

# Problem Set 5

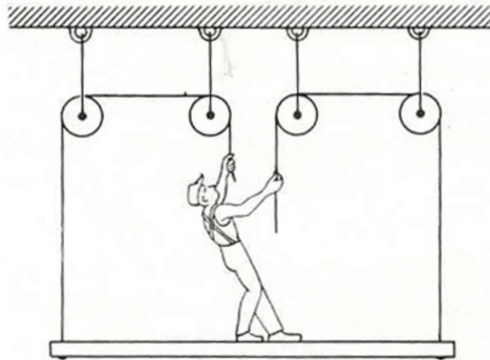
## Applications of Newton's second law

### PHYS-101(en)

#### 1. Painter on a platform

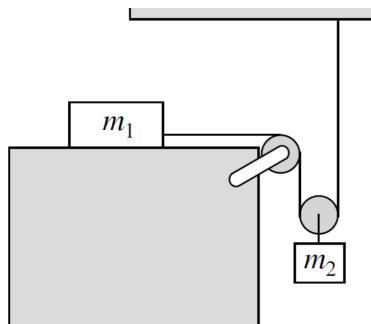
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A painter of mass  $m_1$  stands on a platform of mass  $m_2$  and pulls himself up by two ropes that run over massless, frictionless pulleys as shown. He pulls down on each rope with a force of magnitude  $F$  and accelerates upward together with the platform at a uniform acceleration. Find this uniform acceleration  $a$ .



#### 2. Blocks and pulleys 1

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In the system shown in the figure, *block 1* (of mass  $m_1$ ) lies on a level surface and has a coefficient of kinetic friction  $\mu_k$ . The rope attached to it is anchored on the other end to the ceiling, and is massless and inextensible. The two pulleys are massless and frictionless.

Assume that *block 1* is initially moving to the right.

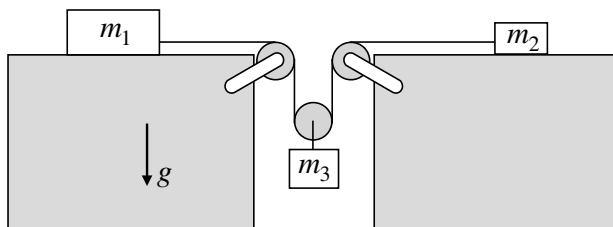
1. Draw free body diagrams for *block 1* and *block 2*, including all the forces acting on each object.

For *block 2*, consider as a single object the system composed by the block and the pulley from which it hangs. This allows you to model the block and the pulley as a single point mass (of combined mass  $m_2$ , since the pulley is assumed to be massless).

- Using the constraint that the total length of the rope does not change in time (why is that?), relate the accelerations of the two blocks.
- Find the acceleration of *block 1* in terms of the parameters of the problem ( $m_1$ ,  $m_2$ ,  $\mu_k$  and the magnitude of the acceleration of gravity  $g$ ).

### 3. Blocks and pulleys 2

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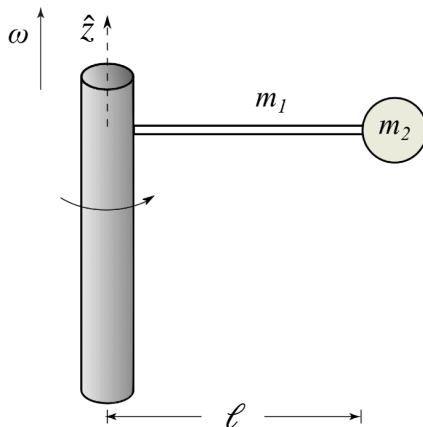


Consider the system shown above, where  $m_1 > m_2$ , the pulleys are massless and frictionless, the rope joining the blocks is massless and inextensible, and the downward acceleration of gravity is  $g$ . The three blocks are made from the same material, as are two tables. As is typical, the coefficient of static friction between the blocks and the tables is greater than the coefficient of kinetic friction,  $\mu_s > \mu_k$ .

- Imagine that, when the system is released from rest, you know block 3 accelerates downward with a constant magnitude  $a$ , but only one of the other blocks moves. Which block does not move, and what is the magnitude and direction of the friction force holding it back?
- Now consider the case where, after the blocks are released from rest, all three of them begin to move. Find the acceleration of all three blocks and the tension in the rope.

#### 4. Tension in massive rotating rope

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One end of a uniform rope of mass  $m_1$  and length  $\ell$  is attached to a shaft that is rotating at a constant angular velocity of magnitude  $\omega$ . The other end is attached to a point-like object of mass  $m_2$ . Find the tension in the rope  $T(\rho)$  as a function of the distance from the shaft  $\rho$ .

Assume that the radius of the shaft is much smaller than  $\ell$ . You may also assume the shaft is rotating fast enough that the mass and the rope are horizontal. And finally, you may assume that this happens in space, far away from any stars or planets, so gravity does not need to be considered. Express your answer in terms of the variable  $\rho$  and some or all of the following parameters:  $m_1$ ,  $m_2$ ,  $\omega$ , and  $\ell$ .

#### 5. Racing around a turn

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You and a friend are racing cars (with mass  $m_1$  and  $m_2$  respectively) around a circular, flat, horizontal turn. You are neck-and-neck with one another (i.e. at the same angular position). But you have the inside lane such that you are turning with a radius  $R_1$ , while she is turning with a somewhat larger radius  $R_2 > R_1$ . Unfortunately, she's going faster, traveling at a constant speed  $v_2$ , while you're only traveling at a constant speed of  $v_1 = v_2 R_1 / R_2$ ! From your reference frame (i.e. facing forwards in your car), what is the net force acting on your friend's car? Which fictitious forces are contributing? What acceleration do you perceive her as having?