APPLICATIONS OF NEWTON'S LAWS OF MOTION

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The Runaway Car

Suppose a car is released from rest at the top of the incline, and the distance from the front edge of the car to the bottom is d. *How long does it take the front edge to reach the bottom, and what is its speed just as it gets there?*

Because a_x = constant,
we can apply
$x_f - x_i = v_{xi}t + \frac{1}{2}a_x t^2$,
to analyze the car's motion

replace displacement by $x_f - x_i = d$

Put, $v_{xi} = 0$, we get

$$d = \frac{1}{2}a_x t^2$$

$$(1) \qquad \sum F_x = mg\sin\theta = ma_x$$

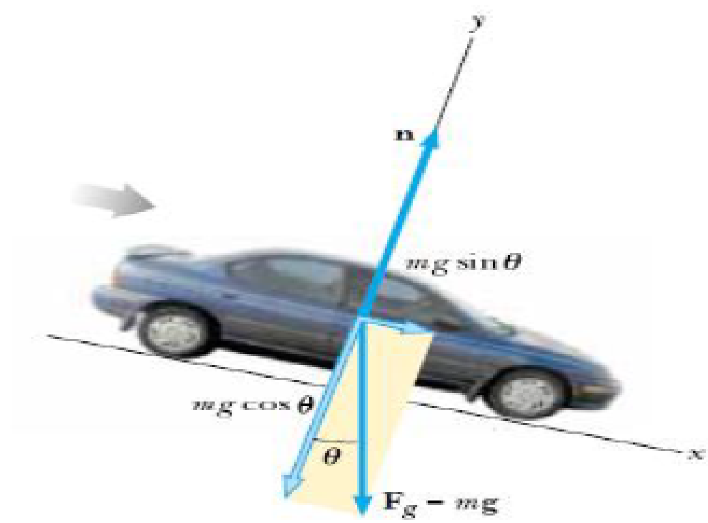
$$(2) \qquad \sum F_y = n - mg\cos\theta = 0$$

Solving (1) for a_x $\boxed{a_x = g\sin\theta}$

put the value of a_x in $d = \frac{1}{2}a_x t^2$ and find time, as follows

$$t = \sqrt{\frac{2d}{a_x}}$$

$$t = \boxed{\sqrt{\frac{2d}{g\sin\theta}}}$$



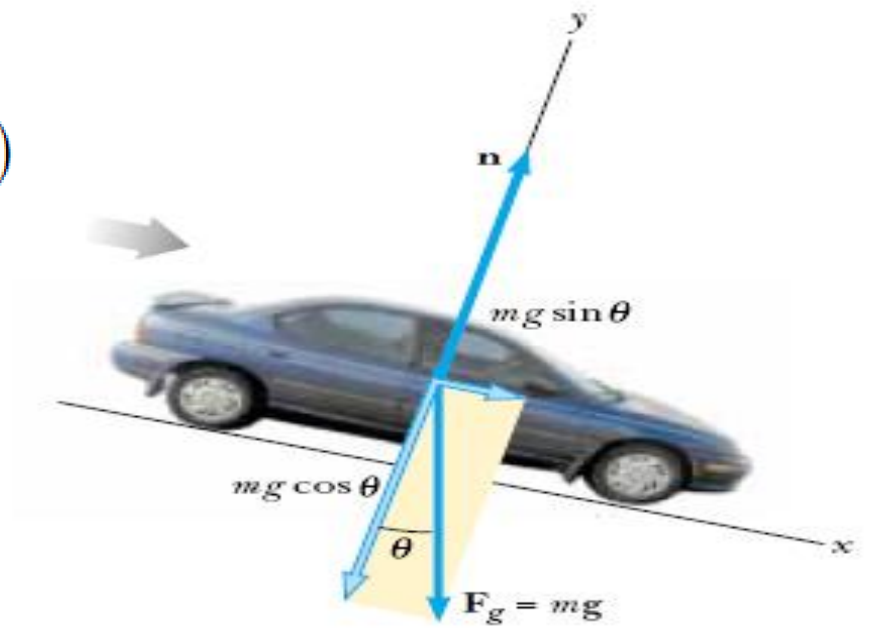
Calculation for Final Velocity

Using $v_{xf}{}^2 = v_{xi}{}^2 + 2a_x(x_f - x_i)$

with $v_{xi} = 0, \quad x_f - x_i = d$

$$v_{xf}{}^2 = 2a_x d$$

$$v_{xf} = \boxed{\sqrt{2gd\sin\theta}}$$



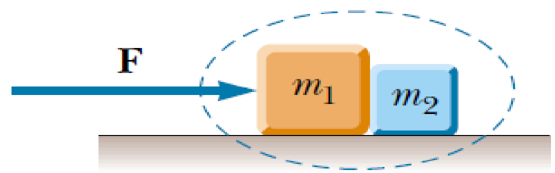
Conclusion

We see that the time t needed to reach the bottom and the speed v_{xf}, are independent of the car's mass.

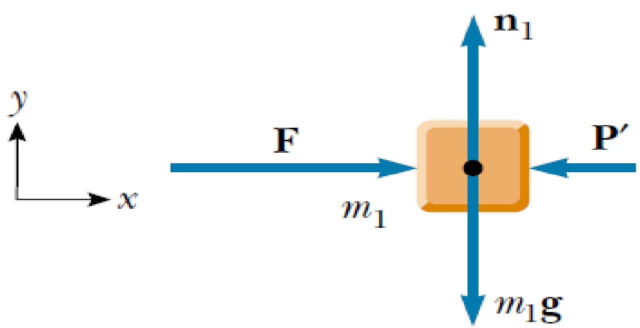
One Block Pushes Another

Two blocks of masses m_1 and m_2 are placed in contact with each other on a frictionless horizontal surface. A constant horizontal force $\mathbf{F}$ is applied to the block of mass m_1. (a) Determine the magnitude of the acceleration of the two-block system.

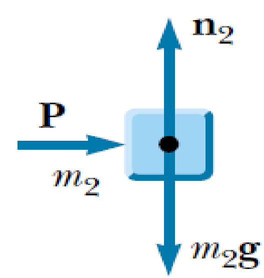
(b) Determine the magnitude of the contact force between the two blocks.



(a)



(b)



(c)

(a) Determine the magnitude of the acceleration of the two-block system.

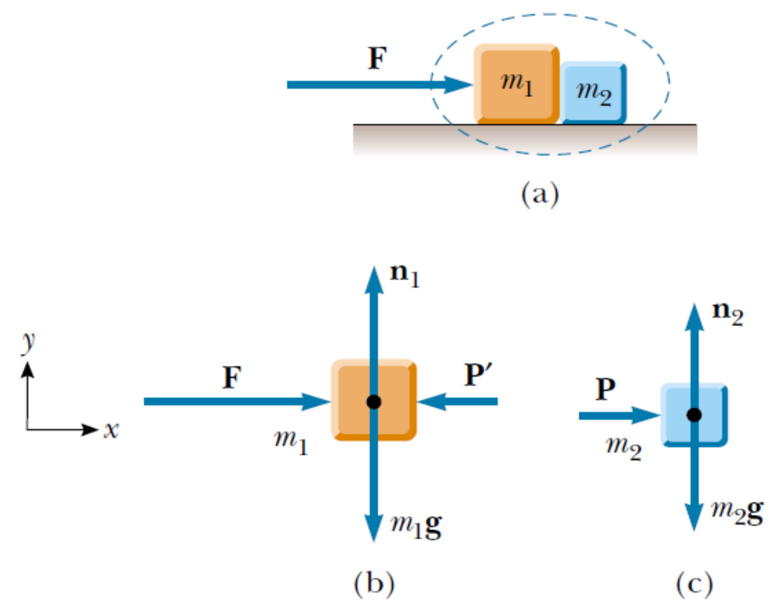
Solution

we know that both blocks must experience the same acceleration because they remain in contact with each other.

F is the only external horizontal force acting on the system (the two blocks), we have

$$\sum F_x(\text{system}) = F = (m_1 + m_2)\, a_x$$

$$(1) \qquad \boxed{a_x = \frac{F}{m_1 + m_2}}$$



(b) Determine the magnitude of the contact force between the two blocks.

To solve this part of the problem, we must treat each block separately with its own free-body diagram, We denote the contact force by **P**.

From Figure c, we see that the only horizontal force acting on block 2 is the contact force **P** (the force exerted by block 1 on block 2), which is directed to the right. Applying Newton's second law to block 2 gives

$$(2) \qquad \sum F_x = P = m_2 a_x$$

Substituting into (2) the value of a_x given by (1), we obtain

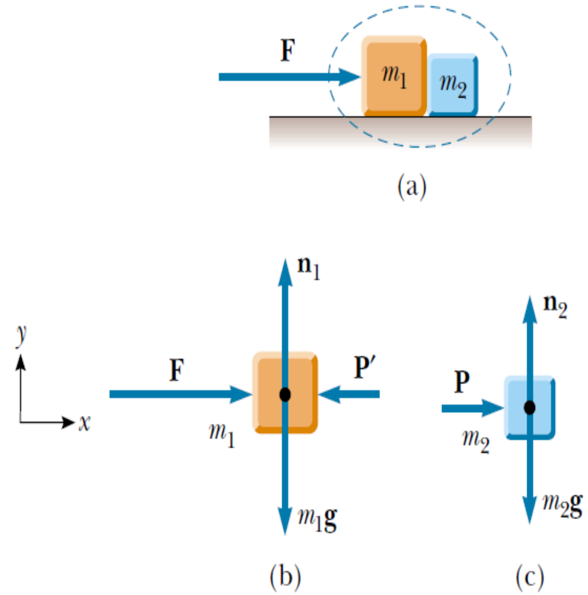
$$(3) \qquad \boxed{P = m_2 a_x = \left(\frac{m_2}{m_1 + m_2}\right) F}$$

$$P = m_2 a_x = \left(\frac{m_2}{m_1 + m_2}\right)F$$

From this result, we see that the contact force **P** exerted by block 1 on block 2 is *less* than the applied force **F**. This is consistent with the fact that the force required to accelerate block 2 alone must be less than the force required to produce the same acceleration for the two-block system.

It is instructive to check this expression for P by considering the forces acting on block 1, shown in Figure b. The horizontal forces acting on this block are the applied force **F** to the right and the contact force **P**′ to the left (the force exerted by block 2 on block 1). From Newton's third law, **P**′ is the reaction to **P**, so that $|\mathbf{P}'| = |\mathbf{P}|$. Applying Newton's second law to block 1 produces

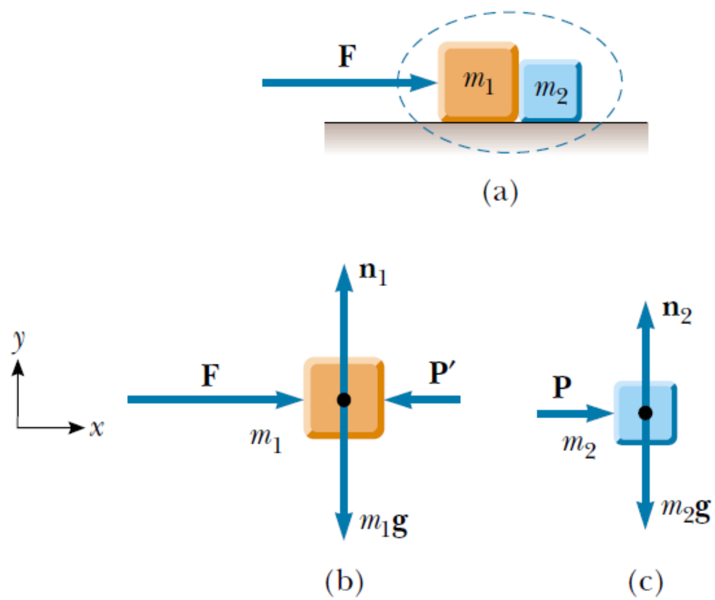
$$(4) \qquad \sum F_x = F - P' = F - P = m_1 a_x$$



$$(4) \qquad \sum F_x = F - P' = F - P = m_1 a_x$$

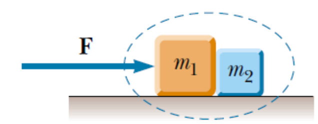
Substituting into (4) the value of a_x from (1), we obtain

$$P = F - m_1 a_x = F - \frac{m_1 F}{m_1 + m_2} = \left(\frac{m_2}{m_1 + m_2}\right) F$$



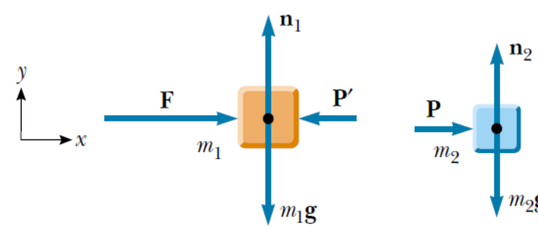
Task 1

Exercise If $m_1 = 4.00$ kg, $m_2 = 3.00$ kg, and $F = 9.00$ N, find the magnitude of the acceleration of the system and the magnitude of the contact force.



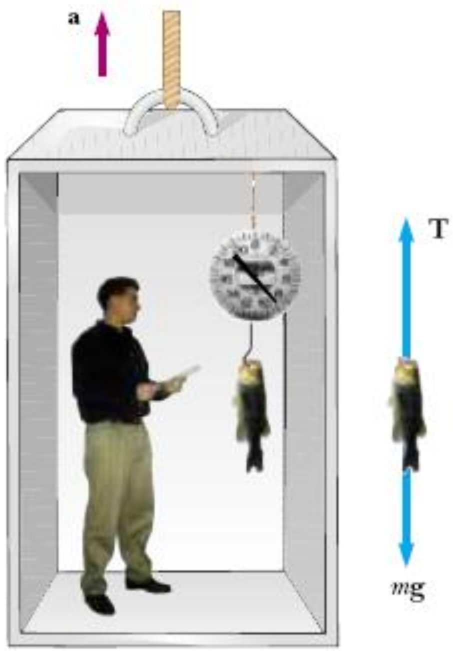
(a)

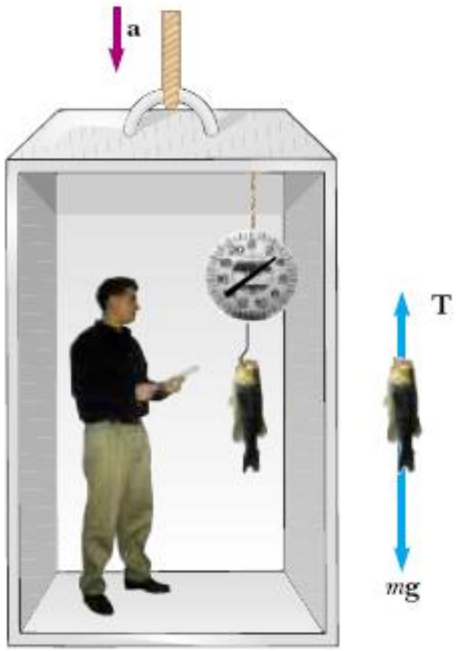
Answer $a_x = 1.29\ \text{m/s}^2$; $P = 3.86$ N.



(b) (c)

Weighing a fish in an Elevator

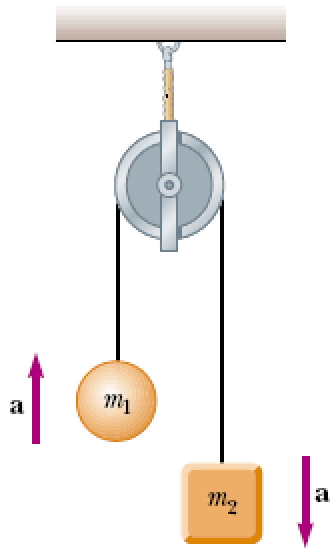


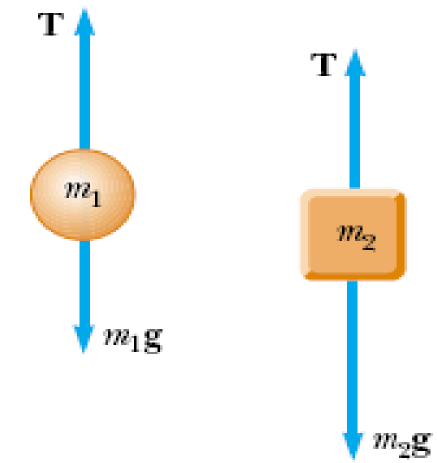


$$\sum F_y = T - mg = ma_y$$

$$T = ma_y + mg = mg\left(\frac{a_y}{g} + 1\right)$$

The Atwood Machine





$$\sum F_y = T - m_1 g = m_1 a_y$$

$$\sum F_y = m_2 g - T = m_2 a_y$$

$$a_y = \left(\frac{m_2 - m_1}{m_1 + m_2}\right) g$$

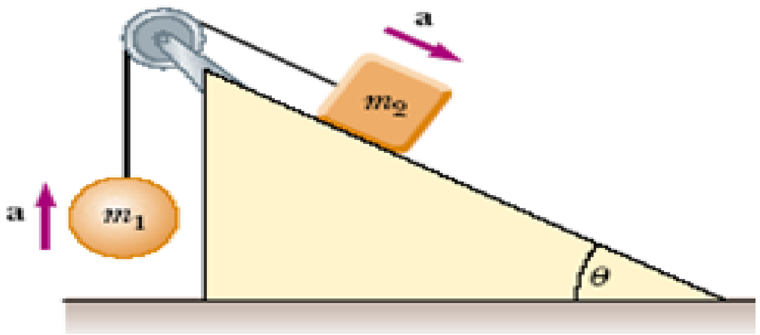
$$T = \left(\frac{2 m_1 m_2}{m_1 + m_2}\right) g$$

Exercise:

When two objects with masses of **3m** and **m** are hung vertically over a frictionless pulley of negligible mass, determine the magnitude of their acceleration and the tension in the lightweight cord.

Example:

A ball of mass $m_1 = 15$ kg and a block of mass $m_2 = 23$ kg are attached by a weightless cord that passes over a frictionless pulley of negligible mass, as shown in **Figure.** The block lies on a frictionless incline of angle $\theta = 48^o$. Find the magnitude of the acceleration of the two objects and the tension in the cord. Draw a free body diagram.



$$\bar{a} = \left(\frac{m_2 \sin\theta - m_1}{m_2 + m_1}\right) g$$

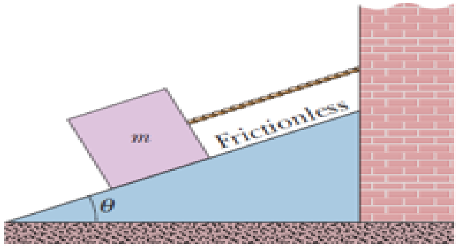
$$T = \left(\frac{m_1 m_2 (\sin\theta + 1)}{m_2 + m_1}\right) g$$

$a=0.5 m/s^2$

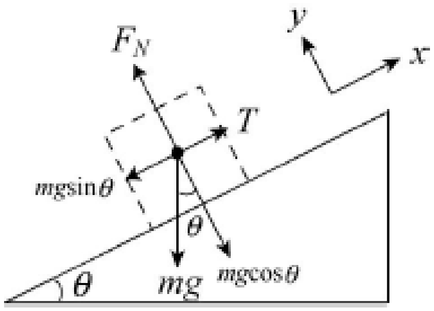
T=155N

Example:

In Figure shown, let the mass of the block be 6.5 kg and the angle θ be 40°.Find (a) the tension in the cord and (b) the normal force acting on the block. (c) If the cord is cut, find the magnitude of the resulting acceleration of the block.



$$T - mg\sin\theta = 0$$
$$F_N - mg\cos\theta = 0,$$



(a)T = 6.5x9.8xSin(40)= 40.94N

(b)F_N = 6.5x9.8xCos(40)= 48.79N

(c) a = -gSinθ = -9.8Sin(40)= - 6.299m/s^2