NEWTON'S REVIEW FOR TEST

NEWTON'S LAWS

1. Why does a child in a wagon seem to fall backward when you give the wagon a sharp pull?

Answer: The child isn't falling backward, rather the wagon is pulling out from underneath him and the friction between his bottom and the wagon is pulling his lower half forward while his top half is staying stationary. (Newton's First Law: A body at rest tends to stay at rest)

2. If the acceleration of a body is zero, are no forces acting on it?

Answer: No, it just means that all the forces acting on it cancel each other out. $F_{net} = 0$.

3. Why might your foot hurt if you kick a heavy desk or a wall?

Answer: the desk is exerting the same force on your foot that your foot is exerting on the desk. This is Newton's third law: For every action, there is an equal and opposite reaction.

4. When you stand still on the ground, how large a force does the ground exert on you? Why doesn't this force make you rise up into the air?

Answer: The ground exerts a force on you that is equal to your weight in Newtons upwards. This force does not make you rise up because it is cancelled out by the force of gravity on your mass downwards.

5. Why is the stopping distance of a truck much shorter than for a train going the same speed?

Answer: A train has a much larger mass than a truck and therefore decelerates at a much lesser rate assuming equal force acts on both, $F = ma$.

6. Big Bubba has a mass of 100 kg on the earth. What is Big Bubba's mass on the moon where the force of gravity is approximately 1/6-th that of Earth's? ________ Explain or show your work.

Answer: 100 kg

Mass is a quantity which is independent of the location of the object. So if Big Bubba has a mass of 100 kg on Earth, then he also has a mass of 100 kg on the moon. Only the weight would change as Big Bubba is moved from the Earth to the moon. He weighs ~1000 N on Earth and 1/6-th this value (~167 N) on the moon.

7. **TRUE or FALSE:**

i. An object which is moving rightward has a rightward force acting upon it.

Answer: False

An object which is accelerating rightward must have a rightward force and a rightward net force acting upon it. But an object which is merely moving rightward does not necessarily have a rightward force upon it. A car that is moving rightward and skidding to a stop would not have a rightward force acting upon it.

ii. For an object resting upon a non-accelerating surface, the normal force is equal to the weight of the object. If false, state the situations that may occur to cause the F_N to be different than the weight of the object.

Answer: False

Quite surprisingly to many, the normal force is not necessarily always equal to the weight of an object. Suppose that a person weighs 800 N and sits at rest upon a table. Then suppose another person comes along and pushes downwards upon the persons shoulders, applying a downward force of 200 N. With a total downward force of 200 N acting upon the person, the total upward force must be 1000 N. The normal force supplies the upward force to support both the force of gravity and the applied force acting upon the person. Its value is equal to 1000 N which is not the same as the force of gravity of the person.

In addition, if the object is at rest on an incline, its F_N is going to be less than its F_g (weight of object). Part of the F_g or weight of the object is going to be pulling it down the incline, however, the force of (static) friction may be large enough to keep the object at rest.

8. Which of the following statements are true of the concept of **force**? List all that apply.

a. A force is a push or pull exerted upon an object which results from the interaction of that object with its environment.
b. Bubba approaches Billie and gives him a swift shove. Timid little Billie keeps his hands in his pocket during this interaction. Subsequently, while Bubba places a force upon Billie, Billie does not place a force upon Bubba.
c. A quarterback throws a football downfield. Once thrown, the force from the quarterback persists upon the ball to cause it to continue on its upward trajectory towards its peak.
d. A sled slides down the hill and reaches the bottom where it gradually slows to a stop. Once on the level ground, the force of the hill persists upon the sled to allow it to continue its forward motion.
e. Forces always cause objects to move.
f. An object can experience two or more forces and not accelerate.
g. A force is a vector quantity; there is always a direction associated with it.
h. Force can be measured in kilograms or Newtons depending upon the system of measurement (metric or otherwise).

Answer: AFGJ and sort of H.

a. **TRUE** - This is a great definition of force.

b. **FALSE** - According to Newton's third law, "one cannot touch without being touched." The force on Billie is the result of an interaction of Bubba's hands with Billie's body. That force on Billie might cause Billie to go flying, but the *reaction force* offers resistance to the motion of Bubba's hands and slows them down. In general, forces will always (without exception) come in pairs.

c. **FALSE** - The force of the quarterback on the football is a contact force which can only exist during the interaction (i.e., the contact) between the quarterback's hands and the football. Once thrown, the football continues its horizontal motion due to its own inertia and its vertical motion is effected by the force of gravity.

d. **FALSE** - Be careful if you answered true to this one. If you did, perhaps you believe in the fatal misconception that a rightward force is required to sustain a rightward motion. The sleds motion to the right can be described as a leftward accelerated motion. Such a leftward acceleration demands that there is a leftward force (despite its rightward force). This leftward force slows the rightward-moving sled down. The hill cannot *push* on the sled unless the hill is in contact with the sled.

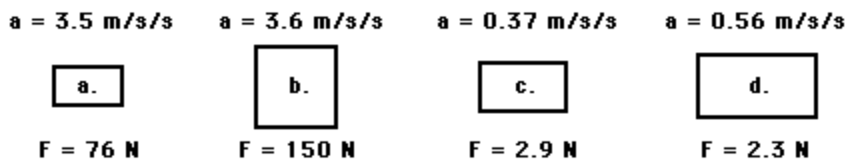
e. **FALSE** - Forces, if unbalanced, can cause objects to accelerate (one form of moving; the other form is moving at a constant velocity). But by no means can one say that forcecs always cause objects to move. For instance, as you sit in your chair, the chair pushes up on your body but your body does not move.

f. **TRUE** - Certainly! As you sit in your chair, the chair pushes up on your body but your body does not accelerate. This upward force (known as the normal force) is balanced by the downward force of gravity. Many objects experience a force yet do not accelerate.

g. **TRUE** - Forces always have a direction associated with them. As such, force is a vector quantity - a quantity which is fully described by both a magnitude (size, value) and a direction.

h. **FALSE** - Force is measured in Newtons in the metric system and in pounds in the British system. Kilograms is a unit of mass.

9. Given the net forces (**F**) upon the objects below and the resulting acceleration (**a**) of each which of the objects below has the greatest inertia?



Answer: b. Mass is a measure of an objects inertia.

10. Consider two identical cans, one filled with lead and the other empty. The cans are located far in space at a place where they are "weightless". Describe a method of determining which can has the greater mass.

Answer: If you pushed them with an equal force, the heavier one would have a smaller acceleration, F = ma.

11. An empty hand is not hurt when it bangs lightly against a wall. Why is it hurt if it does so while carrying a heavy load?

Answer: Newton's First Law states a person in motion tends to stay in motion with the same speed and in the same direction ... unless <u>acted upon by the unbalanced force</u>. The heavier your hand, the more force is required to accelerate it to a stop, F=ma.

ACTION-REACTION FORCES

12. According to Newton's third law, each team in a tug of war pulls with equal force on the other team. What, then, determines which team will win?

Answer: Since the tension in the rope is equal for both teams, its the force of friction on their feet that wins the tug of war. For the team that pushes forward on the ground with the largest force, the ground pushes back and moves them away from their starting point in the right direction and moves the other team towards the center line.

13. According to Newton's third law, every force is accompanied by an equal and opposite *reaction* force. The reason that these forces do not cancel each other is ____.

a. the action force acts for a longer time period

b. the two forces are not always in the same direction

c. one of the two forces is greater than the other

d. the two forces act upon different objects; only forces on the same object can balance each other.

e. ... nonsense! They do cancel each other. Objects accelerate because of the presence of a third force.

Answer: D

Action and reaction forces always act upon the interacting objects for the same amount of time with the same magnitude. So if object A pushes on object B, then object B simultaneously pushes on object A with the same amount of force. The force on object B will be one of perhaps many forces which will govern is motion. But the reaction force is on object A and cannot contribute to object B's motion since it is not acting upon object B. Action-reaction forces can NEVER cancel each other.

14. When a rifle shoots a bullet, Newton's Third Law says that the force that the rifle exerts on the bullet is exactly the same size as the force that the bullet exerts on the rifle - yet the bullet gets a **much** greater acceleration than the rifle. How can this be?

Answer: It is absolutely true that the forces on the rifle and on the bullet are exactly the same size. However, don't forget that Newton's Second Law says that two factors affect the acceleration of an object - the net force on it and its mass (inertia).

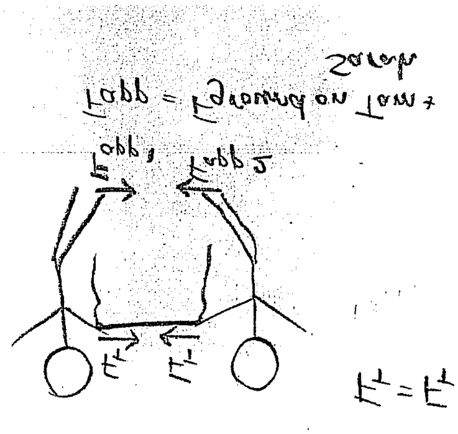
The acceleration of the bullet equals the force that the rifle exerts on it divided by the mass of the bullet.

The two forces are equal, but since the mass of the rifle is much greater than the mass of the bullet, the acceleration of the rifle is much less than the bullet's acceleration.

15. Tam Anh grabs Sarah by the hand and tries to pull her. She tries to remain standing without moving. A student analyzes the situation as follows. "If Tam Anh's force on Sarah is greater than her force on him, he can get her to move. Otherwise, she'll be able to stay where she is." What's wrong with this analysis?

Answer: Newton's Third Law really does say that if A pulls B, then B pulls A with an equal and opposite force. However, **these forces DO NOT CANCEL because they influence the motion of different objects**. The force that A exerts on B influences B's motion, and the force that B exerts on A influences A's motion. The force on B can cancel with other forces on B - but **NOT** with forces on A(and vice versa). In fact, it's the force that the ground exerts on Tam's feet that would push her and thereby pull Sarah in Tam's direction of intended movement. However, if the force that the ground exerts on Sarah's feet is greater than the force exerted on Tam's feet then Tam will be pulled in Sarah's direction. If they both have equal force exerted on their feet by the ground, they will remain stationary, no matter who is pulling on the other's hand with greater force.

See Diagram:



16. When jumping from a boat to shore, it is always advisable to tie up the boat before jumping. Why?

Answer: If you don't, as your legs accelerate your body towards shore, they apply an equal and opposite force to the boat, pushing it away.

17. When a small bug is splattered across a fast moving windshield what experiences more force- the bug or the windshield?

Answer: They both experience the same force as indicated by Newton's Third Law: **For every action, there is an equal and opposite reaction.**

18. Why does the force have a greater effect on the bug?

Answer: Since the bug is so small, the force it exerts on the bus as it accelerates to a stop is very small. Since the bus is so large, it barely notices this force, and has a infinitely small acceleration (deceleration) due to the force of the bug. But we all no what happens to the bug (squash) as it decelerates quickly to a stop as the bus plows forward.

19. If we find a body that we know to be acted on by a force, but that is not moving, what inference can we draw about its state of motion?

Answer: More than one force is acting on the body and these forces are balanced and therefore $F_{net} = 0$.

20. In a tug-of-war, what is the net force acting on the rope when the participants each pull with opposing forces of 500 N? _________ What is the tensional force within the rope? ________

Answer: The $F_{net} = 0$, because two equal and opposite forces are applied to the rope. They sum to 0. Since the rope isn't accelerating, the net force on the rope is zero.
The tension in the rope is 500 N, not 1000 N. If something is pulling on an unmoving rope with a force of 500 N, the tension is 500 N regardless of what applies the opposing force.

21. Why can you exert greater force on the pedals of a bicycle if you pull up on the handlebars?

Answer: When you pull up on the handle bars, the handle bars pull down on you causing you to push down with a greater force on the pedals of the bicycle.

FREE BODY DIAGRAMS and 1-D FORCE

22. Construct free-body diagrams for the following objects; label the forces according to type. Use the approximation that **g=10 m/s²** to determine the magnitude of all forces and the net force and acceleration of the object.

a. A 2-kg box is at rest on a table.

b. A 2-kg box is free-falling from the table to the ground.

c. A 2-kg box equipped with a parachute is falling at a terminal velocity after being dropped from a plane.

d. A 2-kg box is sliding to the right across a table. The force of friction upon the box is 5 N.

e. An 8-N force is applied to a 2-kg box to move it to the right across the table at a constant velocity of 1.5 m/s.

f. An 8-N force is applied to a 2-kg box to accelerate it to the right across a table. The box encounters a force of friction of 5 N.

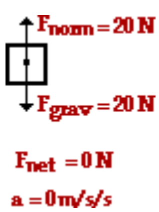
g. A 500-kg freight elevator is descending down the shaft at a constant velocity of 0.50 m/s.

h. A 500-kg freight elevator is moving upwards towards its destination. Near the end of the ascent, the upward moving elevator encounters a downward acceleration of 2.0 m/s/s.

i. A 150-N rightward force is applied to a 20-kg box to accelerate it to the right across a rough surface at a rate of 2.0 m/s/s.

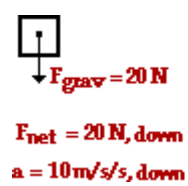
Answer:

a. A 2-kg box is at rest on a table.



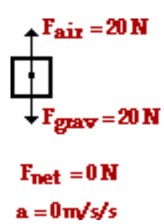
("At rest" would indicate a balance of forces and an acceleration of 0 m/s/s.)

b. A 2-kg box is free-falling from the table to the ground.



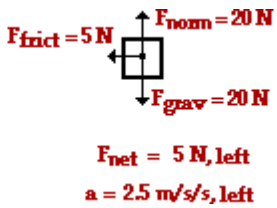
("Free-falling" indicates that the only force that influences the motion is the force of gravity.)

c. A 2-kg box equipped with a parachute is falling at a terminal velocity after being dropped from a plane.



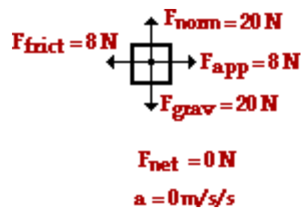
(A "terminal velocity" indicates a constant velocity and a balance of forces.)

d. A 2-kg box is sliding to the right across a table. The force of friction upon the box is 5 N.



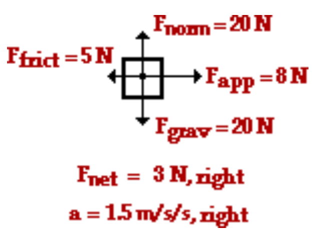
(Friction is directed opposite the motion and causes a leftward acceleration; no rightward force is spoken of, only a rightward motion.)

e. An 8-N force is applied to a 2-kg box to move it to the right across the table at a constant velocity of 1.5 m/s.



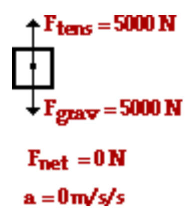
(A "constant velocity" indicates an acceleration of 0 m/s/s and a balance of forces.)

f. An 8-N force is applied to a 2-kg box to accelerate it to the right across a table. The box encounters a force of friction of 5 N.



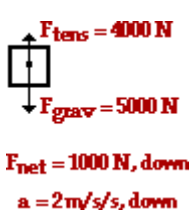
(The horizontal forces can be summed as vectors; divide by the mass to obtain the acceleration value.)

g. A 500-kg freight elevator is descending down the shaft at a constant velocity of 0.50 m/s.



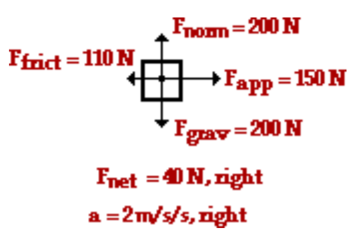
(A "constant velocity" indicates an acceleration of 0 m/s/s and a balance of forces.)

h. A 500-kg freight elevator is moving upwards towards its destination. Near the end of the ascent, the upward moving elevator encounters a downward acceleration of 2.0 m/s/s.



(Begin by multiplying m•a to find the net force - 1000 N, down. The downward gravity force must be 1000 N more than the upward tension force.)

i. A 150-N rightward force is applied to a 20-kg box to accelerate it to the right across a rough surface at a rate of 2.0 m/s/s.



(Begin by mulitplying m•a to determine the net force - 40 N, right. The rightward applied force must be 40 N more than the leftward friction force.)

23. A 72-kg skydiver is falling from 10000 feet. At an instant during the fall, the skydiver encounters an air resistance force of 540 Newtons. Determine the acceleration of the skydiver at this instant.

Answer: 2.30 m/s^2, down

There are two forces acting upon the skydiver - gravity (down) and air resistance (up). The force of gravity has a magnitude of m•g = (72 kg) •(9.8 m/s/s) = 706 N. The sum of the vertical forces is

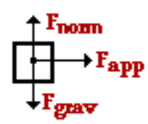
$$\cdot F_y = 540 \text{ N, up} + 706 \text{ N, down} = 166 \text{ N, down}$$

The acceleration of the skydiver can be computed using the equation $\cdot F_y = m \cdot a_y$.

$$a_y = (166 \text{ N, down}) / (72 \text{ kg}) = 2.30 \text{ m/s}^2\text{, down}$$

24. A 5.2-N force is applied to a 1.05-kg object to accelerate it rightwards across a friction-free surface. Determine the acceleration of the object. (Neglect air resistance.)

Answer: 4.95 m/s^2, right



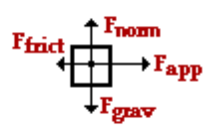
Upon neglecting air resistance, there are three forces acting upon the object. The up and down force balance each other and the acceleration is caused by the applied force. The net force is 5.2 N, right (equal to the only rightward force - the applied force). So the acceleration of the object can be computed using Newton's second law.

$$a = F_{net} / m = (5.2 \text{ N, right}) / (1.05\text{kg}) = 4.95 \text{ m/s}^2\text{, right}$$

25. A 5.2-N force is applied to a 1.05-kg object to accelerate it rightwards. The object encounters 3.29-N of friction. Determine the acceleration of the object. (Neglect air resistance.)

Answer: 1.82 m/s^2, right

Upon neglecting air resistance, there are four forces acting upon the object. The up and down forces balance each other. The acceleration is rightward since the rightward applied force is greater than the leftward friction force. The horizontal forces can be summed as vectors in order to determine the net force.



$$F_{net} = \cdot F_x = 5.2 \text{ N, right} - 3.29 \text{ N, left} = 1.91 \text{ N, right}$$

The acceleration of the object can be computed using Newton's second law.

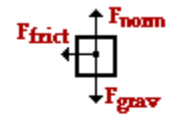
$$a_x = \cdot F_x / m = (1.91 \text{ N, down}) / (1.05\text{kg}) = 1.82 \text{ m/s}^2\text{, right}$$

26. A 1250-kg small aircraft decelerates along the runway from 36.6 m/s to 6.8 m/s in 5.1 seconds. Determine the average resistive force acting upon the plane. (Assume that its engine/propeller makes no contributes to its forward motion).

Answer: 7304 N

This problem is similar to the two previous problems in many respects: the free-body diagram is identical or similar and the acceleration is not given but determinable from the kinematic information.

$v_i = 36.6$ m/s, $v_f = 6.8$ m/s, and $t = 5.1$ s



The acceleration of the object is the velocity change per time:

a = Delta v / t = (6.8 m/s - 36.6 m/s) / (5.1 s) = -5.84 m/s^2 or 5.84 m/s^2, left.

This acceleration can be used to determine the net force:

F_{net} = m•a = (1250 kg) • (5.84 m/s/s, left) = 7304 N, left

The friction forces (surface and air) provide this net force and are equal in magnitude to this net force.

FRICTION

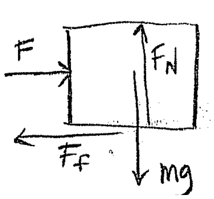
27. Why do you push harder on the pedals of a bicycle when first starting out than when moving at a constant speed?

Answer: a. You have to overcome static friction which is larger than kinetic friction (moving friction), b. You are accelerating when you go from rest to a constant velocity which requires force, F = ma. At a constant speed, you are just overcoming the force of friction and possibly the force of gravity if you are on an incline.

28. If the coefficient of kinetic (sliding or moving) friction between a 35 kg crate and the floor is 0.30, what horizontal force is required to move the crate at a steady speed across the floor? What horizontal force is required if coefficient of friction is zero?

Answer: $F_f = \mu F_N$. With constant velocity, the acceleration is zero.
Using the free body diagram for the crate, we can write $F_{net} = ma$ and the F_{net} equation for the crate:
$F_{net} = F - F_f$
$ma = F - \mu F_N$
$a = 0$
$0 = F – (0.30)(35)(9.80)$
$F = 102.5 = 1.0 \times 10^2$ N

If $\mu = 0$, there is **<u>no force</u>** required to maintain constant speed. On a frictionless surface a force is not required to keep an object moving at a constant speed; a force is only needed to accelerate an object or counter the effects in a force of friction is acting on an object.



29. A box is given a push so that it slides across the floor. How far will it go, given that the coefficient of kinetic friction is 0.20 and the push imparts an initial speed of 4.0 m/s?

HINT:Draw a free body diagram for the box as it is sliding, note the initial force to get the box moving only acts at the starting point to get the object moving and does not continue to act on the box as it moves.

Answer: The force of friciton provides the acceleration. The force net on the box is represented by the equation:
$F_{net} = \mu F_N$
$ma = \mu gm$
$a = (0.20)(9.80)$
$a = 1.96\ m/s^2$

Note that the friction force is acting in the opposite direction as the movement and therefore the box is decelerating or accelerating in a negative direction in relation to movement.

We can find the distance from the motion data:
$v_f^2 = v_i^2 + 2a(d_f - d_i)$
$0 = (4.0)^2 + 2(-1.96)(d_f - 0)$
$d_f = 4.0816 = 4.1\ m$

30. A motorcyclist is coasting with the engine off at a steady speed of 17 m/s but enters a sandy stretch where the coefficient of friction is 0.80. Will the cyclist emerge from teh sandy stretch without having to start the engine if the sand lasts for 15 m? If so, what will be the speed upon emerging?

Answer: We find the acceleration from the F_{net} equation for the motorcycle. The kinetic friction force is the only forces acting on the motorcycle, therefore:
$F_{net} = \mu F_N$
$ma = \mu gm$
$a = (0.80)(9.80)$
$a = 7.84\ m/s^2$

We can find the distance from the motion data:
$v_f^2 = v_i^2 + 2a(d_f - d_i)$
$v_f^2 = (17.0)^2 + 2(-7.84)(15 - 0)$
$v_f = 7.3\ m/s$

ELEVATORS

31. A 75.0 kg person stands on a scale in an elevator. What does the scale read(in kg) when (a) the elevator is at rest, (b) the elevator is climbing at a constant speed of 4.2 m/s, (c) the elevator is falling at 5.0 m/s, (d) the elevator is accelerating upward at 3.5 m/s^2, (e) the elevator is accelerating downward at 4.0 m/s^2

Answer: We take the positive direction to be upward.
The scale reads the force the person exerts on the scale. From Newton's third law, this is also the magnitude of the normal force acting on the person. The effective mass on the scale is $F_N = m_{scale}g$.
We write $F_{net} = ma$ from the force diagram for the person:
$F_{net} = F_N - mg$
$ma = m_{scale}g - mg$

(a) When the elevator is at rest, $a = 0$
$ma = m_{scale}g - mg$

$0 = m_{scale}g – mg$
$m_{scale} = m \quad m_{scale} = 75.0$ kg

(b) When the elevator is climbing at constant speed, a = 0
$ma = m_{scale}g – mg$
$0 = m_{scale}g – mg$
$m_{scale} = m \quad m_{scale} = 75.0$ kg

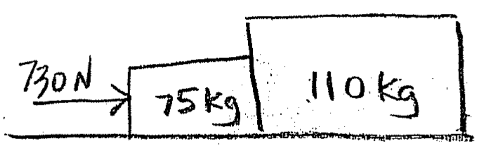
(c) When the elevator is falling at constant speed, a = 0
$ma = m_{scale}g – mg$
$0 = m_{scale}g – mg$
$m_{scale} = m \quad m_{scale} = 75.0$ kg

(d) When the elevator is accelerating upward, a is positive:
$ma = m_{scale}g – mg$
$75.0(3.5) = m_{scale}(9.8) – 75.0(9.8)$
$m_{scale} = 101.78 = 1.0 \times 10^2$ kg

(e) When the elevator is accelerating downward, a is negative:
$ma = m_{scale}g – mg$
$75.0(-4.0) = m_{scale}(9.8) – 75.0(9.8)$
$m_{scale} = 44$ kg

COUPLED SYSTEMS

32. Two crates of mass 75 kg and 110 kg are in contact and at rest on a horizontal surface. A 730 kg force is exerted on the 75 kg crate. If the coefficient of kinetic friction is 0.15, calculate (a) the acceleration of the system, and (b) the force that each crate exerts on the other.



Answer:
a. The two crates must have the same acceleration.

Note $F_{12} = F_{21}$ as stated in Newton's Third Law: Action-Reaction forces are equal and opposite.

Look at the system and only 3 forces are left

System $F_{net} = F_a - \mu F_{N1} - \mu F_{N2}$
$(m_2 + m_1)\, a = 730 – (0.15)(75)(9.80) – (0.15)(110)(9.80)$
$(75+110)\, a = ….$
$a = 2.4759 = 2.5\ m/s^2$

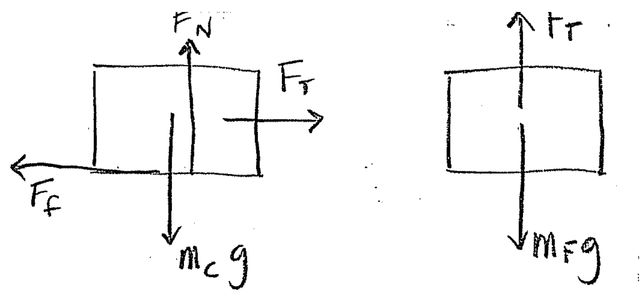
b. We find the force between the crates from crate 2:
$F_{21} - \mu F_{N2} = m_2 a$
$F_{21} – (0.15)(110)(9.80) = (110)(2.5)$
$F_{21} = 4.4 \times 10^2$ N

PULLEYS

33. Figaro the cat (5.0 kg) is hanging on the tablecloth, pulling Cleo's fishbowl (11kg) toward the edge of the table. The coefficient of kinetic (sliding) friction between the tablecloth (ignore its mass) under the fishbowl and the table is 0.44. (a) What is the acceleration of Figaro and the fishbowl? (b) If the fishbowl is 0.90 m from the edge of the table, how much times does it take for Figaro to pull Cleo off the table?
Hint: Treat the table cloth like a pulley.

Answer: For each object we take the direction of the acceleration as the positive direction. The kinetic friction from the table will oppose the motion of the bowl.

(a) From the force diagrams we have the following F_{net} equations:



Look at the system and only 2 forces are left
System $F_{net} = F_{gF} - F_f$
$Ma = m_F g - \mu m_C g$
$(m_C + m_F)\, a = m_F g - \mu m_C g$
$(11.0 + 5.0)\, a = 5.0(9.80) - 0.44(11.0)(9.80)$
$a = 0.098 \text{ m/s}^2$

(b) We find the time for the bowl to reach the edge of the table from
$d = v_i t + \frac{1}{2} a t^2$
$0.9 = 0 + \frac{1}{2}(0.098)(t^2)$
$t = 4.3 \text{ s}$