More Collisions, Action and Reaction, and Systems

(Systems is the really important bit)

CPR deadline problem

- Due to the start of Daylight savings in California, the deadline for CPR submission changed from 9pm to 10pm yesterday without me knowing!
- I've given everyone an extension until 10pm tonight.
- Let me know if anything else goes wrong...

Zoho Viewer problem

- Seems to mangle some (but not all) pdf files from windows computers.
- Sometimes they come through with mangled or missing diagrams. Sometimes they don't come through at all - you get a spinning wheel.
- But files do seem to "save" correctly - so do this.
- e.g. http://viewer.zoho.com/docs/vcaVbP
- Best not to use Zoho - more reliable alternatives exist and are explained in the instructions.

Collisions and Vectors Continued

- Remember - we talked about collisions, momentum being conserved, and dealing with vectors graphically.
- Now lets talk about vectors done by components.

Using components

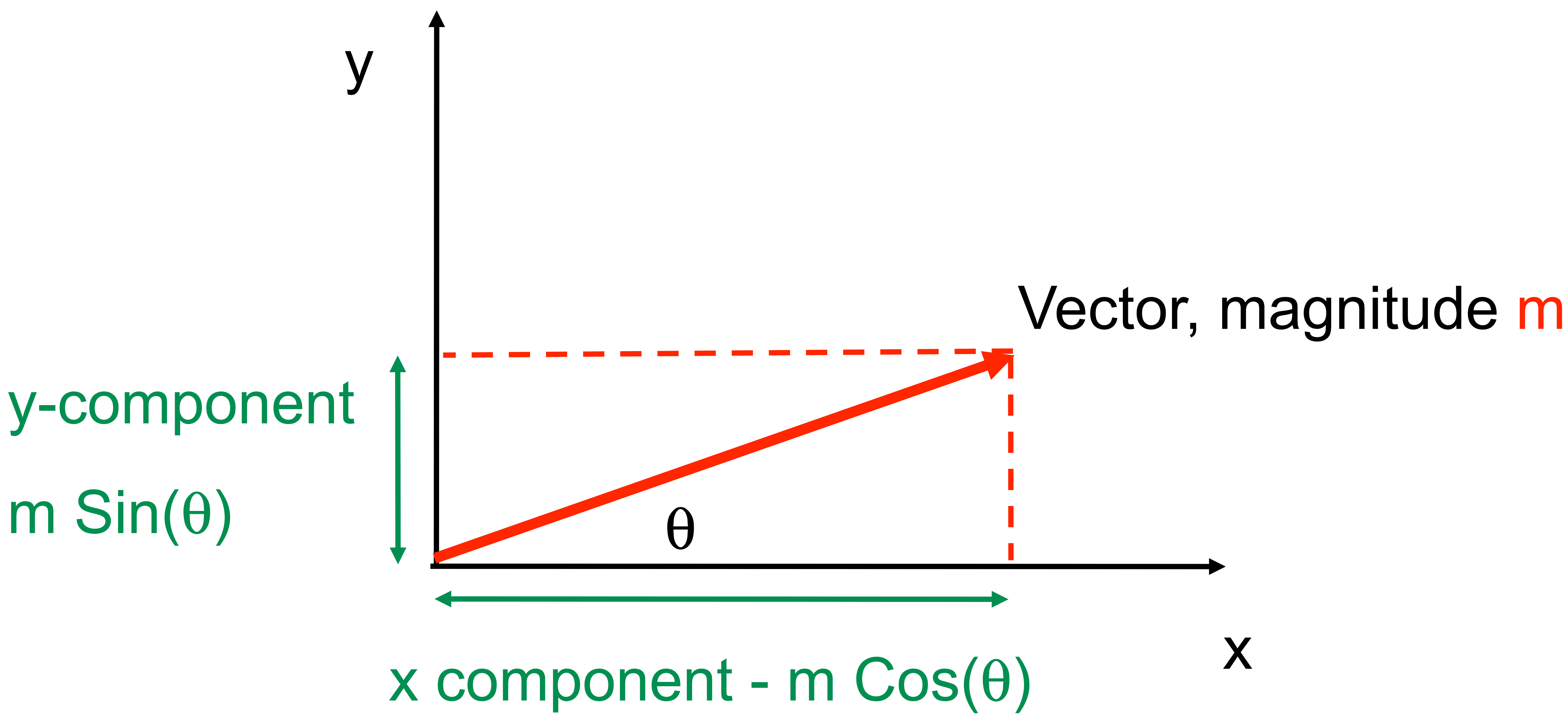
- An incredibly powerful way to deal with vectors.
- Revolutionised all of physics when it was invented (300 year ago, by Rene Descartes).
- You have to pick some “coordinate axes”
- Then work out “the components” of each vector along each axis.
- Then just add-up or subtract these components - as scalars.
- It allows you to turn one vector problem into three scalar problems.

Pick your axes…

- The answer will be the same regardless of which axes you choose.
- So choose whatever set of axes make your calculation easiest.

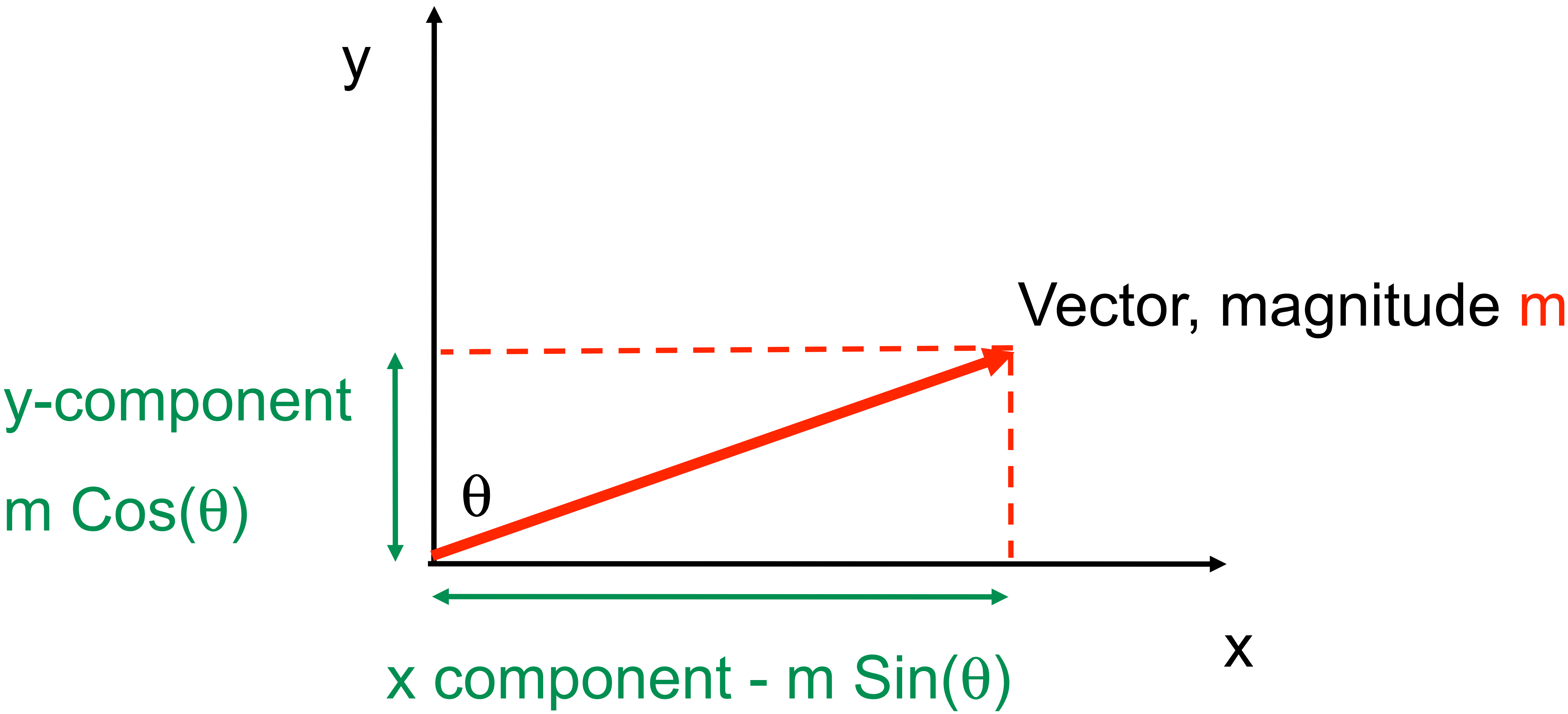
Converting a vector to components

- Trigonometry



Watch where θ is...

- Trigonometry



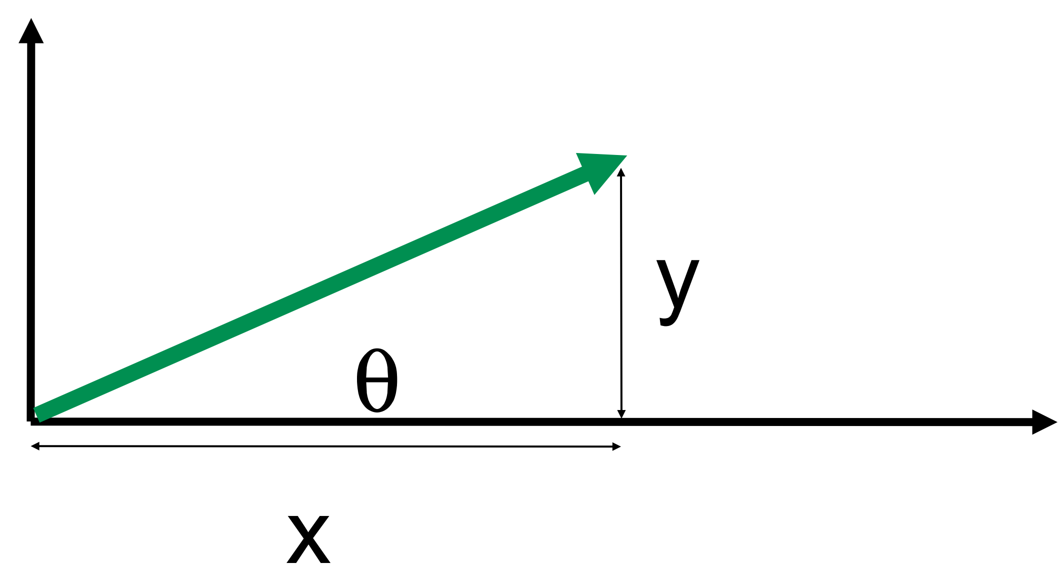
Converting components back into a vector

- If you have components (x, y, z), the magnitude m of the vector is (Pythagorus)

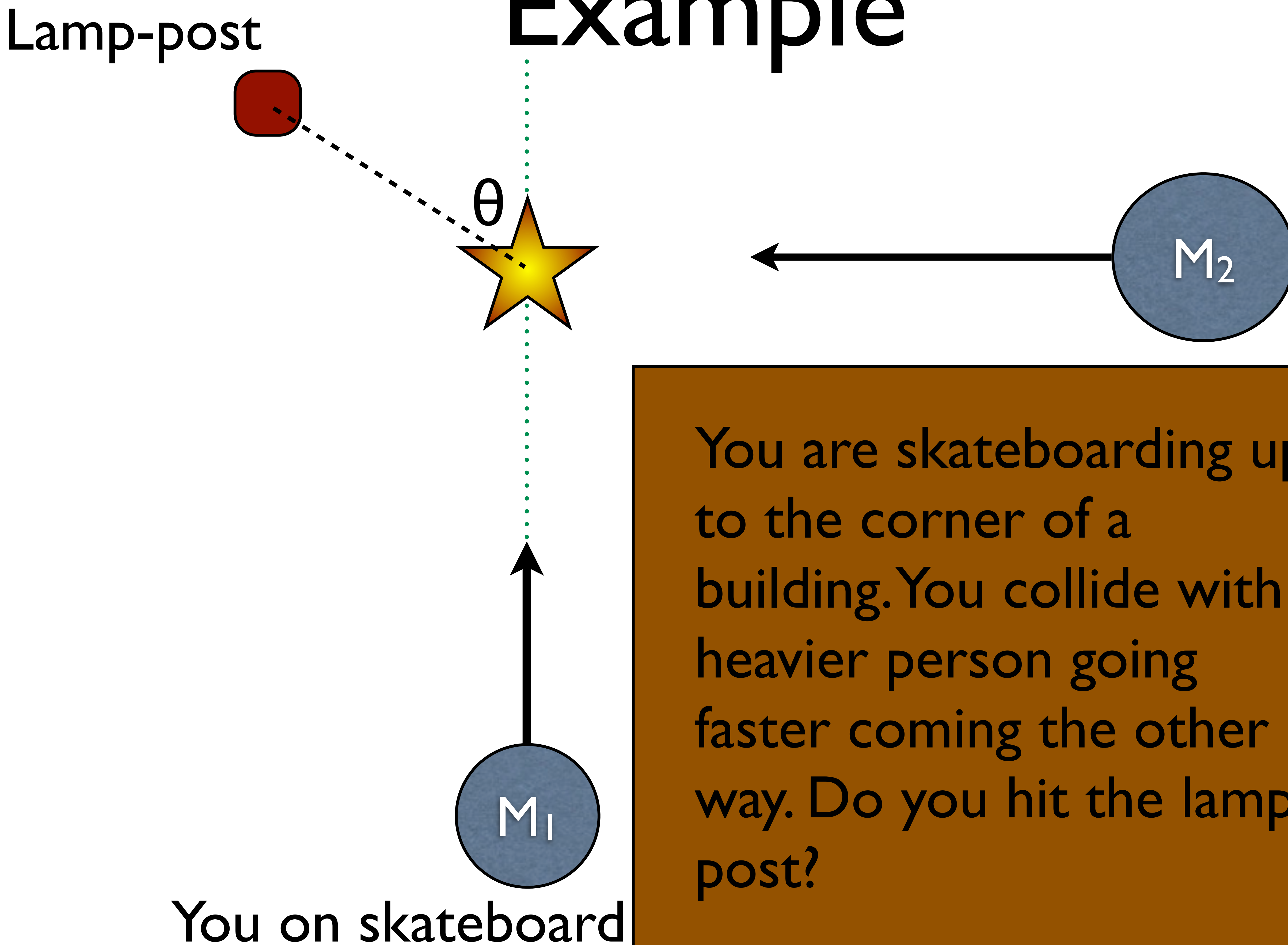
$$m = \sqrt{x^2 + y^2 + z^2}$$

- The angle to the x axis (if z=0) is:

$$\theta = \arctan(y / x)$$

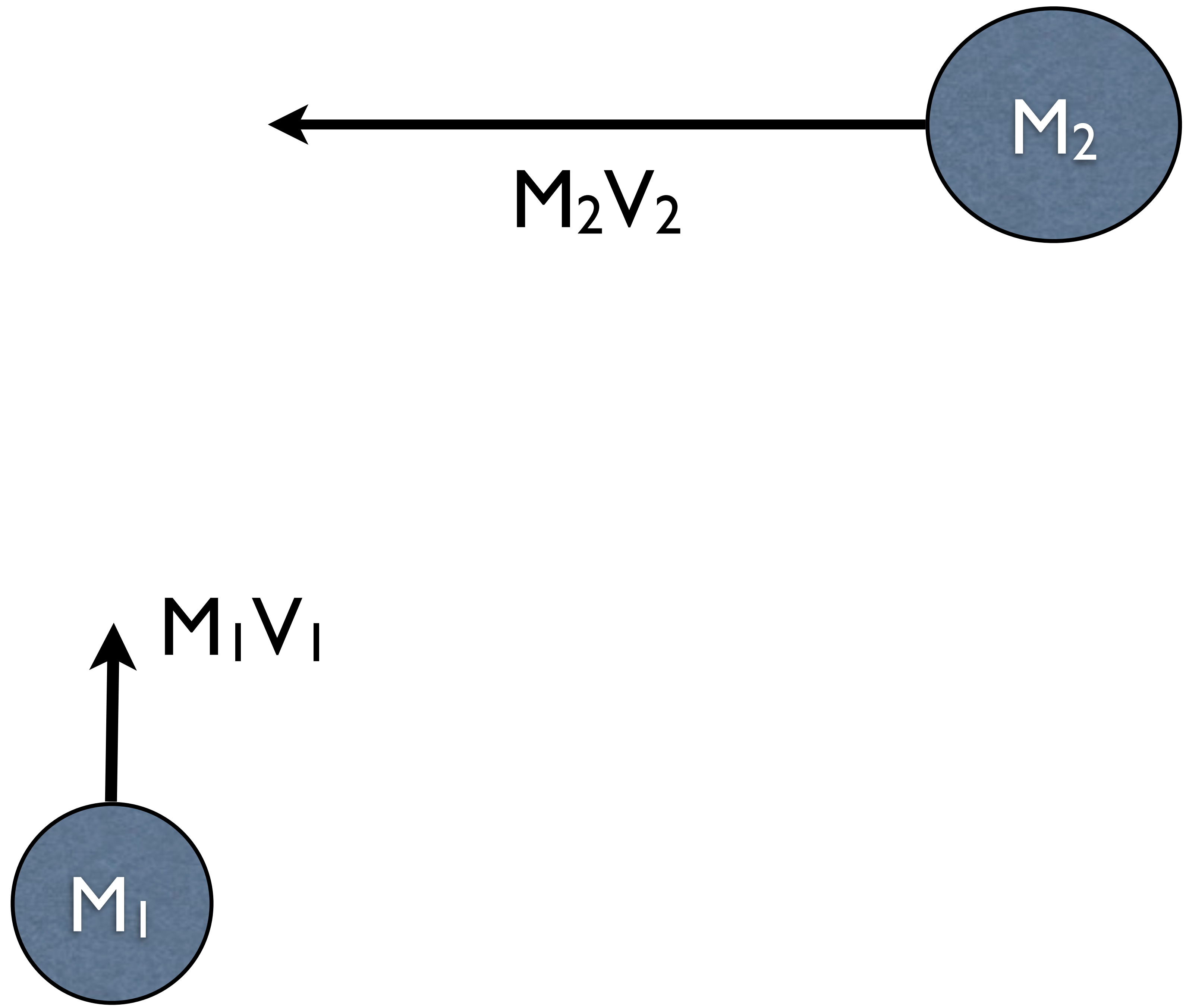


Example

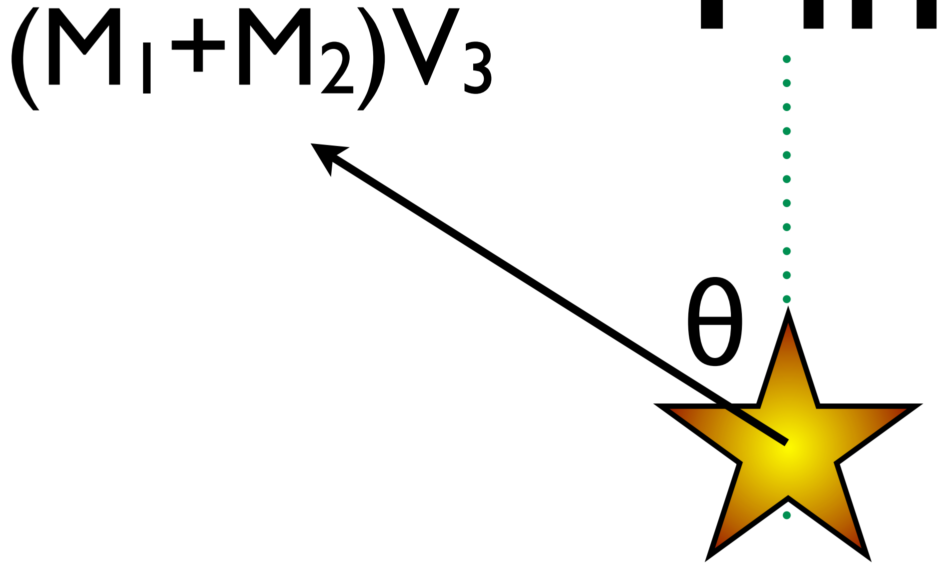


You are skateboarding up to the corner of a building. You collide with a heavier person going faster coming the other way. Do you hit the lamp-post?

Initial momentum



Final Momentum



All the momenta are VECTORS.
The most common mistake in doing questions like this is to forget to treat them as vectors.

In the upward direction, $M_1V_1 = (M_1+M_2)V_3 \cos(\theta)$

In the leftwards direction, $M_2V_2 = (M_1+M_2)V_3 \sin(\theta)$

To see if we will hit the lamp-post, we need to determine θ.
Divide bottom equation by top to eliminate V_3.

So we get...

$$\tan\theta = \frac{M_2 V_2}{M_1 V_1}$$

- So

$$\theta = \arctan\frac{M_2 V_2}{M_1 V_1}$$

TO find how fast we hit

- We could substitute θ back into one of the equations and solve for V_3.
- Or there is a mathematical trick - square both equations and add them together, and make use of the fact that $\sin^2\theta + \cos^2\theta = 1$

Answer

$$(M_1V_1)^2 + (M_2V_2)^2 = (M_1 + M_2)^2 V_3^2 (\sin^2\theta + \cos^2\theta)$$

$$V_3 = \frac{\sqrt{(M_1V_1)^2 + (M_2V_2)^2}}{M_1 + M_2}$$

In general - write down the initial and final momentum.

Set each component of momentum to be equal before and after the collision.

Key Facts

- Momentum is conserved in collisions.
- If energy is conserved too, the collision is elastic and the objects bounce back at the same relative velocity.
- If objects are not all moving along the same line, you have to treat momentum as a VECTOR.

Systems

And Newton's Third Law

A paradox

Which is larger?

- Imagine the horse is moving at a steady speed. Which is larger?
- The force by which the horse pulls the cart, or the force by which the cart pulls back on the horse?
- Clicker Question

Equal

- Newton's Third Law
- Every action has an equal and opposite reaction.

What about acceleration?

- If the horse was accelerating the cart (say starting from rest and breaking into a gallop) -
- Are the forces still equal?
- Clicker Question: By yourself.

They are equal

- But if the forces are equal and opposite, as Newton's third law says they must be.
- Equal and opposite forces cancel out.
- So there can be no net force.
- So how can the cart accelerate?

How to resolve this?

- Systems.
- The Momentum principle is that:

"In a given collection of objects (a system), momentum is conserved unless an external force is applied to this system."

What is a system?

- All the conservation laws (momentum, energy and angular momentum) apply everywhere.
- So you can define any system you like.
- The trick is to be self-consistent.

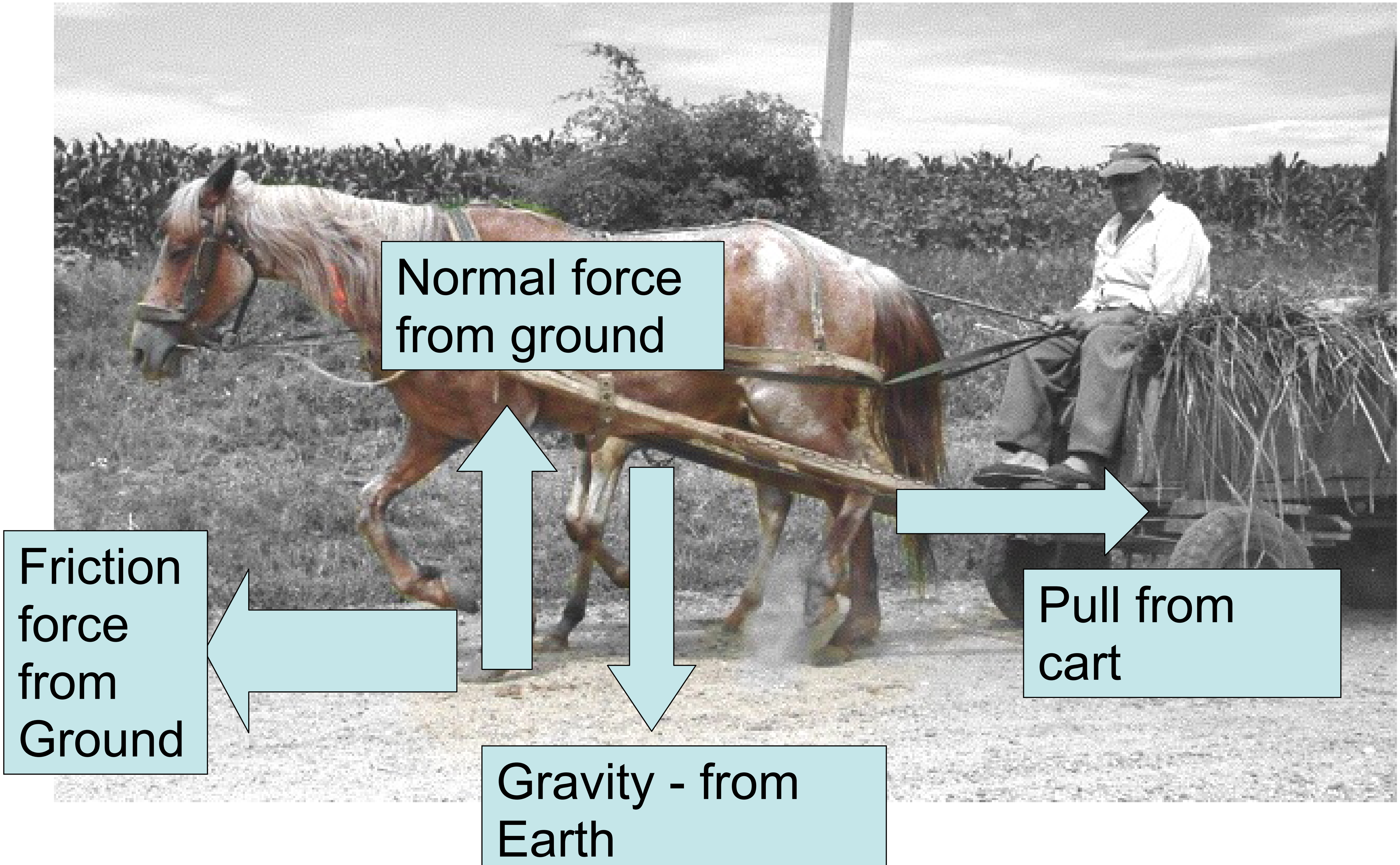
What systems shall we use?

Horse only? What forces apply?

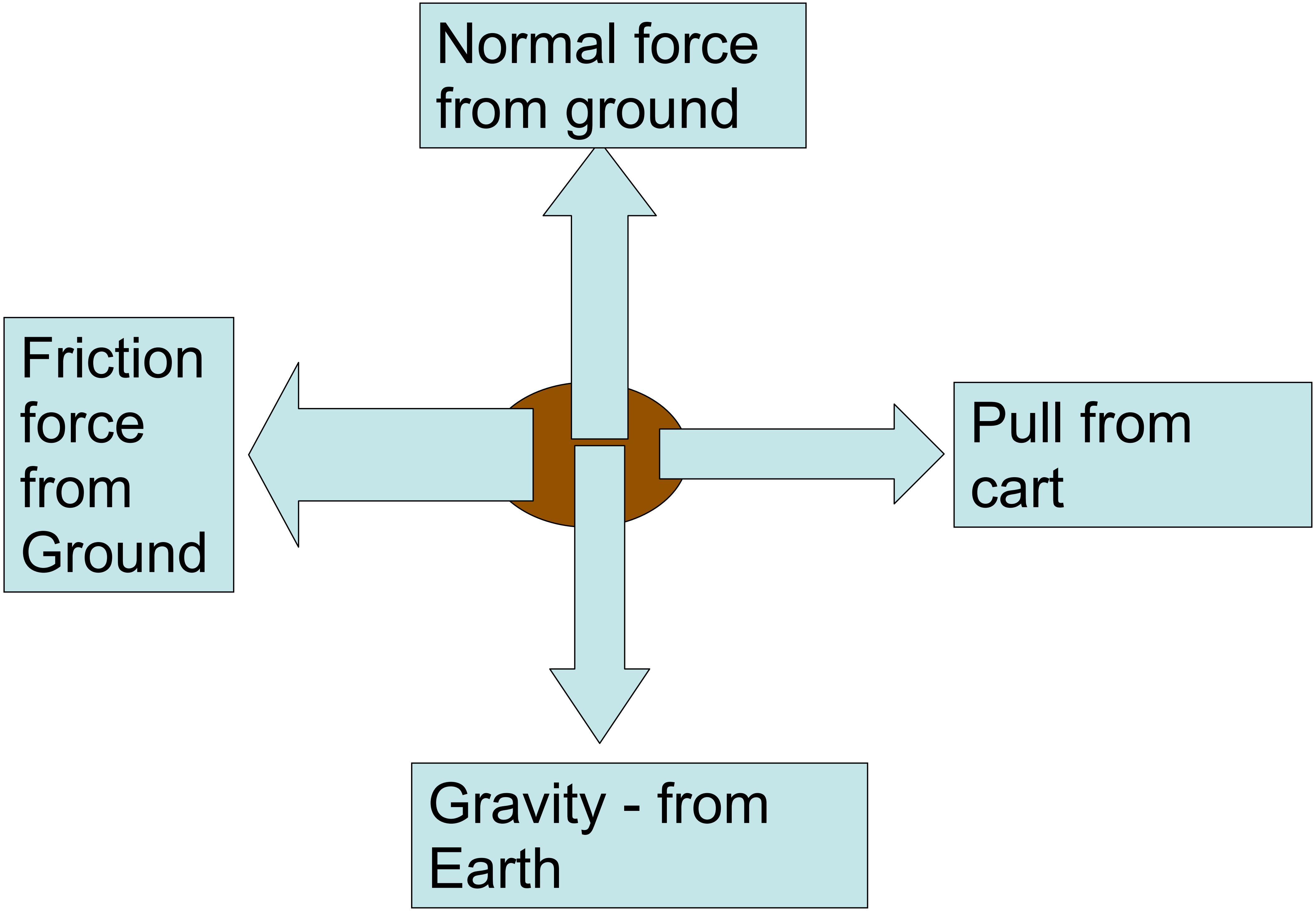
Clicker Question…

- What forces apply?

Horse only? What forces apply?



Free body diagram



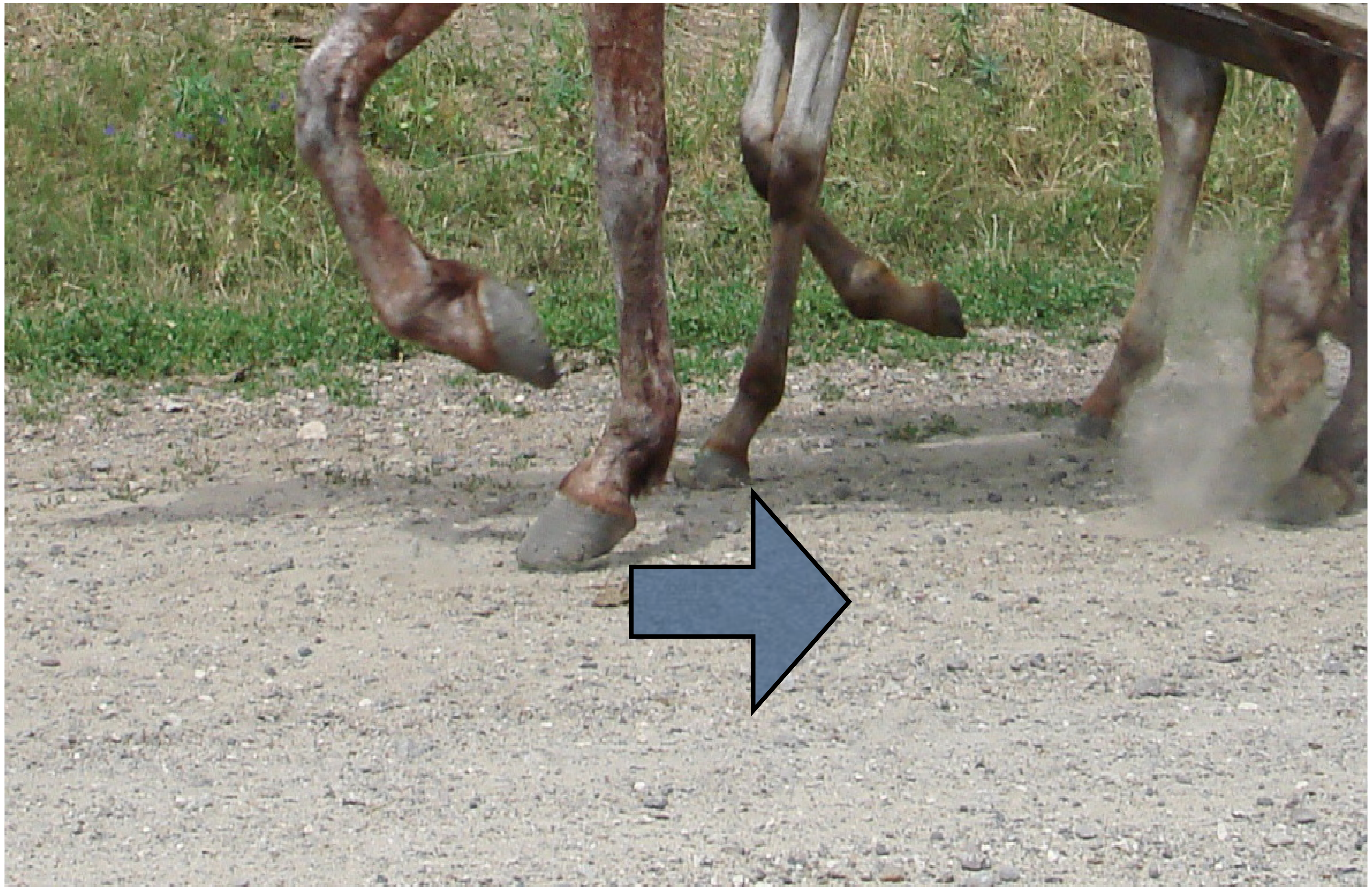
Why is friction forwards?

- We know it must be.
- As otherwise the net force would be backwards and the horse could not continue at a uniform speed.
- But why? Doesn’t friction oppose motion?
- Any ideas? Discuss.

Imagine the road were ice

- If the horse's hooves were slipping, in which way would they move relative to the ground?

legs are trying to go backwards



Friction stops them from doing so...

Car accelerates

- What are the forces?
- Is there a friction force?
- If so - does it point forwards or backwards?

It points forward

- (there is probably also some drag which points backwards. But if its accelerating, the net force must be forwards)
- Otherwise it wouldn't be accelerating...

Car on Skateboard

- One way to think about it. Imagine the car was resting on a skateboard.
- When you put your foot on the accelerator, which way will the skateboard go?
- That tells you the direction of the force the car applies to the road.

the road pushes back in the opposite direction

Car decelerates

- What are the forces?
- Is there a friction force?
- If so - does it point forwards or backwards?

Backwards

- Now you are using the brakes.
- If you skidded, the wheels would be moving forward along the road.
- So friction must be backwards.

So two ways to work it out.

- Draw a free-body diagram. In which direction does the force have to point to make the object behave as observed?
- Work out which way the hooves or tyres would push the ground if the ground were a skateboard. Friction pushes back.

Meanwhile, back to the cart

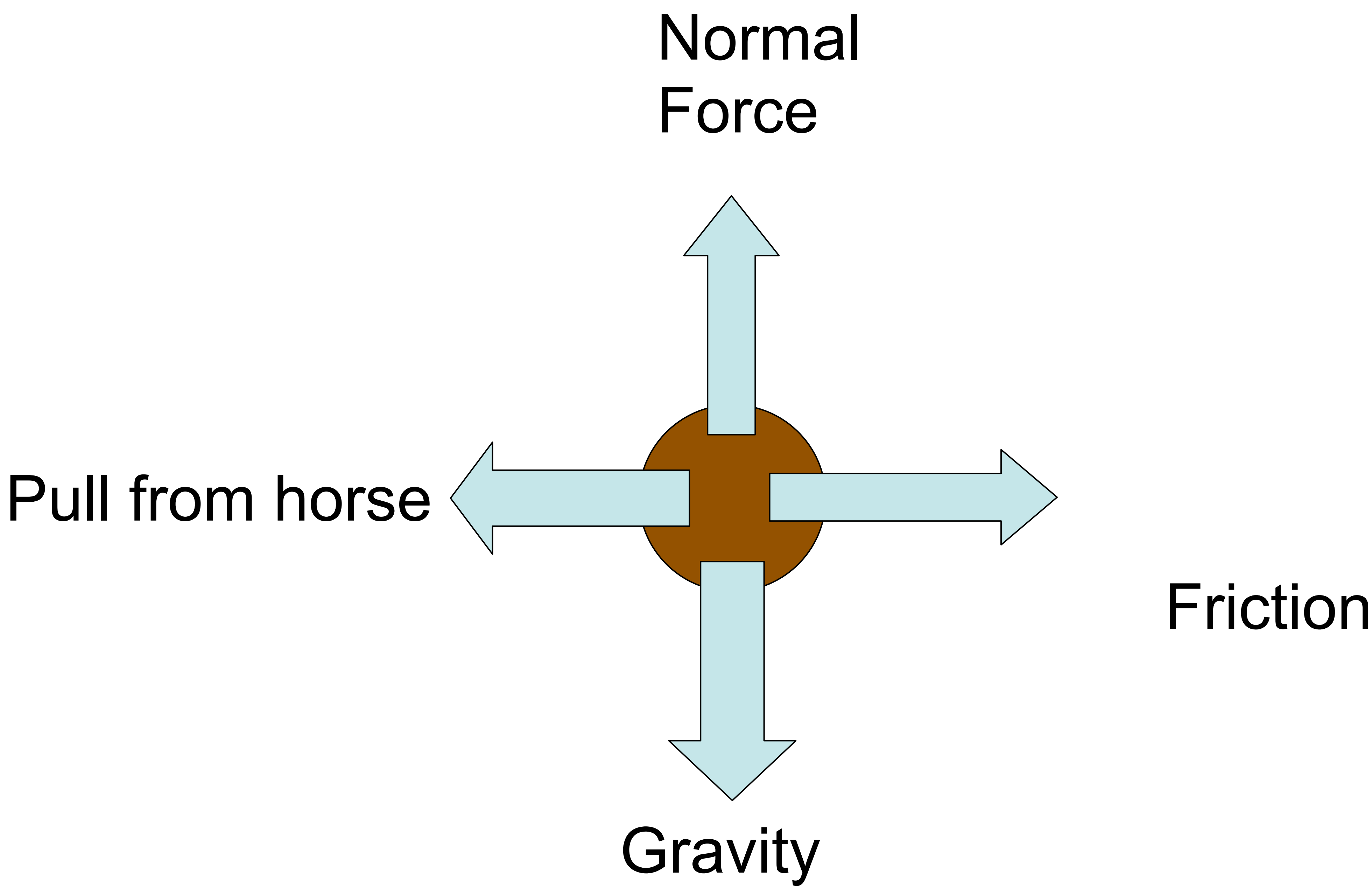
- It will accelerate if...
- the forward friction at its hoofs is greater than the backward pull from the cart.

Make the CART the system

What forces apply here?

- Draw a free-body diagram.

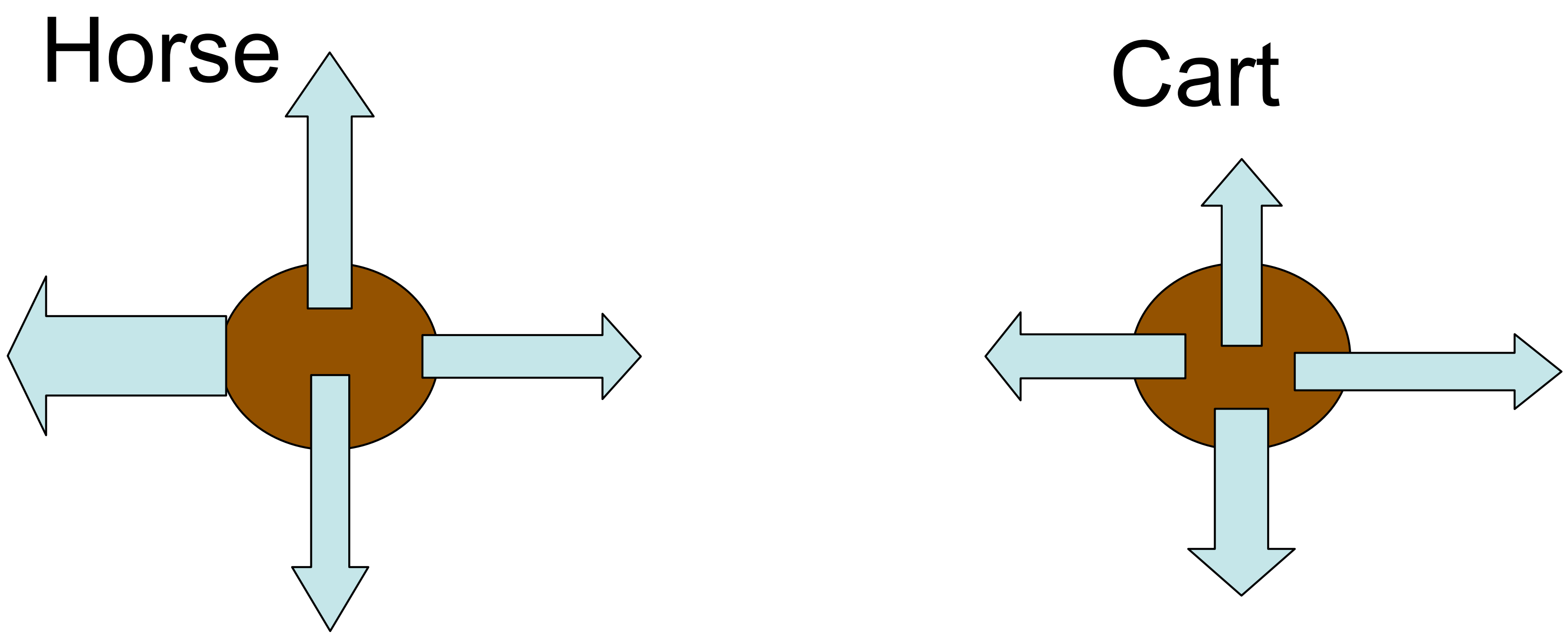
Free body diagram for cart.



It will accelerate if…

- The forward force from the horse is greater than the backward friction force on its wheels.

Where does Newton's third law come in?



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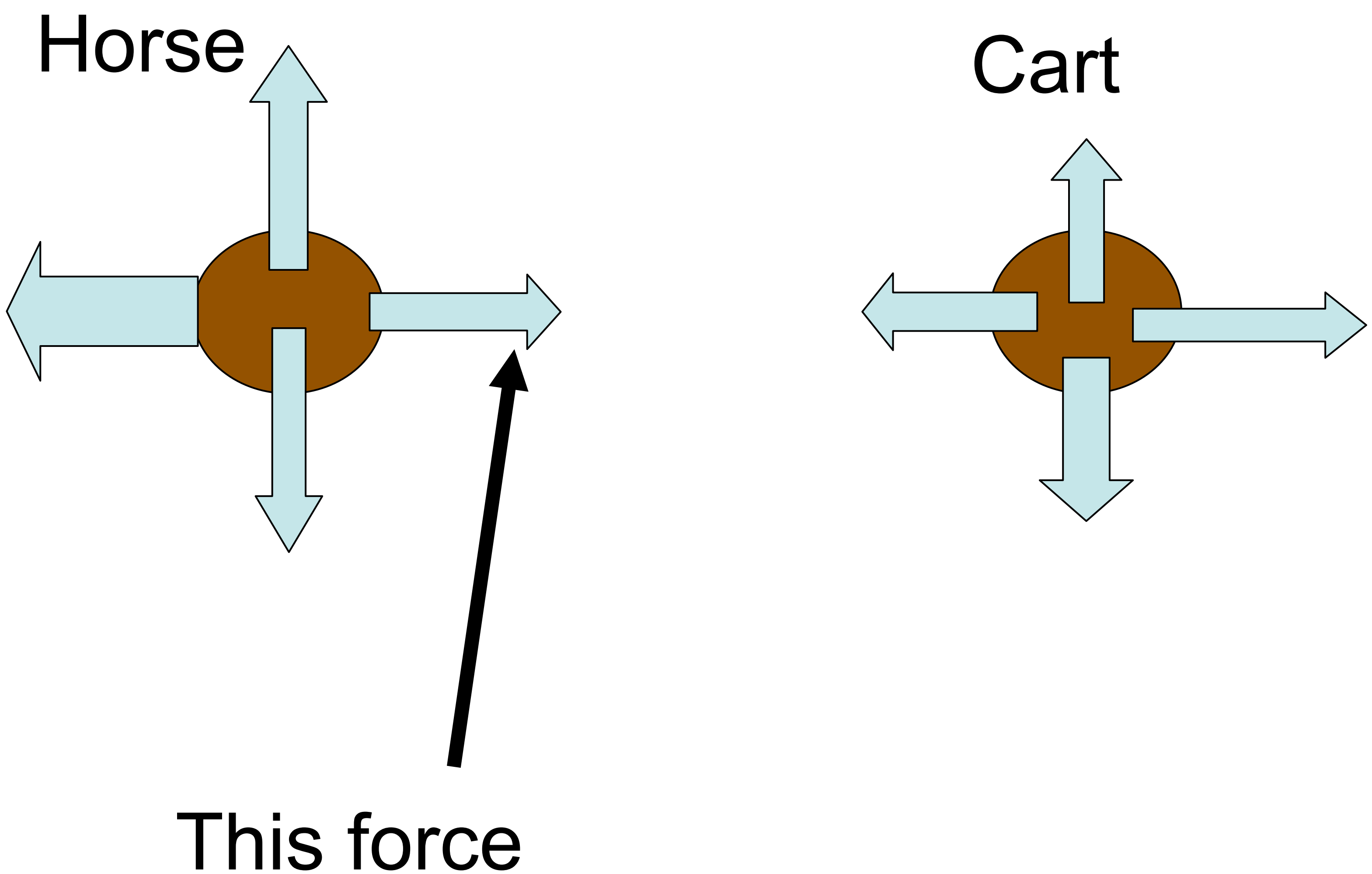

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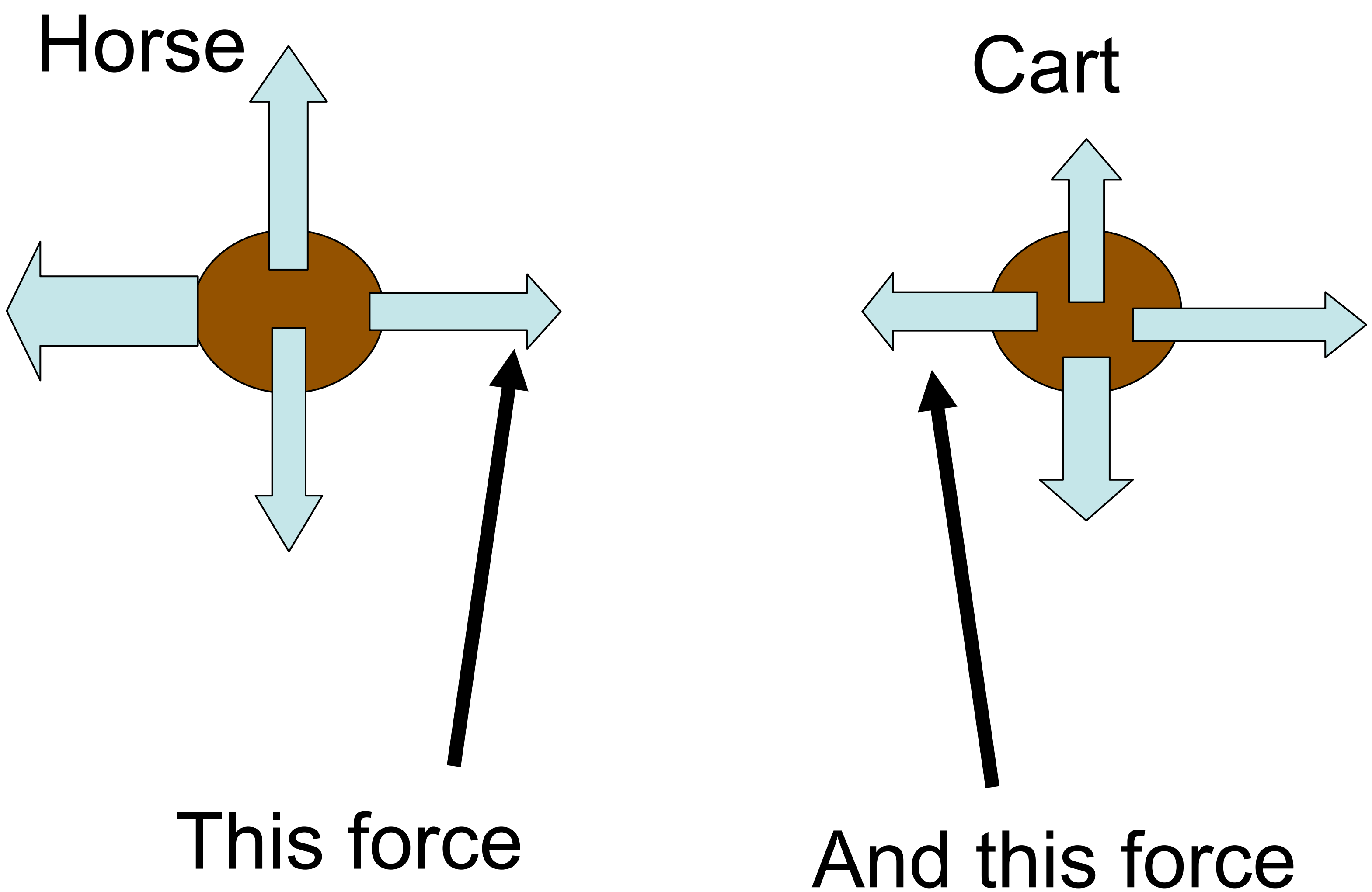
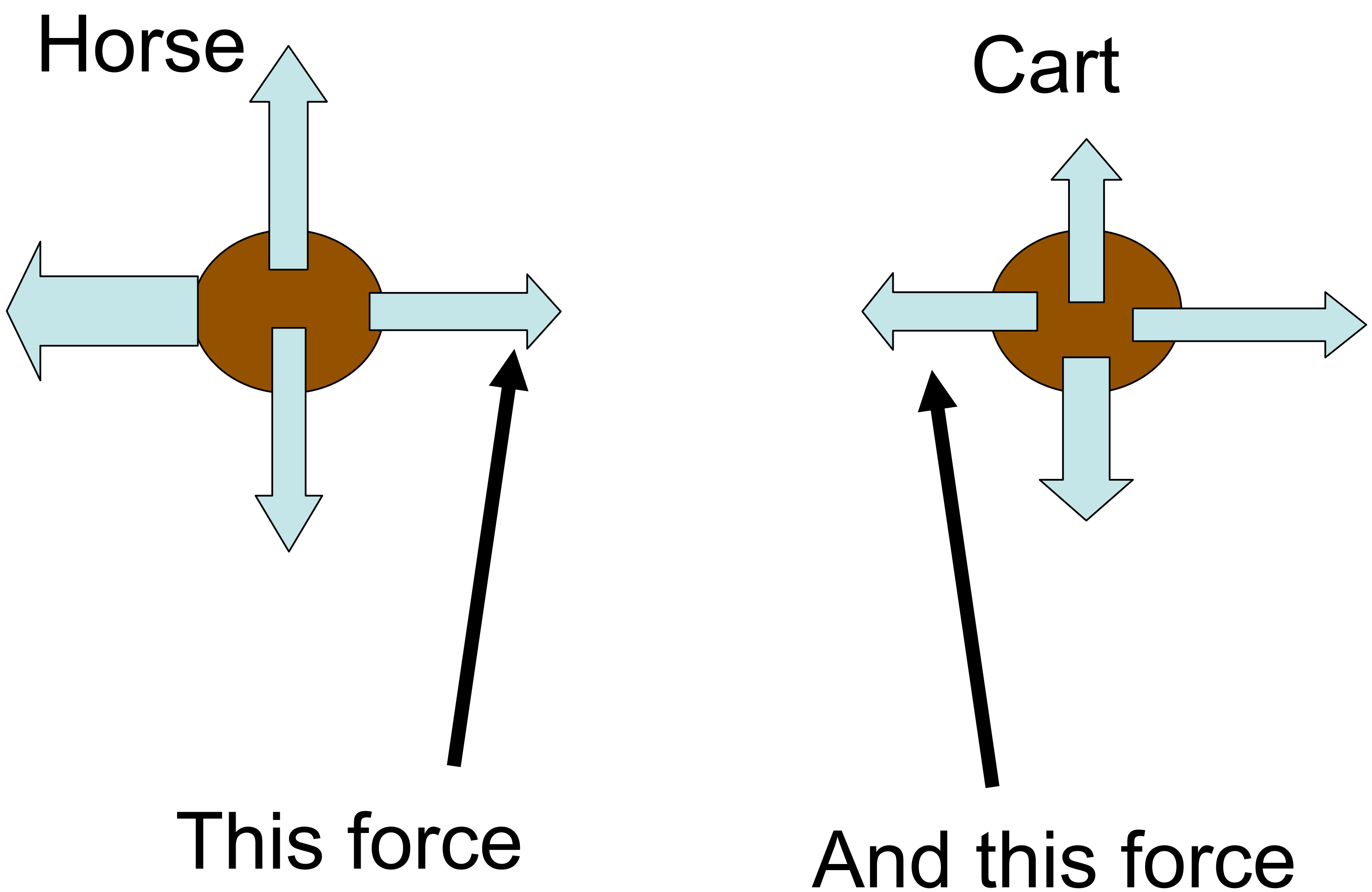


Where does Newton's third law come in?



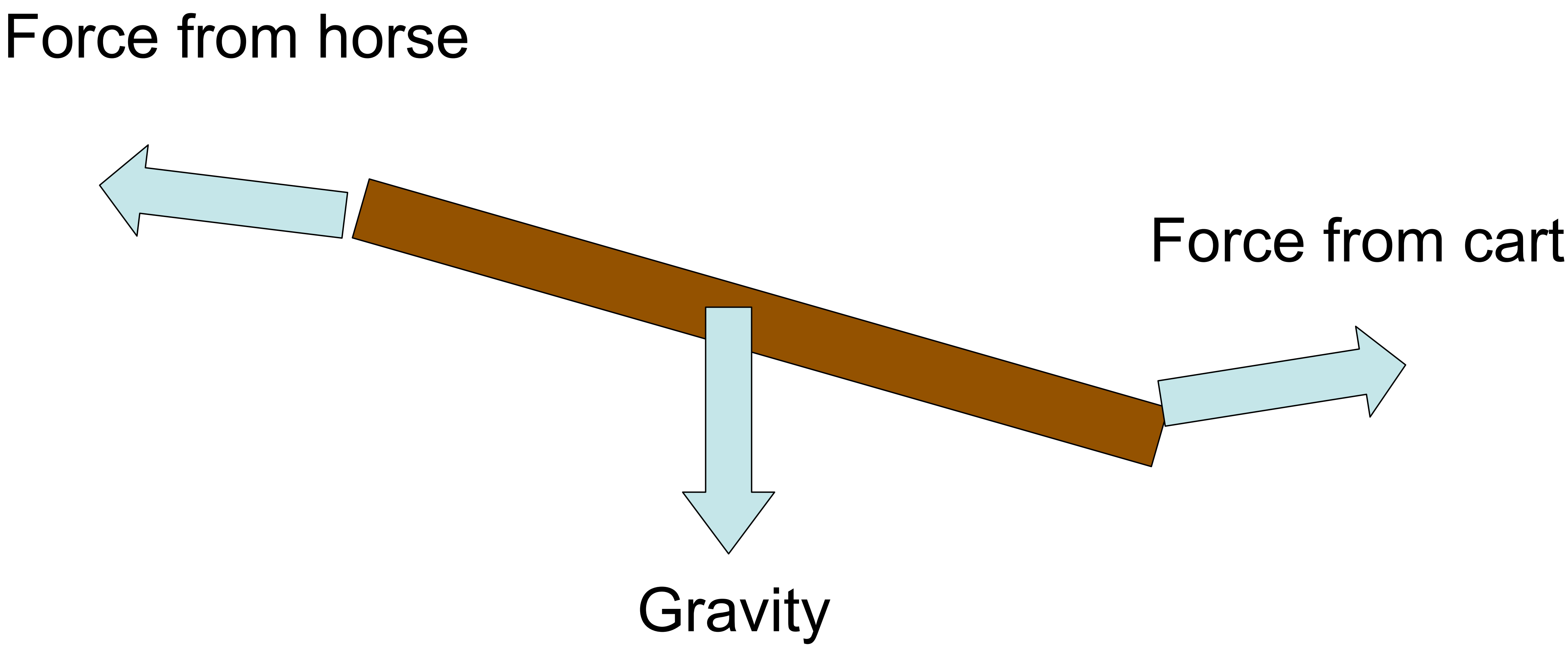
Must be equal and opposite.

But they are acting on different systems

- These forces were equal and opposite - and if they were both acting on the same system, they would not accelerate it.
- But if we choose either the horse or the cart as our system, only one applies to it.

How about the yolk connecting them?

Free-body diagram of Yolk

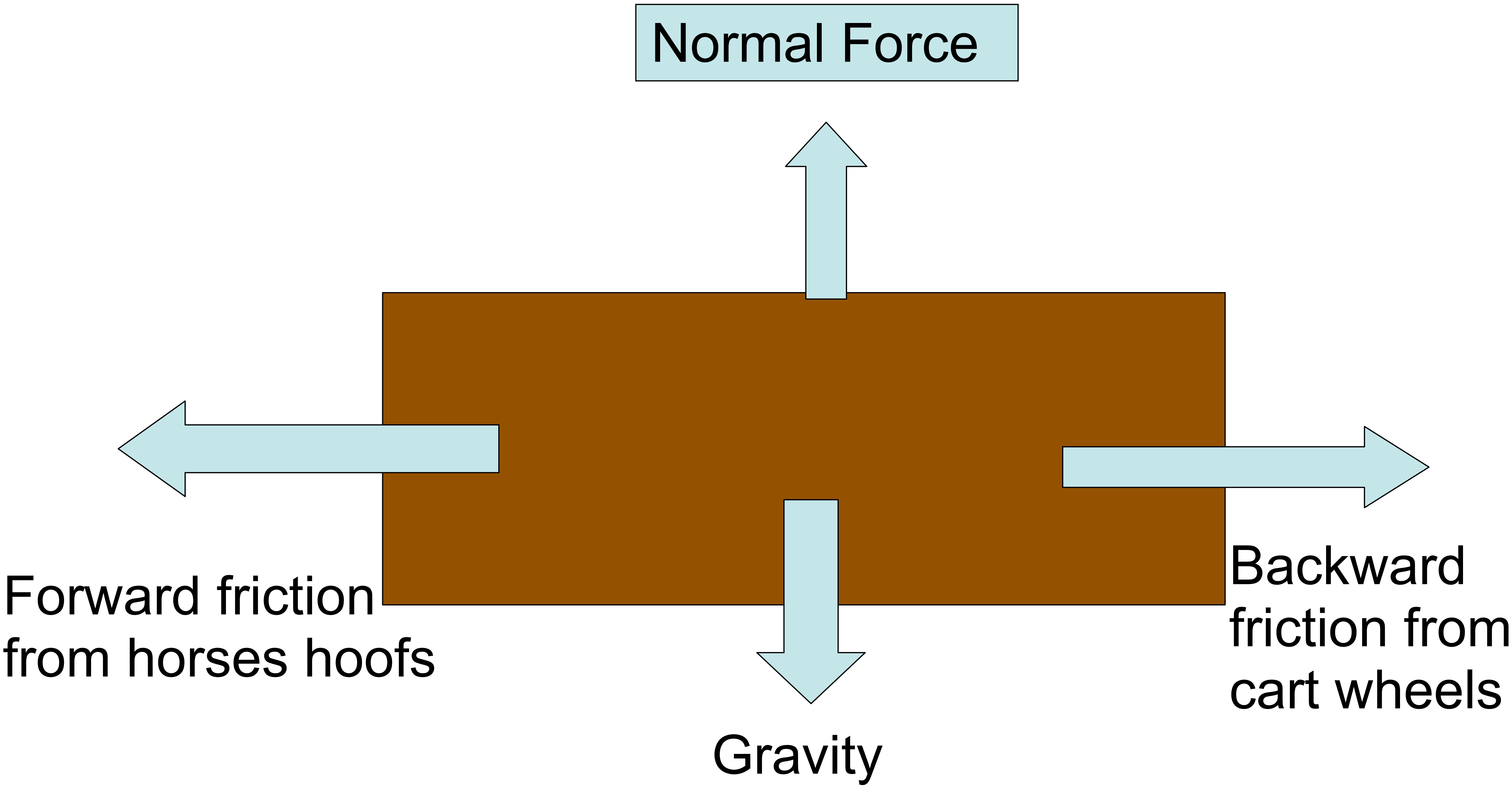


It will accelerate if…

- The forward force from the horse is greater than the backward pull from the cart.

Horse and cart?

Free-body diagram



Internal forces

- In this case the force between horse and cart, and vice versa, is *internal to the system* - it applies from one part of the system to another, and can hence be ignored.
- Only count forces applied to the system from outside.
- Due to Newton’s third law, any internal forces will cancel out.

Or many other possibilities

- For example the horse and road combined - or the horses' nose, or a cubic centimetre half way up the yolk…
- Regardless - if the forces ON THIS SYSTEM balance, it will not accelerate.
- If they do not balance, it will.

What you need to do

- Draw free-body diagram, to make it clear to yourself which forces act on which bodies.
- Define your system. And stick to it.
- The laws of physics will apply to any system you choose - so choose the one that makes your calculation easiest.

Big source of mistakes

- I strongly urge you to try and get in the habit of thinking “what is my system?”, “What forces are acting on this system?”
- Not doing this is a huge source of error and frustration.

Conclusions

- Newton's third law (every action has an equal and opposite reaction) applies always and everywhere.
- But don't confuse forces with damage or acceleration - if a bug hits your windscreen, the forces are equal and opposite, but the acceleration and damage are not!
- And remember that the action and reaction apply to different systems. Being careful to think through your systems is a very very good habit!