chapter 5

Newton's Law of Motion

Static system

1. Hanging two identical masses
   - Context in the textbook: Section 5.3, combination of forces, Example 4.

Vertical motion without friction

2. Elevator: Decelerating while rising
3. After the cable breaks . . .
   - Context in the textbook: Complementary to Example 6 in Section 5.5.

Motion along a horizontal plane without friction

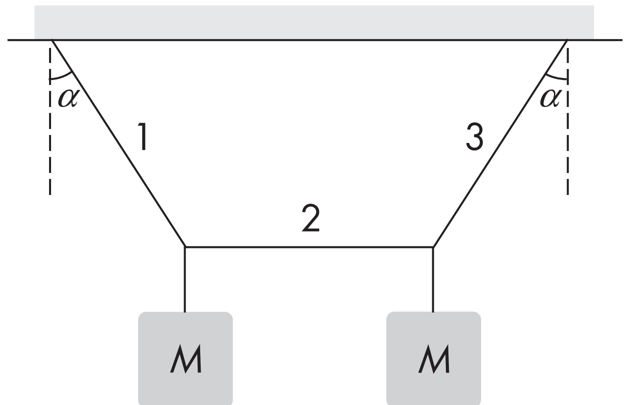
4. Pushing two blocks
   - Context in the textbook: Section 5.6, motion with constant force, Fig. 5.36.

Motion along an incline

5. Pushing up an incline without friction
   - Context in the textbook: Example 9 in Section 5.6.

Motion in a system with an ideal pulley.

6. Hanging weight versus pulling force
7. Moving cart with pulley and blocks
   - Context in the textbook: Examples 10 and 11 in Section 5.6.



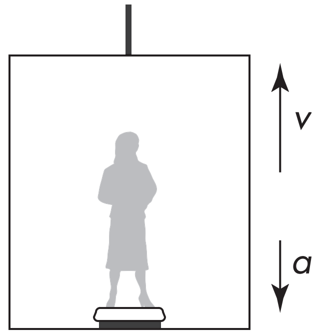
Two identical masses are suspended symmetrically, as shown, so that T_1, the tension along string 1, is equal to T_3, the tension along string 3.
Find T_2, the tension along string 2:

	A	B	C	D
T_2	$T_1 \cos \alpha$	$T_1 \sin \alpha$	$2T_1 \cos \alpha$	$2T_1 \sin \alpha$

Extra: Now lengthen string 2. This is done both to the right and to the left while maintaining the symmetry of the setup. Will T_2 increase, stay the same, or decrease?

Explanation: String 2 is pulled to the left by the horizontal component of T_1 (that is, $T_{1x} = T_1 \sin \alpha$) and to the right in equal magnitude by the horizontal component of T_3. Because tension is defined as the magnitude of either of the pulling forces, the tension along string 2 is $T_1 \sin \alpha$.
Answer = B.

Explanation—extra: As string 2 is lengthened, α decreases. Also notice from the vertical forces that $T_1 \cos \alpha = Mg$. Thus $T_2 = T_1 \sin \alpha = Mg \tan \alpha$ decreases.



A woman in an elevator is standing on a scale. When the elevator is at rest, the scale reading is $S = 50$ kg, corresponding to a weight of approximately 500 N. While the elevator is moving upward, it is decelerating with $|a| = g/10$. The new scale reading will be which of the following?

	A	B	C
S (in kg)	< 50	$= 50$	> 50

Hint: Newton's Second Law is $mg - F_{scale} = ma$.

Extra: Determine F_{scale} in N.

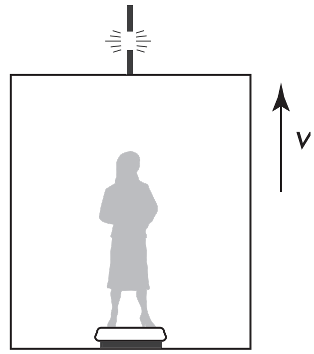
Explanation: Intuitively, as an ascending elevator comes to stop, a person feels lighter—that is, less than < 50 kg. This is confirmed by Newton's Second Law, which tells us that

$F_{scale} = mg - ma < mg$. Answer = A.

Explanation—extra: Let the downward direction of a be positive. The force equation takes the form $mg - F_{scale} = mg/10$.

$F_{scale} = mg - mg/10 \approx 50 \times 10 \times (1 - 1/10) = 450$ N.

So the scale reading is about $450/10 = 45$ kg.



A woman in an elevator is standing on a scale. As the elevator ascends at a constant speed, the scale reading is $S = 50$ kg. In force units it is approximately 500 N. If the cable suddenly breaks, the new scale reading will be which of the following?

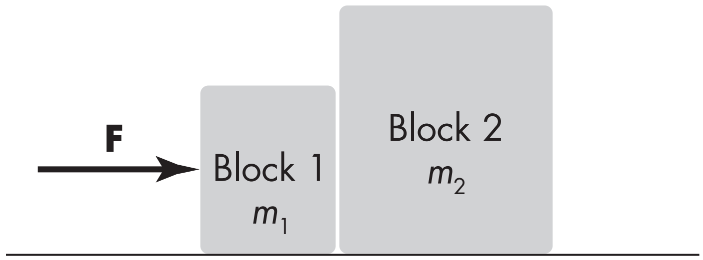
	A	B	C	D
S (in kg)	$S = 0$	$0 < S < 50$	$S = 50$	$S > 50$

Hint: Use $mg - F_{scale} = ma$.

Extra: Soon after that, the elevator starts descending. Will the scale reading change? If so, describe the change.

Explanation: Using the equation given in the hint, with $a = g$, we find that $F_{scale} = 0$, or $S = 0$. Answer = A.

Explanation—extra: After the cable breaks, $a = g$ whether the elevator is rising or falling. This implies that after the break, $S = 0$, regardless whether the elevator is rising or falling.



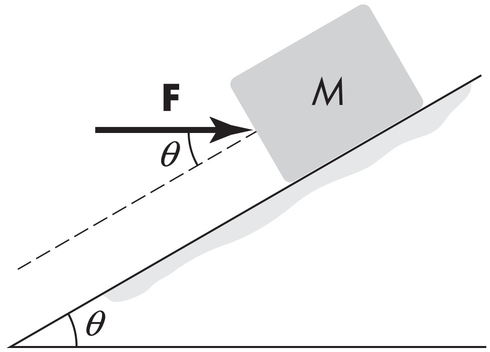
In this figure, let F_{21} be the force exerted on block 2 from block 1. If the system accelerates with a constant acceleration a, which of the following is the equation of motion from Newton's Second Law for block 2?

A	$F = m_2 a$
B	$F_{21} = m_2 a$
C	$F + F_{21} = m_2 a$

Extra: What is $F - F_{21}$ in terms of m_1, m_2, and a? What happens to the motion of block 1 when $F = F_{21}$?

Explanation: The force on block 2 is F_{21}. Answer = B.

Explanation—extra: Applying Newton's Second Law to block 1, $F - F_{21} = m_1 a$. Notice that this difference is proportional to the acceleration of block 1. When $F = F_{21}$, $a = 0$. This occurs when block 1 is not moving or if block 1 is moving with a constant speed.



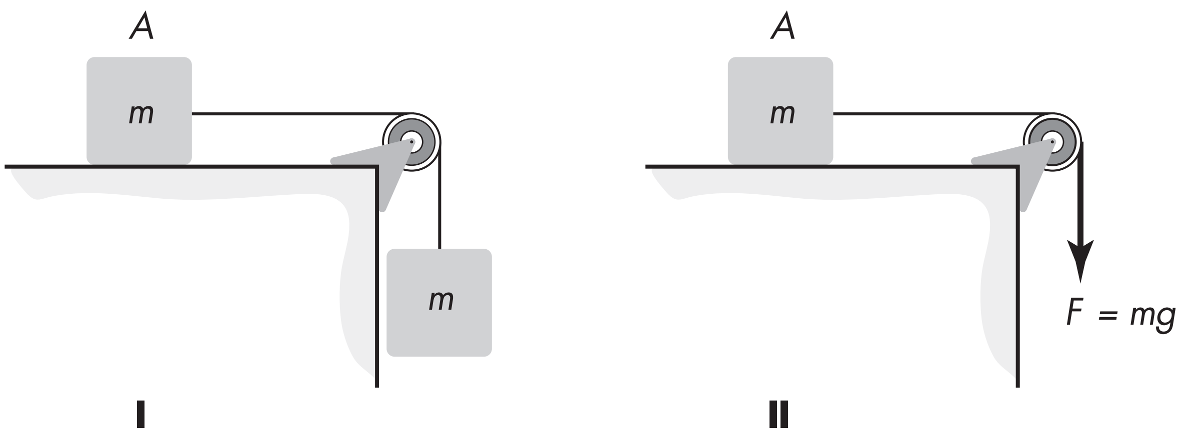
A block is pushed up a frictionless inclined plane as shown. Determine the magnitude of the horizontal force vector, $F = |\mathbf{F}|$, that will keep the block sliding up the incline with a constant velocity:

	A	B	C	D
F	$mg \sin \theta$	$mg \cos \theta$	$mg \tan \theta$	$mg \cot \theta$

Extra: Is the force required for the block to stay at rest greater than, equal to, or less than F given here?

Explanation: To push the block up the inclined plane at a constant velocity, there must be no net force on the block along the direction of the incline. Therefore the component of **F** along the incline must cancel the component of the weight along the incline. The reader should sketch a vector diagram to show that this cancellation implies that $F \cos \theta = mg \sin \theta$, or $F = mg \tan \theta$. Answer = C.

Explanation—extra: Because both the stationary and constant velocity cases have $a = 0$, the cancellation condition remains valid. Therefore the force is the same for both cases.



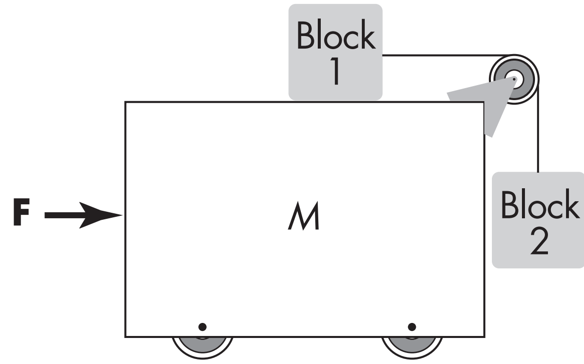
Consider the two possible accelerations of block A across the table toward the pulley. If friction is assumed to be negligible in each case, then the acceleration of block A is which of the following?

A	Greater in case I.
B	Greater in case II.
C	Both are the same.

Extra: Find the ratio of a_I/a_{II}.

Explanation: Applying Newton's Second Law to case I gives $mg = (m + m)a_I$. Or $a_I = g/2$. The corresponding equation for case II gives $mg = ma_{II}$. It gives $a_{II} = g$. So the second case has a greater acceleration. Answer = B.

Explanation—extra: From the explanation section, it follows that the ratio $a_I/a_{II} = 1/2$.



In this setup consider the surfaces in contact with the blocks, the wheels of the cart, and the pulley all to be frictionless. Let $m_1 = 3m_2$. The force F is adjusted so that block 1 is stationary with respect to the horizontal surface of the cart. The acceleration of the cart is a. The tension of the string is given by which of the following?

	A	B	C
Tension of the string	m_1a	$(m_1 + m_2)a$	$(m_1 - m_2)g$

Extra: Determine a.

Explanation: Applying Newton's Second Law to block 1 gives $T_1 = m_1a$. Answer = A.

Explanation—extra: Because the string tension is also given by m_2g, $T_1 = m_1a = m_2g$. Solving for a gives $a = m_2g/m_1 = g/3$.