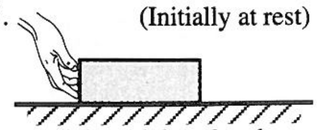
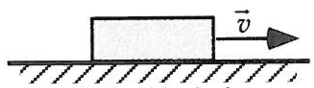
1. A block initially at rest is given a quick push by a hand. The block slides across the floor, gradually slows down, and comes to rest.

   a. In the spaces provided, draw and label separate free-body diagrams for the block at each of the three instants shown.

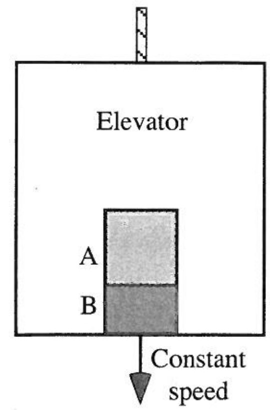
1. (Initially at rest)	*2.*	*3.*
 A quick push by a hand...	 the sliding block slows...	 and is finally at rest.

   b. Rank the magnitudes of all the *horizontal* forces in the diagram for instant *1*. Explain.

   c. Are any of the forces that you drew for instant *1* missing from your diagram for instant *2?* If so, for each force that is missing, explain how you knew to include the force on the first diagram but not on the second.

   d. Are any of the forces that you drew for instant *1* missing from your diagram for instant *3?* If so, for each force that is missing, explain how you knew to include the force on the first diagram but not on the third.

2. Two crates, A and B, are in an elevator as shown. The mass of crate A is *greater than* the mass of crate B.



a. The elevator moves downward at *constant speed.*

i. How does the acceleration of crate A compare to that of crate B? Explain.

ii. In the spaces provided below, draw and label separate free-body diagrams for the crates.

Free-body diagram for crate A	Free-body diagram for crate B

iii. Rank the forces on the crates according to magnitude, from largest to smallest. Explain your reasoning, including how you used Newton's second and third laws.

iv. In the spaces provided at right, draw arrows to indicate the direction of the *net force* on each crate. If the net force on either crate is zero, state so explicitly. Explain.

Direction of net force

Crate A	Crate B

Is the magnitude of the *net force* on crate A *greater than, less than,* or *equal to* that on crate B? Explain.

b. As the elevator approaches its destination, its speed decreases. (It continues to move downward.)

i. How does the acceleration of crate A compare to that of crate B? Explain.

ii. In the spaces provided below, draw and label separate free-body diagrams for the crates in this case.

Free-body diagram for crate A	Free-body diagram for crate B

iii. Rank the forces on the crates according to magnitude, from largest to smallest. Explain your reasoning, including how you used Newton's second and third laws.

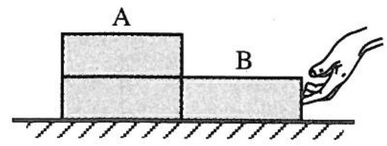
iv. In the spaces provided at right, draw arrows to indicate the direction of the *net force* on each crate. If the net force on either crate is zero, state so explicitly. Explain.

Direction of net force

Crate A	Crate B

Is the magnitude of the *net force* acting on crate A *greater than, less than,* or *equal to* that on crate B? Explain.

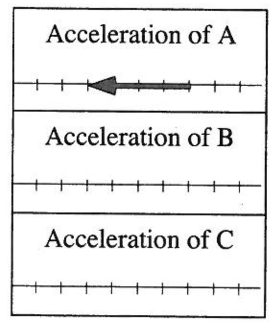
3. A hand pushes three identical bricks as shown. The bricks are moving to the left and speeding up. System A consists of two bricks stacked together. System B consists of a single brick. System C consists of all three bricks. *There is friction between the bricks and the table.*



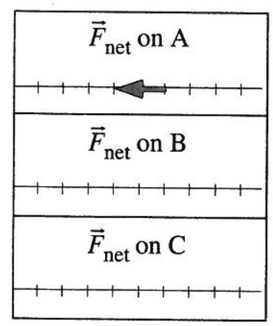
a. In the spaces provided at right, draw and label separate free-body diagrams for systems A and B.

Free-body diagram for system A	Free-body diagram for system B

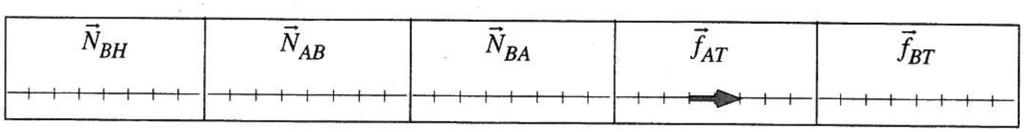
b. The vector representing the acceleration of system A is shown at right. Draw the acceleration vectors for systems B and C using the same scale. Explain.



c. The vector representing the net force on system A is shown at right. Draw the net force vectors for systems B and C using the same scale. Explain.



d. The vector representing the frictional force on system A is shown below. Draw the remaining force vectors using the same scale.

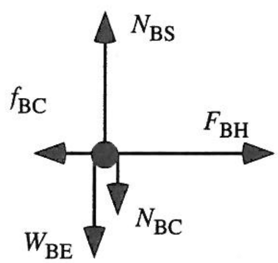
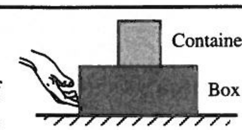
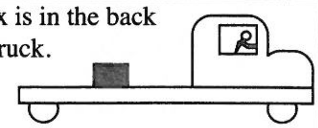
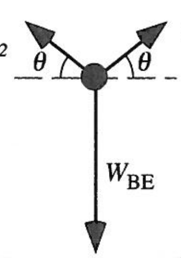


Explain how you knew to draw the force vectors as you did.

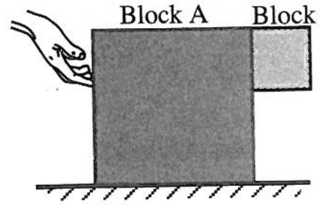
4. The table below provides information about the motion of a box in four different situations. In each case, the information given about the motion is in one of the following forms: (1) the algebraic form of Newton's second law, (2) the free-body diagram for the box, or (3) a written description and picture of the physical situation. In each case, complete the table by filling in the information that has been omitted. Case 1 has been done as an example.

(All symbols in the equations represent positive quantities. In each case, use a coordinate system for which $+x$ is to the right and $+y$ is toward the top of the page.)

KEY: B– box, C– small container, H– hand, S– surface, E– Earth, R, R_1, R_2 – massless ropes

	(1) Algebraic form of Newton's second Law $\vec{F}_{net} = m\vec{a}$	(2) Free-body diagram for box	(3) Written description and picture of physical situation
a. Example	ΣF_x: $F_{BH} - f_{BC} = m_B a_x$ ΣF_y: $N_{BS} - W_{BE} - N_{BC} = 0$	Net force is to the right 	A small container is on top of a box. The box is pushed by a hand in the $+x$-direction. There is friction between the container and the box. The box is accelerating to the right on a frictionless surface. 
b.	ΣF_x: $T_{BR}\cos\theta - F_{BH} = -m_B a_x$ ΣF_y: $T_{BR}\sin\theta + N_{BS} - W_{BE} = 0$	Net force is ________	
c.		Net force is ________	A box is in the back of a truck. The truck accelerates in the $+x$-direction on a straight highway. The box does not move relative to the truck. 
d.		Net force is down 	

5. Two blocks are pushed to the right so that they move together with increasing speed. Block B remains at the height shown. Ignore friction between the ground and block A but not between block A and block B. The mass of block A is 10 kg and the mass of block B is 2 kg. Let system C represent the system consisting of both blocks A and B. (Use $g = 10\ m/s^2$.)



a. For block A, block B, and system C: (1) draw free-body diagrams, (2) identify any Newton's third law force pairs, and (3) write out the algebraic form of Newton's second law.

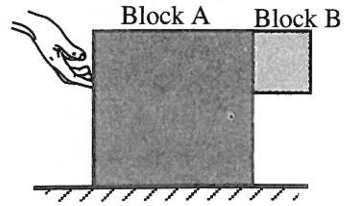
		Block A	Block B	System C
Free-body diagrams				
Algebraic form of Newton's 2nd law:	*x*:			
	y:			

b. Using *only* the forces in your free-body diagram for system C, calculate the magnitude of the force exerted on system C by the ground (N_{CG}).

c. Using *only* the forces in your free-body diagrams for block A and block B, calculate the magnitude of the force exerted on block A by the ground (N_{AG}).

How should the value of N_{CG} compare to N_{AG}?

d. Suppose the friction between the two blocks is reduced so that block B slides down as the blocks move to the right. The downward component of the acceleration of block B is 1 m/s^2.



i. For block A and block B: (a) draw new free-body diagrams and (b) write out the algebraic form of Newton's second law.

ii. Is the magnitude of the force exerted on block A by the ground in this case *greater than, less than,* or *equal to* the force exerted on block A by the ground in part c? Explain.

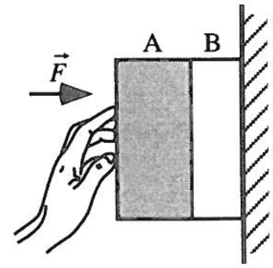
		Block A	Block B
Free-body diagrams			
Algebraic form of Newton's 2nd law:	*x:*		
	y:		

iii. Calculate the magnitude of the force exerted on block A by the ground. Show your work.

Sample Examination Questions

6. *Forces*

A hand pushes *horizontally* with a constant force on two blocks stacked against a wall (μ_s between finger and block A is zero). The blocks and wall do not accelerate. The mass of block A is greater than that of block B. The coefficient of static friction between the block and wall is the same as the coefficient of static friction between the two blocks.

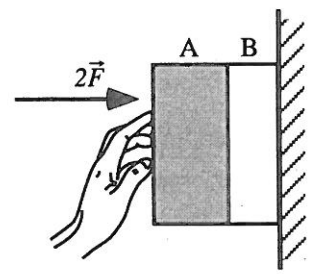


Draw a separate free-body diagram for each block. For each force on your free-body diagrams, be sure to indicate:

- the type of force (*e.g.*, tension, weight ...),
- the object on which the force is exerted, and
- the object exerting the force.

a. Rank the magnitudes of the *vertical* forces that you have shown from largest to smallest. Explain how you applied Newton's second and third laws to obtain your answer.

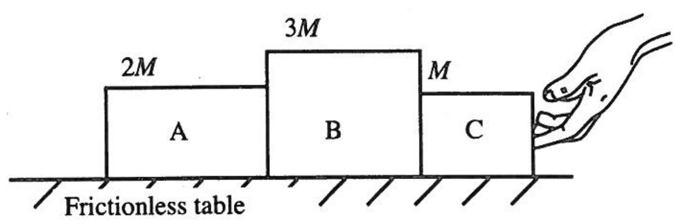
b. Suppose the hand pushes *horizontally* with a constant force that is *twice as large* as in part a.



Would the friction force exerted by the wall be *greater than*, *less than*, or *equal to* the friction force by the wall in part a? (Assume the blocks and wall do not accelerate.) Explain.

7. *Newton's second and third laws*

Blocks A, B, and C are being pushed across a frictionless table by a hand that exerts a constant horizontal force. Block A has mass $2M$, block B has mass $3M$, and block C has mass M.



a. Draw separate free-body diagrams for each of the three blocks. Label your forces to make clear:

- the object on which the force is exerted,
- the object exerting the force, and
- the type of force (normal, frictional, gravitational, *etc.*)

b. Draw vectors that represent the *net force* on each block. Draw the vectors with correct relative magnitudes. Explain how you knew to draw the net force vectors as you did.

c. Suppose the mass of block B were doubled (the other blocks are left unchanged), and the hand pushes with the *same force* as in part a.

i. Would the *magnitude* of the acceleration of block A *increase, decrease,* or *remain the same?* Explain.

ii. Would the *magnitude* of the net force on block A *increase, decrease,* or *remain the same?* Explain.