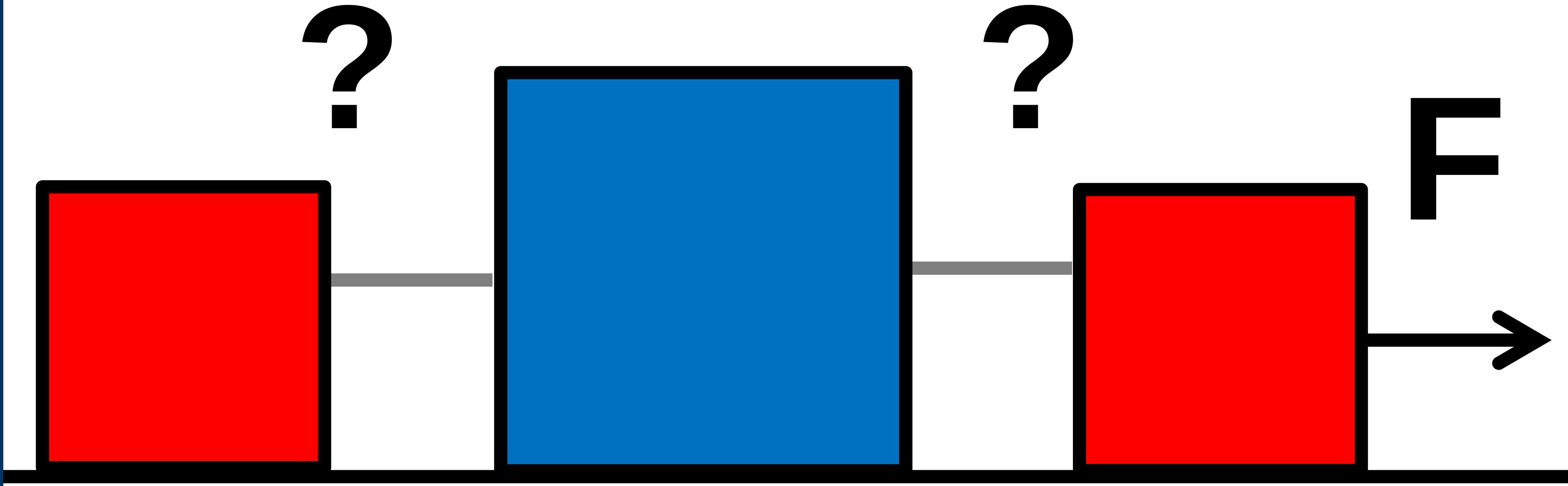
Department of
Curriculum and Pedagogy

Physics
Forces: Tension

Science and Mathematics
Education Research Group

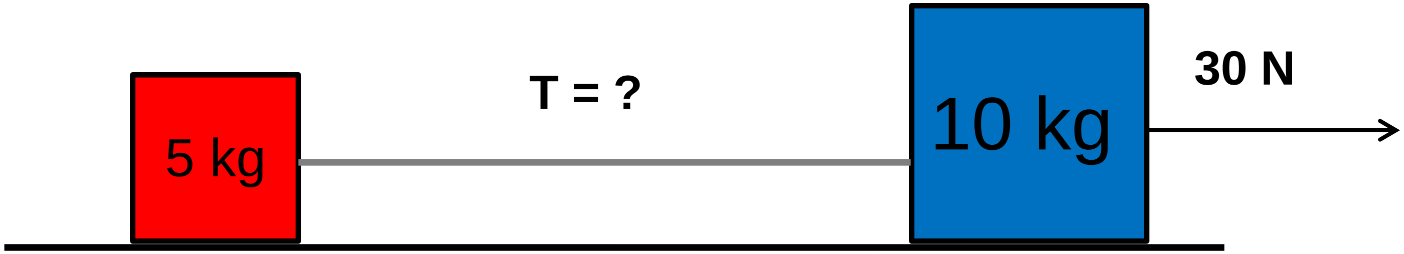
Supported by UBC Teaching and Learning Enhancement Fund 2012-2013

Tension Forces



Tension Forces I

Two masses on a frictionless table are connected by a string with negligible mass. The 10 kg mass is pulled with a force of 30 N to the right. What is the tension in the string?



A. 0 N

B. 5 N

C. 10 N

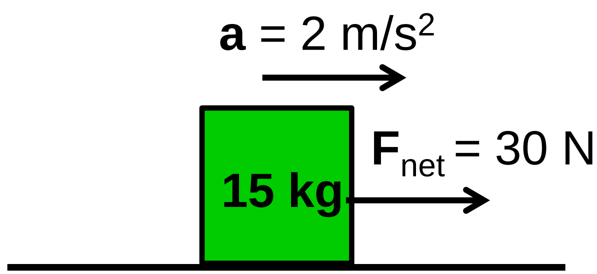
D. 15 N

E. 30 N

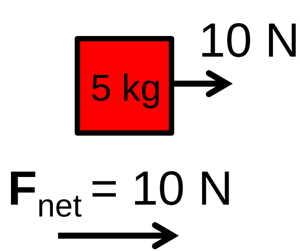
Solution

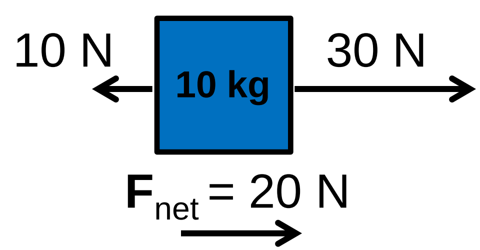
Answer: C

Justification: The two masses can be treated as a single 15 kg mass. From **F** = m**a**, the acceleration of the two blocks must be 2 m/s.



In order for the 10 kg to accelerate at 2 m/s^2, it must experience a net force of 20 N (a 10 N force must pull the block left). The 5 kg block must experience a net force of 10 N (a 10 N force must pull the block right). Notice that the 10 N tension force satisfies both conditions.

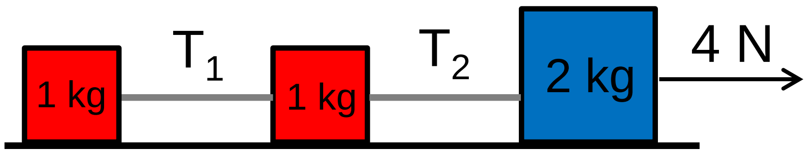




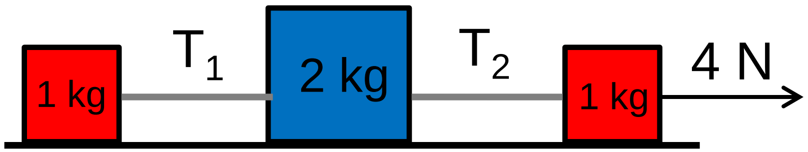
Tension Forces II

Three blocks on a frictionless table are connected by two strings with negligible mass. Which arrangement will minimize the tension in the two strings (minimize $T_1 + T_2$)?

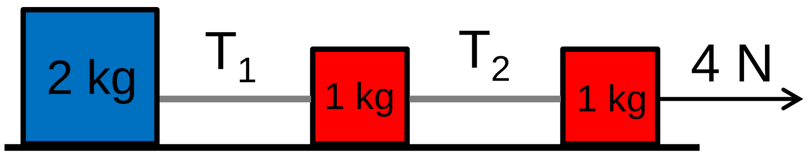
A.



B.



C.



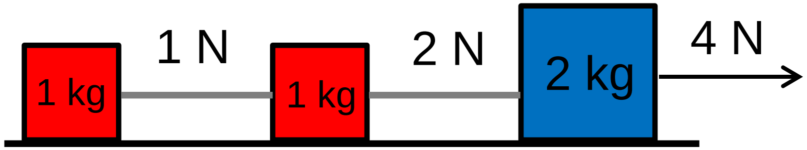
D. $T_1 + T_2$ is the same in all three cases

Solution

Answer: A

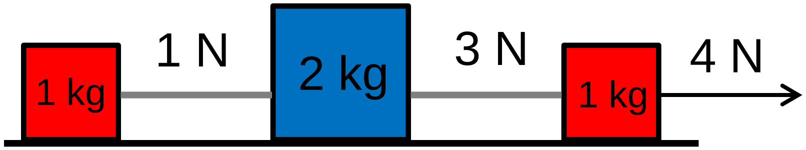
Justification: The string of blocks will be accelerating at 1 m/s^2. Therefore, the 2 kg block must experience a net force of 2 N, while the 1 kg blocks experience 1 N.

A.



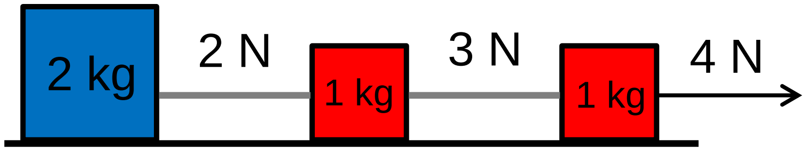
$T_1 + T_2 = 3$ N

B.



$T_1 + T_2 = 4$ N

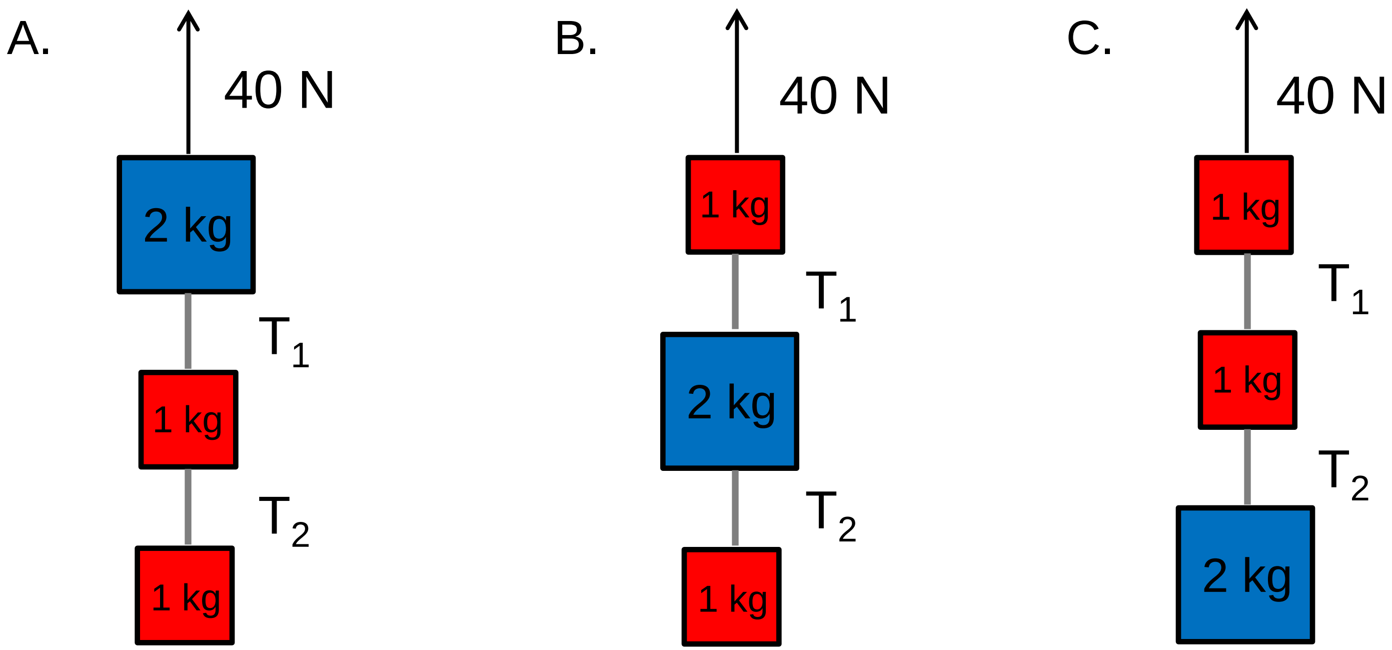
C.



$T_1 + T_2 = 5$ N

Tension Forces III

The three blocks are now arranged vertically as shown. A 40 N force is applied to the top block to prevent the blocks from falling. Which arrangement will minimize the tension in the two strings (minimize $T_1 + T_2$)? (Assume $g = 10\ m/s^2$)

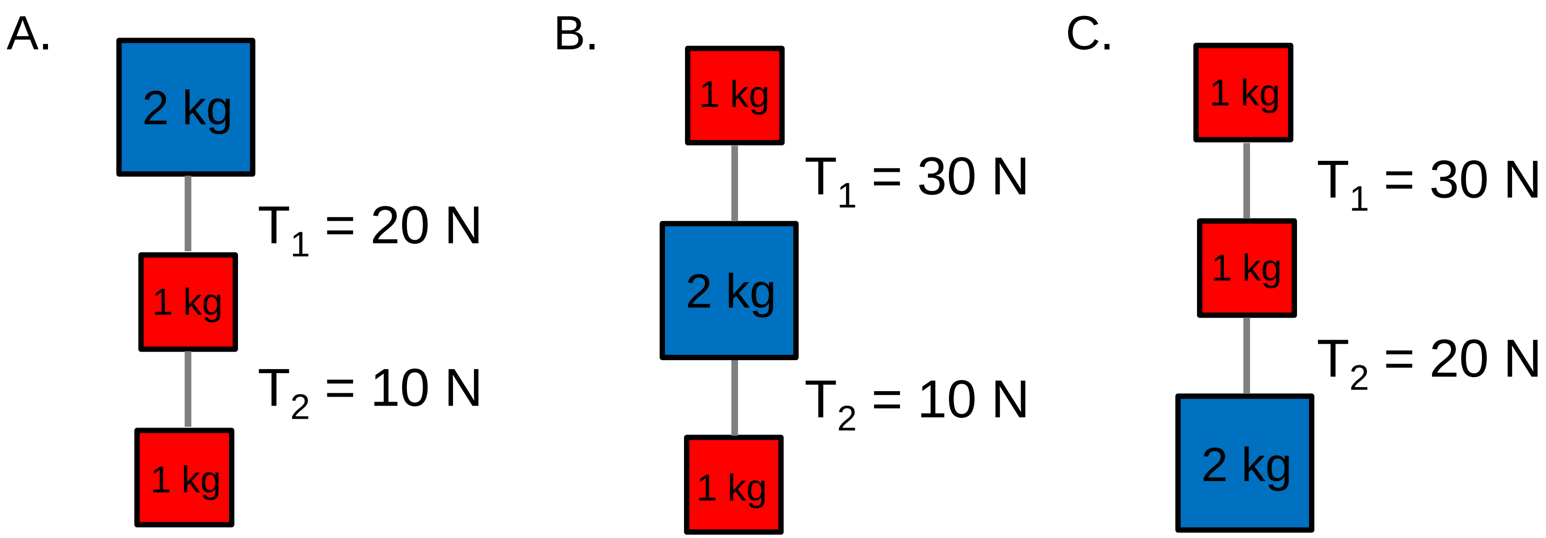


D. $T_1 + T_2$ is the same in all three cases

Solution

Answer: A

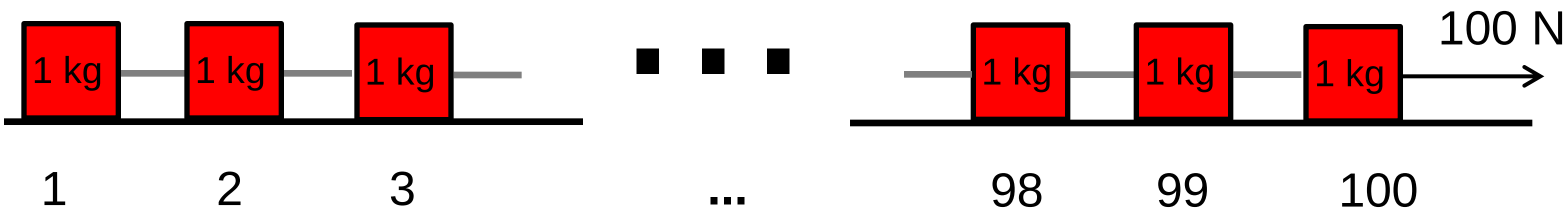
Justification: When the 2 kg block is on top, there is less tension in the strings below it. The tension of a string only depends on the mass of the blocks below it. The net force on each of the small blocks is 10 N, and 20 N on the larger block.



$\mathbf{T_1 + T_2 = 30\ N}$ $\mathbf{T_1 + T_2 = 40\ N}$ $\mathbf{T_1 + T_2 = 50\ N}$

Tension Forces IV

A hundred 1 kg masses are strung together on a frictionless table. A force of 100 N is applied to the last mass. What is the tension in the string connecting the 49^{th} block to the 50^{th} block?



A. 1 N

B. 49 N

C. 50 N

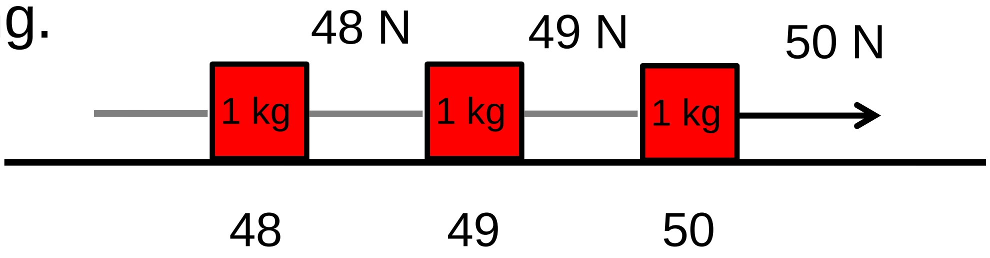
D. 51 N

E. 100 N

Solution

Answer: B

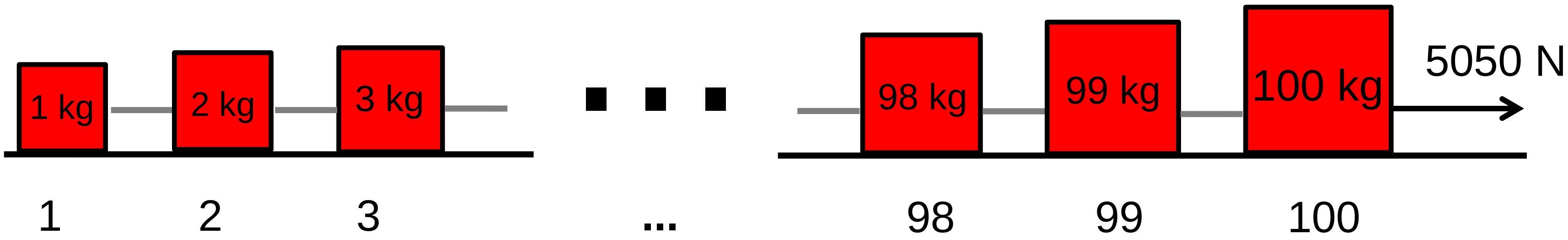
Justification: Treat the one hundred 1 kg masses as a single 100 kg mass. The 100 kg mass will accelerate 1 m/s^2 due to the 100 N force acting on it. Since all the pieces are connected, every 1 kg piece will accelerate at 1 m/s^2. In order for a 1 kg mass to accelerate at 1 m/s^2, it must experience a net force of 1 N. The tension in a string must therefore be 1 N higher than the previous string.



Notice that the net force on the n^{th} block is $\mathbf{F}_n = n - (n - 1) = 1$ N.

Tension Forces V

One hundred blocks are strung together on a frictionless table. The n^{th} block in the chain has a mass of n kg. A force of 5050 N is applied to the last block. What is the tension in the string connecting the 49^{th} block to the 50^{th} block?



A. 49 N

B. 50 N

C. 1225 N

D. 1275 N

E. 3825 N

Solution

Answer: C

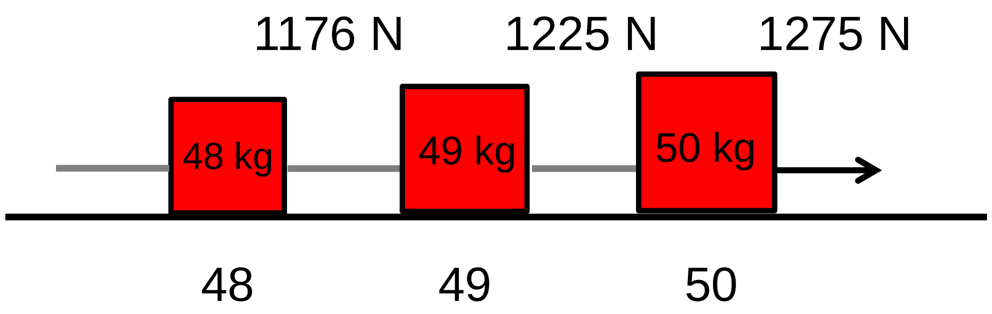
Justification: Treat the one hundred masses as a single 5050 kg block.

$$S_{100} = \frac{100(1+100)}{2} = 5050$$

Since 5050 N is applied to this 5050 kg block, every piece accelerates at 1 m/s^2. Thus every piece must experience a net force equal to its mass. Using the following property of summations:

$$S_n - S_{n-1} = n$$

$$S_{49} - S_{48} = 1225 - 1176 = 49\,\text{N}$$



Tension Forces VI

The three blocks are now placed on a table **with friction** and pulled with a force of 6 N as shown in the diagrams. The table now applies a friction force of 2 N on the blocks. In the scenario below, what are the tensions in each string?

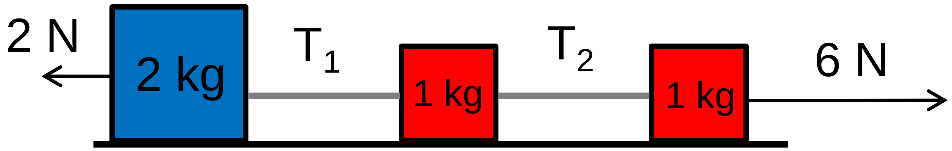
A. T_1 = 2 N and T_2 = 3 N

B. T_1 = 5 N and T_2 = 4 N

C. T_1 = 4 N and T_2 = 5 N

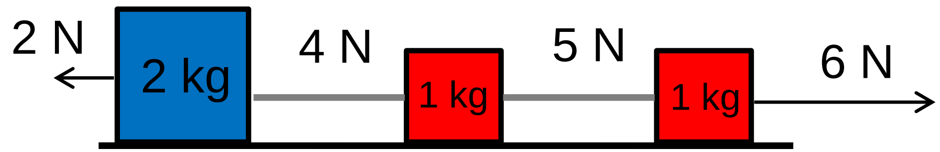
D. T_1 = 4 N and T_2 = 7 N

E. T_1 = 4 N and T_2 = 3 N

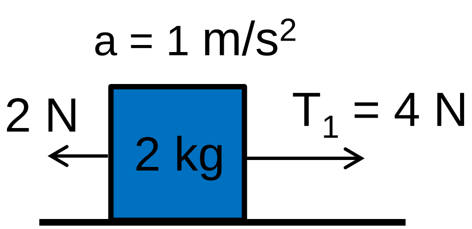


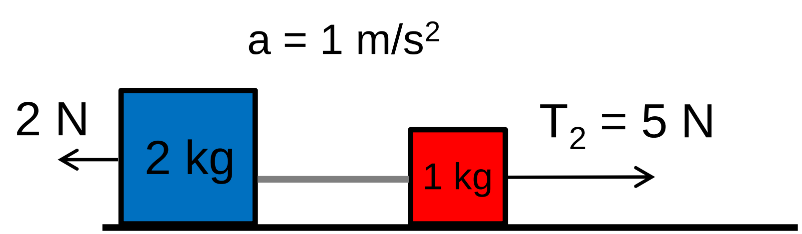
Solution

Answer: C



Justification: Treat the 3 blocks as one unit and use the net force to determine that the blocks will have an acceleration of 1 m/s^2. The individual tensions can be calculated by writing out a net force equation for the different systems of blocks, and then using the net force to solve for the unknown tension.





$F_{net} = ma = 2\text{ N}$
$F_{net} = T_1 - (2\text{ N})$
$T_1 = 4\text{ N}$

$F_{net} = ma = 3\text{ N}$ *treat as a single 3 kg block*
$F_{net} = T_2 - (2\text{ N})$
$T_2 = 5\text{ N}$