

Transportation and Horse Power - Science

Physics - The Horse and Wagon Explained (No Friction Case)

Students should be able to grasp Newton's Laws of Motion and their application.

Answers should be similar to: "The wagon moves because it's attached to the horse." or "If the horse pushes harder on the ground than the wagon pulls on the horse, then the wagon accelerates."

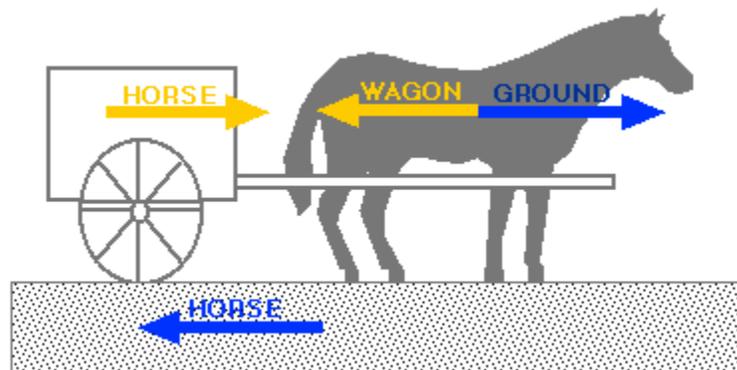
The Key

Even though a complete answer to the Horse and Wagon Question can get rather involved, a clear explanation only hinges on a couple of simple points:

- An object accelerates (or not) because of the forces that push or pull on it. (Newton's 2nd Law)
- Only the forces that act on an object can cancel. Forces that act on different objects don't cancel - after all, they affect the motion of different objects!

The Forces - No Friction

The diagram at right shows the **horizontal** forces that act on the horse, the wagon, and the earth. The convention for drawing the forces in the diagram is:



- The force is drawn as an arrow pointing in the direction of the force.
- The force is drawn on the object getting pushed or pulled.
- The force is labeled with the object doing the pushing or pulling.

For example, the yellow arrow labeled "wagon" is a force exerted **by** the wagon **on** the horse. The blue arrow labeled "horse" is a force exerted **by** the horse **on** the ground.

What are the Newton's Third Law Force Pairs?

The two forces colored yellow in the diagram are a Newton's Third Law force pair - "horse pulls wagon" and "wagon pulls horse". They are equal in magnitude and opposite in direction.

The two forces colored blue in the diagram are a Newton's Third Law force pair - "horse pushes ground" and "ground pushes horse". They are also equal in magnitude and opposite in direction.

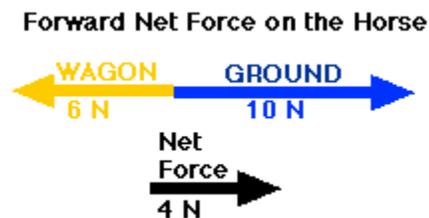
Why does the wagon accelerate?

Newton's 2nd Law says that an object accelerates if there is a net (unbalanced) force on it. Looking at the wagon in the diagram above, you can see that there is just one force exerted on the wagon - the force that the horse exerts on it. The wagon accelerates because the horse pulls on it! The amount of acceleration equals the net force on the wagon divided by its mass (Newton's Second Law).

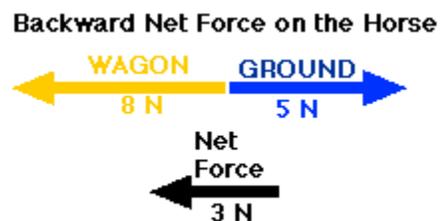
Why does the horse accelerate?

There are 2 forces that push or pull on the horse in the diagram above. The wagon pulls the horse backwards, and the ground pushes the horse forward. The net force is determined by the relative sizes of these two forces.

If the ground pushes harder on the horse than the wagon pulls, there is a net force in the forward direction, and the horse accelerates forward.



If the wagon pulls harder on the horse than the ground pushes, there is a net force in the backward direction, and the horse accelerates backward. (This wouldn't happen on level ground, but it could happen on a hill...)



If the force that the wagon exerts on the horse is the same size as the force that the ground exerts, the net force on the horse is zero, and the horse does not accelerate.



In any case, the acceleration of the horse equals the net force on the horse divided by the horse's mass (Newton's Second Law).

Why does the ground push on the horse, anyway?

The force "ground pushes horse" is the Newton's Third Law reaction force to "horse pushes ground". These 2 forces are exactly the same size. If the horse wants the ground to push him forward, he just needs to push backwards on the ground.

These two forces do not cancel because they act on different objects. The force "ground pushes horse" tends to accelerate the horse, and the force "horse pushes ground" tends to accelerate the ground.

What about the ground?

Looking at the force diagram at the top of the page, you see that there is one horizontal force pushing on the ground - the horse pushes on the ground. Therefore, there is a net force on the ground, so the ground should accelerate. Does it?

Of course it does! However the amount of acceleration equals the size of the net force divided by the mass of the Earth - and the mass of the earth is about 6×10^{24} kg. This means that the acceleration of the ground is much, much too small to notice.

Summary:

So, it is possible for horses to pull wagons! It is true that the force that the horse exerts on the wagon is the same size as the force that the wagon exerts on the horse, but these forces do not combine to produce a zero net force. The force exerted on the wagon (by the horse) affects the motion the wagon, and the force exerted on the horse affects the motion of the horse.

<http://www.batesville.k12.in.us/Physics/PhyNet/Mechanics/Newton3/HorseAndCart2.html>