# Physics 121: Newton's 1/2 Laws, Free Body Diagrams

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# Reminder

- Next HW is due next Thursday (28th of September). Covers chapter 5 on Forces.

# What Do Forced Do?

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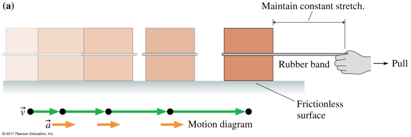
Attach a rubber band to a block and stretch the rubber band (to a fixed amount) to pull the block across a frictinless surface. We know that the block with change it's motion (accelerate).



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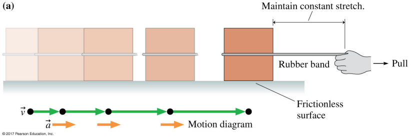


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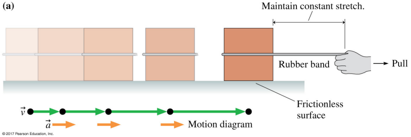


- What happens to the acceleration if I add a second rubber band? Does it go up/down? By how much? The forces add so you get $F' = 2F$.
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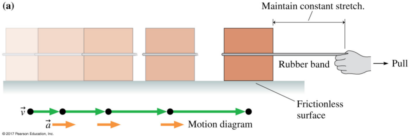


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but what is $c$?

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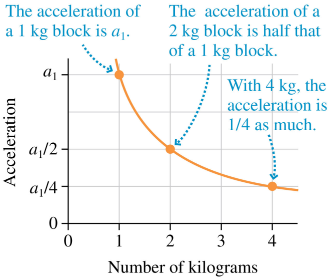
- What if I were to double the mass of the block (say from 1kg to 2kg), what would happen to the acceleration? Think of pushing a broken down car vs a broken down semi ...
- It's harder to change the motion of an object with large mass. In fact it turns out that the acceleration is **inversely proportional** to the mass of the object.

$$a = \frac{F}{m}$$

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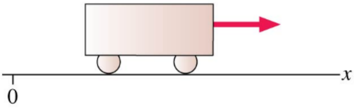
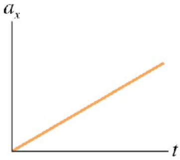
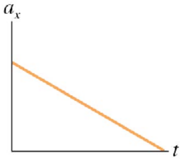
# Quick Check

A cart is pulled to the right with a constant, steady force. How will its acceleration graph look?

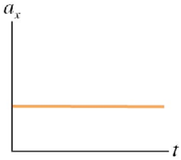



A.




B.




C.

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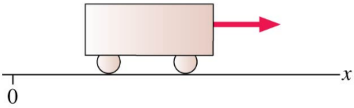


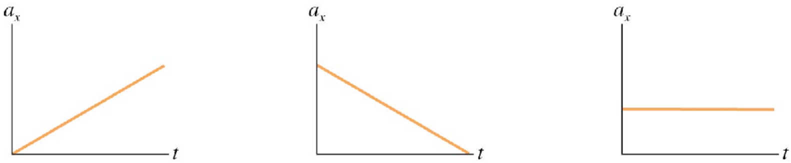


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$$\text{Force Unit} = \text{kg} \times \frac{\text{m}}{\text{s}^2} = \frac{\text{kg m}}{\text{s}^2} = \text{N}$$

- This is called a **newton**, so 1 N $= 1$ kg m/s$^2$.

# Inertial Mass

- 1 kg of mass is defined by a particular metal block in a vault in Paris (90% Platinum 10% Iridium). So it seems we could say that the mass of an object is related to how much stuff/matter it is made of.

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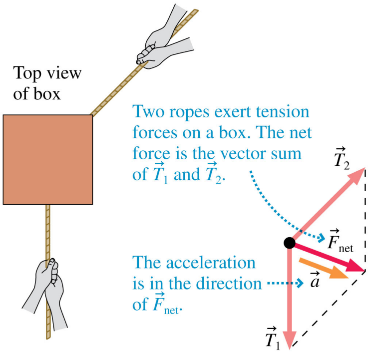
- Mass *resists* acceleration due to a force, this is called **inertia** and so we call this mass **inertial mass**.

- When there are multiple forces acting on an object the amount and direction of the acceleration is dictated by the net force.

$$\vec{a} = \frac{\vec{F}_{net}}{m}$$

more commonly seen as

$$\vec{F}_{net} = m\vec{a}$$




The acceleration is **NOT** $(T_1 + T_2)/m$ but

$$\vec{a} = \frac{\vec{T}_1 + \vec{T}_2}{m}$$

- Forces don't *overcome* eachother, they simply add together to create a net force. Forces don't compete.
- One more interesting aspect of forces is that when an agent exerts a force on an object, the object exerts a force on agent as well. This is called **Newton's third law** and we'll talk more about it later. Think of hitting a solid brick wall . . . your hand exerted the force, but clearly the wall exerted one back.

# Quick Check

A constant force causes an object to accelerate at $4\ m/s^2$. What is the acceleration of an object with twice the mass that experiences the same force?

A. $1\ m/s^2$

B. $2\ m/s^2$

C. $4\ m/s^2$

D. $8\ m/s^2$

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- An object in motion tends to . . . stay in motion.
- This is also called the law of inertia and is fully stated as

**Newton's first law** An object that is at rest will remain at rest, or an object that is moving will continue to move in a straight line with constant velocity, if and only if the net force acting on the object is zero.

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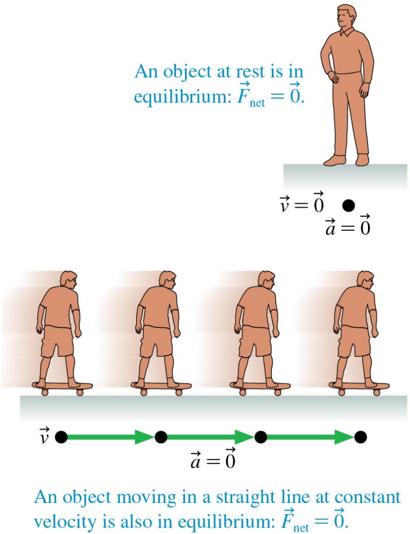
# Newton's 1st Law

- An object on which the net force is zero and thus is either at rest or moving in a straight line with constant velocity is said to be in mechanical equilibrium and thus has zero acceleration.

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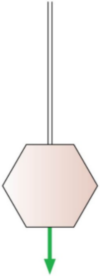
An object on a rope is lowered at constant speed. Which is true?



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B. The rope tension equals the object's weight.

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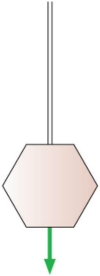

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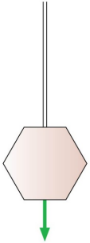

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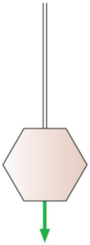

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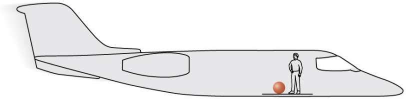
  - Zero

# Inertial Reference Frames

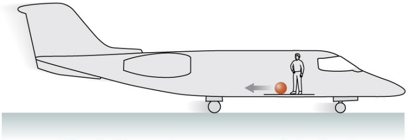
- An **inertial reference frame** is a reference frame in which Newton's laws are valid . . . unlike the "car" reference frame in the dummy in the car situation.
- Inertial reference frames are non-accelerating reference frames.

**(a)** Cruising at constant speed.



The ball stays in place; the airplane is an inertial reference frame.

**(b)** Accelerating during takeoff.



The ball accelerates toward the back even though there are no horizontal forces; the airplane is *not* an inertial reference frame.

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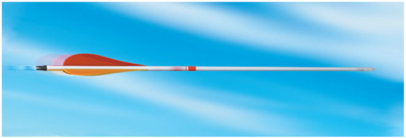
# Forces

- Every force has an agent which causes the force.
- Forces exist at the point of contact between the agent and the object (except for the few special cases of long-range forces).
- Forces exist due to interactions happening now, not due to what happened in the past.
- Consider a flying arrow.
  - A pushing force was required to accelerate the arrow as it was shot.
  - However, no force is needed to keep the arrow moving forward as it flies.
  - It continues to move because of inertia.



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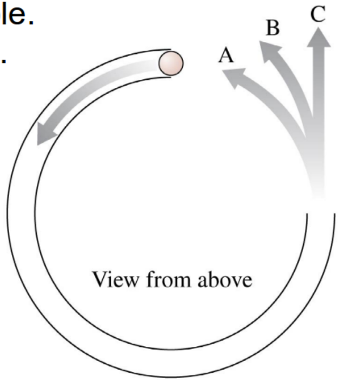
A hollow tube lies flat on a table. A ball is shot through the tube. As the ball emerges from the other end, which path does it follow?



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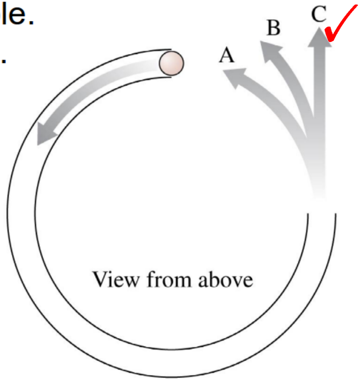

**TACTICS BOX 5.3**

MP

## Drawing a free-body diagram

1. **Identify all forces acting on the object.** This step was described in Tactics Box 5.2.
2. **Draw a coordinate system.** Use the axes defined in your pictorial representation.
3. **Represent the object as a dot at the origin of the coordinate axes.** This is the particle model.
4. **Draw vectors representing each of the identified forces.** This was described in Tactics Box 5.1. Be sure to label each force vector.
5. **Draw and label the *net force* vector $\vec{F}_{net}$.** Draw this vector beside the diagram, not on the particle. Or, if appropriate, write $\vec{F}_{net} = \vec{0}$. Then check that $\vec{F}_{net}$ points in the same direction as the acceleration vector $\vec{a}$ on your motion diagram.

Exercises 24–29

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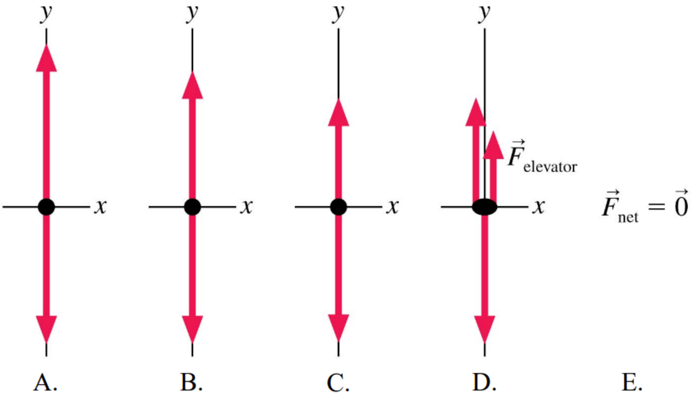
An elevator, lifted by a cable, is moving upward and slowing. Which is the correct free-body diagram?



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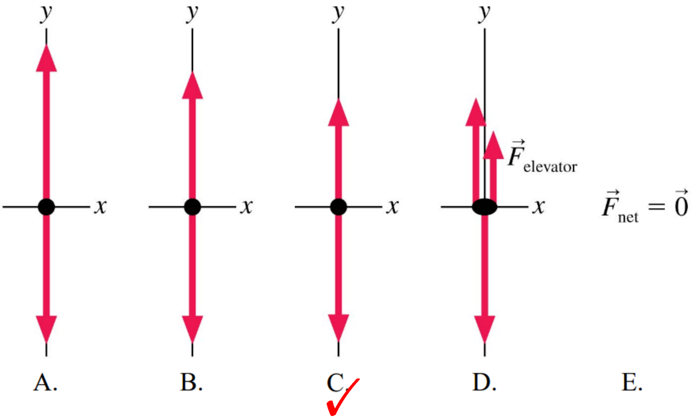

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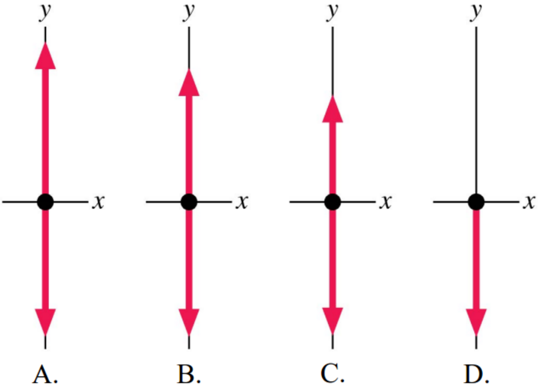
A ball has been tossed straight up. Which is the correct free-body diagram just after the ball has left the hand? Ignore air resistance.



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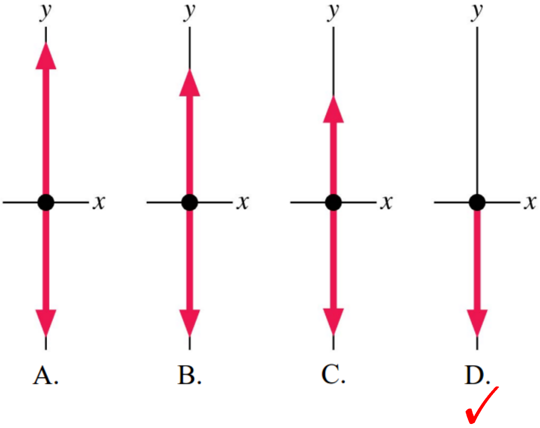
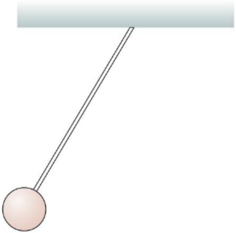
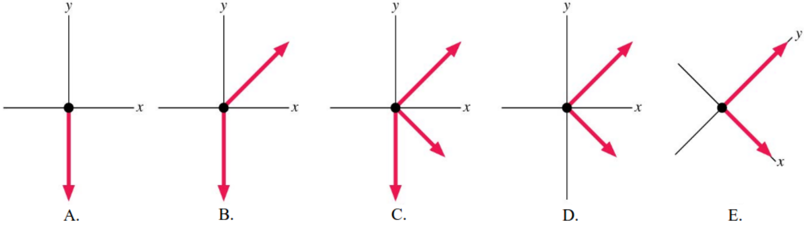


A ball, hanging from the ceiling by a string, is pulled back and released. Which is the correct free-body diagram just after its release?





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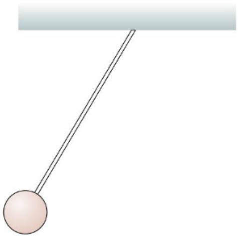

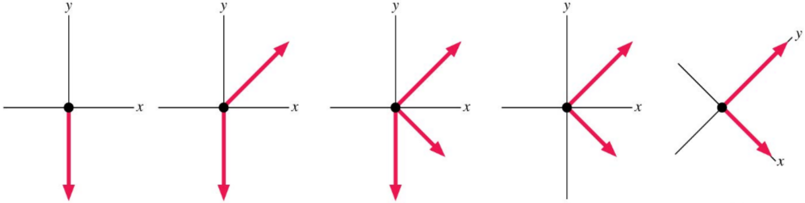


A. B. C. D. E.

# Picture References

Consider the Following (accessed 25 Sep 2017) https://i.ytimg.com/vi/71VT6oTto1g/maxresdefault.jpg