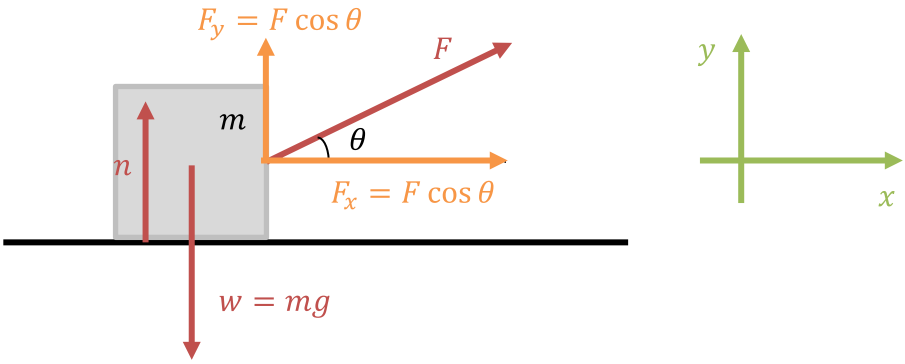
Problem 1.

a) We draw a sketch of the forces and the chosen coordinate system. We also sketch the x- and y-components of the applied force F



Here it should be emphasized that the normal force n is not equal to the weight w, as the force F has a y-component.

b) We write Newtons 2. law in the x-direction:

N2(x): $$ma = F_x = F\cos\theta \Leftrightarrow$$

$$a = \frac{F}{m}\cos\theta$$

c) We determine the normal force by setting up Newton's second law in the y-direction. In this direction the acceleration is zero, as the block is not moving in this direction.

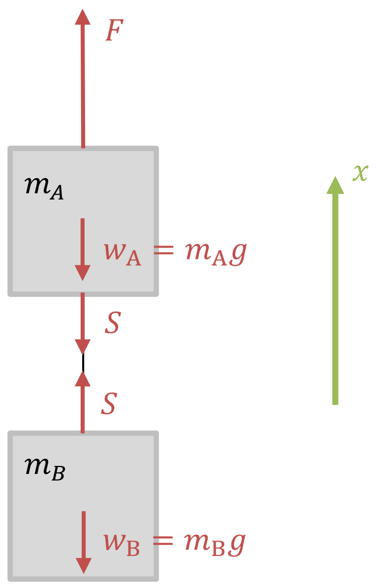
N2(y): $$0 = n - mg + F_y = n - mg + F\sin\theta \Leftrightarrow$$

$$n = mg - F\sin\theta$$

Note that if F becomes too large, the block will accelerate upwards, losing contact with the surface.

Problem 2.

We draw a sketch with the forces and the coordinate system.



a) We consider the forces on both blocks in the x-direction:

N2(A+B, x): $(m_A + m_B)a = -w_B + S - S - w_A + F \Leftrightarrow$

$$(m_A + m_B)a = F - (m_A + m_B)g \Leftrightarrow$$

$$a = \frac{F}{m_A + m_B} - g$$

b) We set up Newton's 2. law for block B.

N2(B, x): $m_B a = S - m_B g$

By inserting the solution for the acceleration in question a), we obtain the solution:

$$m_B\left(\frac{F}{m_A + m_B} - g\right) = S - m_B g \Leftrightarrow$$

$$\frac{m_B F}{m_A + m_B} - m_B g = S - m_B g \Leftrightarrow$$

$$S = \frac{m_B}{m_A + m_B} F$$

Notice that this question could also be solved by considering block A instead of block B.

c) By inserting the values of $F = 30.0\ \mathrm{N}$, $m_A = 3.00\ \mathrm{kg}$ og $m_B = 2.00\ \mathrm{kg}$ in the expression for the acceleration, we determine its value.

$$a = -3.82\ \mathrm{m/s^2}$$

Problem 3.

a) The sum of the forces is equal to mass times acceleration by Newton's second law.

$$\sum F = ma$$

The acceleration is given by the slope of the tangent on the $v - t$ graph. The maximum slope is within the interval $6 - 10$ s, where the acceleration is

$$a = \frac{\Delta v}{\Delta t} = \frac{11.0\,\frac{\mathrm{m}}{\mathrm{s}} - 3.0\,\frac{\mathrm{m}}{\mathrm{s}}}{10.0\ \mathrm{s} - 6.0\ \mathrm{s}} = 2.0\,\frac{\mathrm{m}}{\mathrm{s}^2}$$

The sum of the forces is

$$\sum F = 2.0\ \mathrm{kg} \cdot 2.0\,\frac{\mathrm{m}}{\mathrm{s}^2} = 4.0\ \mathrm{N}$$

b) The sum of the forces are zero, when the acceleration is zero e.g. when the velocity is constant. This occurs in the interval $[2.0\ \mathrm{s}, 6.0\ \mathrm{s}]$.

c) The acceleration at time $t = 1.4$ s is calculated from the slope on the $v - t$ graph. This applies in the interval $0 - 2.0$ s

$$a = \frac{\Delta v}{\Delta t} = \frac{3.0\,\frac{\mathrm{m}}{\mathrm{s}} - 0\,\frac{\mathrm{m}}{\mathrm{s}}}{2.0\ \mathrm{s} - 0\ \mathrm{s}} = 1.5\,\frac{\mathrm{m}}{\mathrm{s}^2}$$

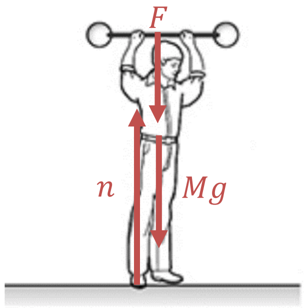
The sum of the forces is

$$\sum F = 2.0\ \mathrm{kg} \cdot 1.5\,\frac{\mathrm{m}}{\mathrm{s}^2} = 3.0\ \mathrm{N}$$

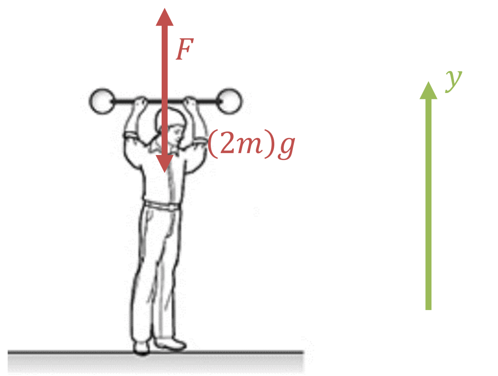
Problem 4.

We draw separate force diagrams for the man and the barbell.

Force diagram for man



Force diagram for barbell



We have introduced the force F, that the man applies to the barbell. Newton's 3. law states that the barbell must exert the same but opposite force on the man.

Setting up Newton's 2. law for the man that is not moving (i.e., no acceleration)

N2(man, y): $$0 = n - Mg - F \Leftrightarrow$$ $$n = Mg + F$$

To determine the force F, we set up Newton's 2. law for the barbell, which has a known acceleration a in the positive y-direction:

N2(barbell, y): $$2ma = F - 2mg \Leftrightarrow$$ $$F = 2m(a + g)$$

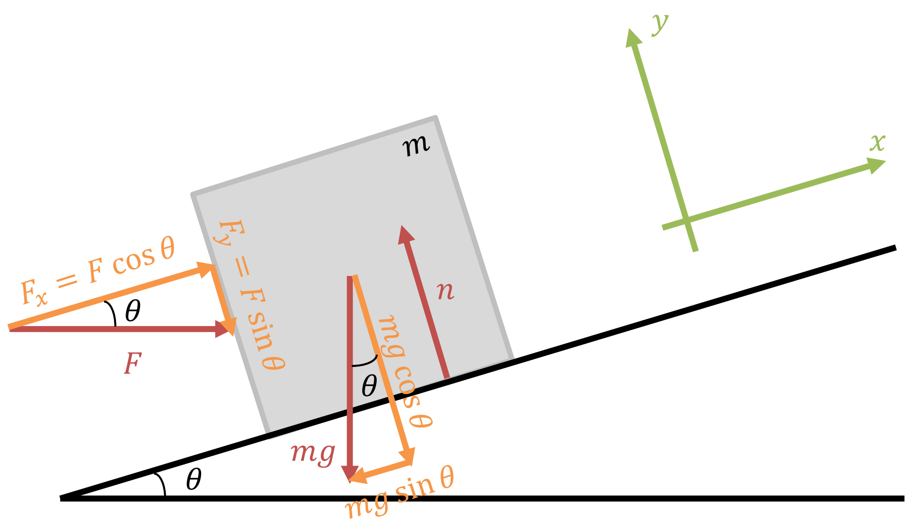
We insert the expression for F into the expression for the normal force n

$$n = Mg + 2m(a + g)$$

The answer is option F.

Problem 5.

a) We draw a sketch with the forces and a tilted coordinate system, where the x-axis is parallel with the inclined plane. We also illustrate the components of the force F and the force of gravity in the tilted coordinate system.



b) The block only accelerates along the x-axis in the tilted coordinate system. Therefore we set up Newton's second law in the x-direction.

N2(x): $$ma = \underbrace{F\cos\theta}_{x-\text{component of force } F} - \underbrace{mg\sin\theta}_{x-\text{component of force of gravity}} \Leftrightarrow$$

$$a = \frac{F}{m}\cos\theta - g\sin\theta$$

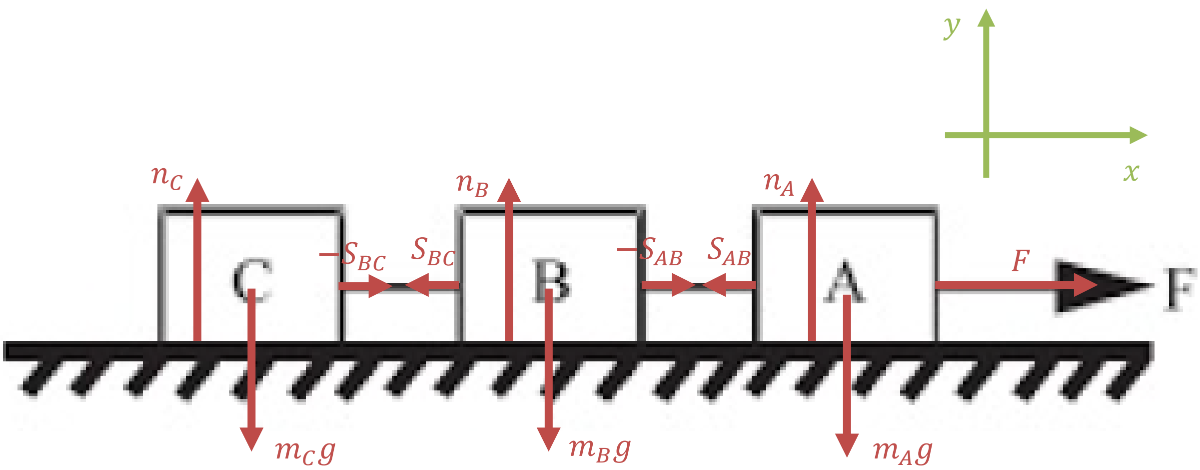
c) We set up Newton's 2. law in the y-direction, where the acceleration is 0

N2(y): $$0 = n - \underbrace{F\sin\theta}_{y-\text{component of force } F} - \underbrace{mg\cos\theta}_{y-\text{component of force of gravity}} \Leftrightarrow$$

$$n = F\sin\theta + mg\cos\theta$$

Problem 6.

We consider the system of connected blocks on a smooth surface (no friction between surface and blocks), where a force F is applied to block A. Wes ketch the force diagram and insert a coordinate system.



In the sketch above we have drawn all the forces that affect the blocks. Notice that the normal force is equal to the weight of the blocks in the y-direction. The motion of interest is along the x-direction. Notice that the tension of the strings are in pairs according to Newton's third law.

a) Since the blocks are connected by massless strings, the acceleration of all the blocks will be equal. To determine the acceleration, the most simple way is to determine the forces on *all* the blocks in the x-direction. We set up Newton's 2. law for the system of 3 blocks.

N2(A+B+C, x):

$$(m_\mathrm{A} + m_\mathrm{B} + m_\mathrm{C})a = \sum F_x = S_{BC} - S_{BC} + S_{AB} - S_{AB} + F \Leftrightarrow$$
$$(m_\mathrm{A} + m_\mathrm{B} + m_\mathrm{C})a = F \Leftrightarrow$$

$$a = \frac{F}{m_\mathrm{A}+m_\mathrm{B}+m_\mathrm{C}}$$

b) We set up Newton's 2. law for block C only:

N2(C, x):

$$m_\mathrm{C} a = S_\mathrm{BC}$$

$$S_\mathrm{BC} = \frac{m_\mathrm{C}}{m_\mathrm{A}+m_\mathrm{B}+m_\mathrm{C}} F$$

c) We set up Newton's 2. law for block B only

N2(B,x):

$$m_\mathrm{B} a = S_\mathrm{AB} - S_\mathrm{BC}$$

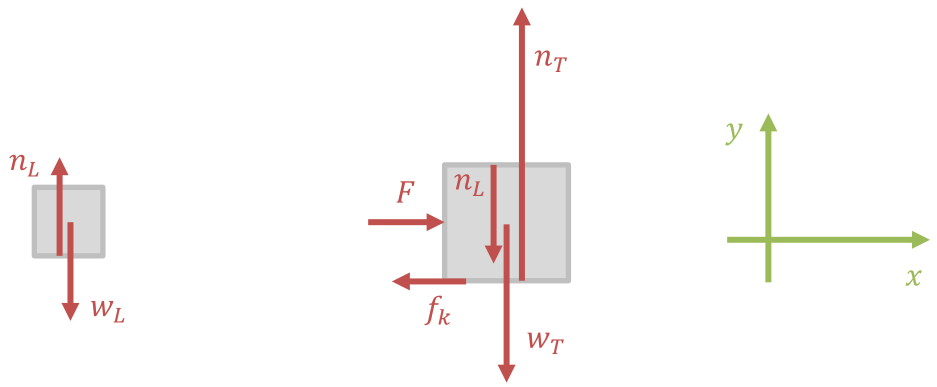
$$S_\mathrm{AB} = m_\mathrm{B} a + S_\mathrm{BC}$$

$$S_\mathrm{AB} = \frac{m_\mathrm{B}+m_\mathrm{C}}{m_\mathrm{A}+m_\mathrm{B}+m_\mathrm{C}} F$$

Problem 7.

In this exercise it should be noted that friction forces are present both between the boxes and between the box and the surface.

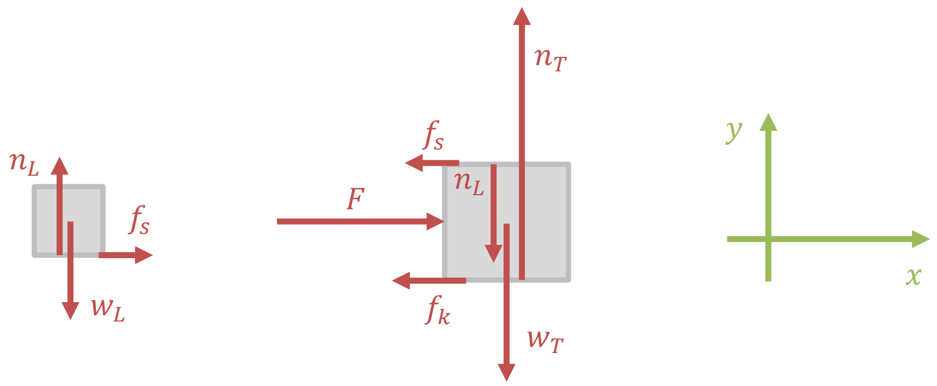
a) Since the blocks are moving with constant velocity, *the acceleration must be 0*. This means that *the sum of the forces in both directions are 0.* Force diagram:



Notice that the force vectors sum to zero in both the x- and y-directions for each block. f_k donotes the dynamic friction force between the heavy block and the surface.

Pay attention to n_L that affects the heavy block due to Newton's 3. law.

b) Now both blocks are accelerating, we expect the sum of all forces to be positive in the x-direction for each block. Both blocks have the same acceleration, as their relative velocity is 0.



Here f_s denotes the static friction force.