Lecture 6

Checking, and Circular Motion

Course Representatives

- We need to elect some.
- Their job is to be a point of contact between students and university. It involves 1 or 2 meetings, and being prepared to listen to your classmates and take their concerns to your lectures or beyond.
- If you are interested in taking on this job - put a posting on the forum. We'll have an election next week.

Drop-ins

- A chance to work on your homework in a friendly environment, with help right there is you need it.
- Second year students will be on hand to help you with anything in the course.
- Sign up now on Wattle
- Optional

Checking

- Everyone makes mistakes. The trick is to find and fix them.
- Here are three tricks to help you do this.

Trick 1: Is the answer ludicrous?

- Look at your answer. Apply your common sense. Is it totally ridiculous?
- Here are some (clicker) examples taken from actual exam papers.

Clicker Question

- A basketball player jumps vertically upwards and throws a basketball sideways at 17m/s, at an angle of 12 degrees above the vertical.
- What is the horizontal speed of the player just before she lands?
- Could the answer be 12 m/s?

The Answer

- It’s hard to imagine the player recoiling at 12 m/s - that’s nearly 40 km/hr.
- You would bounce off the opposite wall every time you made a pass if this was true.

Clicker Question

- If you burn a litre of petrol, how much energy do you get out.
- Could the answer be 10^{17} J?

The Answer

- That's more energy than an atom bomb - not plausible.
- (the student used $E=mc^2$...)

Clicker Question

- A cyclist of mass 80kg is cycling up a 10% slope hill at a constant speed of 7 m/s.
- Because the speed is constant, he is exerting no power and hence doing no work.
- Could this be true?

The Answer

- It's hard work cycling uphill, so you must be using energy!

Conclusion

- If you produce an answer, LOOK AT IT!
- If it is clearly silly, you have probably made a mistake.
- Even if you haven't got time to find and fix the mistake, you will get credit for pointing this out.

Method 2: Form/ Behaviour of Equation

- You can usually tell how the equation behaves just by looking at it.
- Does it behave in a sensible way?
- Does it go up when the right variables increase?
- Does in give sensible answers for special cases like zero speed, angles of 90 degrees etc?

Clicker Question

- Imagine that you work for the European Space Agency, and are trying to calculate how much the path of a spacecraft will be deflected if it passes a distance d from an asteroid of mass m.
- Which of these equations is plausible?

$$\frac{Gm}{d^3}$$

$$\frac{e^m}{dG}$$

$$Gm^2e^d$$

$$\frac{1}{Gmd}$$

$$\frac{G}{md}$$

The answer

- You'd expect the deflection to increase as the mass of the asteroid increases, decrease as the distance increases, and be zero if the gravitational constant was zero.
- Only the first answer meets these expectations.

$$\frac{Gm}{d^3}$$

G is on the top so it makes this increase

$$\frac{GM}{d^3}$$

It is cubed,, which means it has a bigger effect

d is on the bottom, so it makes this decrease

The 3rd Method: Dimensions/Units

- The units (dimensions) on both sides of an equation must be the same.
- If they are not, the equation MUST be wrong.
- You often need to go back to the fundamental units (mass, length, time).

Example

- Let's say you do a problem and find that the acceleration is given by

$$a = \frac{mg}{\sqrt{1 + \frac{v}{c}}}$$

where m is a mass, g is 9.8 m s^{-2}, v is the velocity and c is the speed of light.
Is this plausible?

Mass, units kg

Gravitational acceleration, units m s^{-2}

$$a = \frac{mg}{\sqrt{1 + \frac{v}{c}}}$$

Acceleration, units m s^{-2}

No units

Velocity of light, units m/s

Velocity, units m/s

Substitute in units

$$\frac{m}{s} = \frac{kg\frac{m}{s}}{\sqrt{1 + \frac{m/s}{m/s}}}$$

Cancel

$$\frac{m}{s} = \frac{kg\frac{m}{s}}{\sqrt{1+\frac{\cancel{m/s}}{\cancel{m/s}}}} = \frac{kg\ m}{s}$$

which doesn't match. So this must be wrong

Tricks

- Sine, Cosine, Tan etc are ratios, as are angles, and hence have no dimensions.
- If you don't remember the units of something, find a true equation that involves it and use that to find out the dimensions.

For example

- What are the dimensions of force?
- F = ma, mass has dimensions kg, acceleration has m s^{-2}.
- So dimensions of force are $$\frac{kg\ m}{s^2}$$

Energy

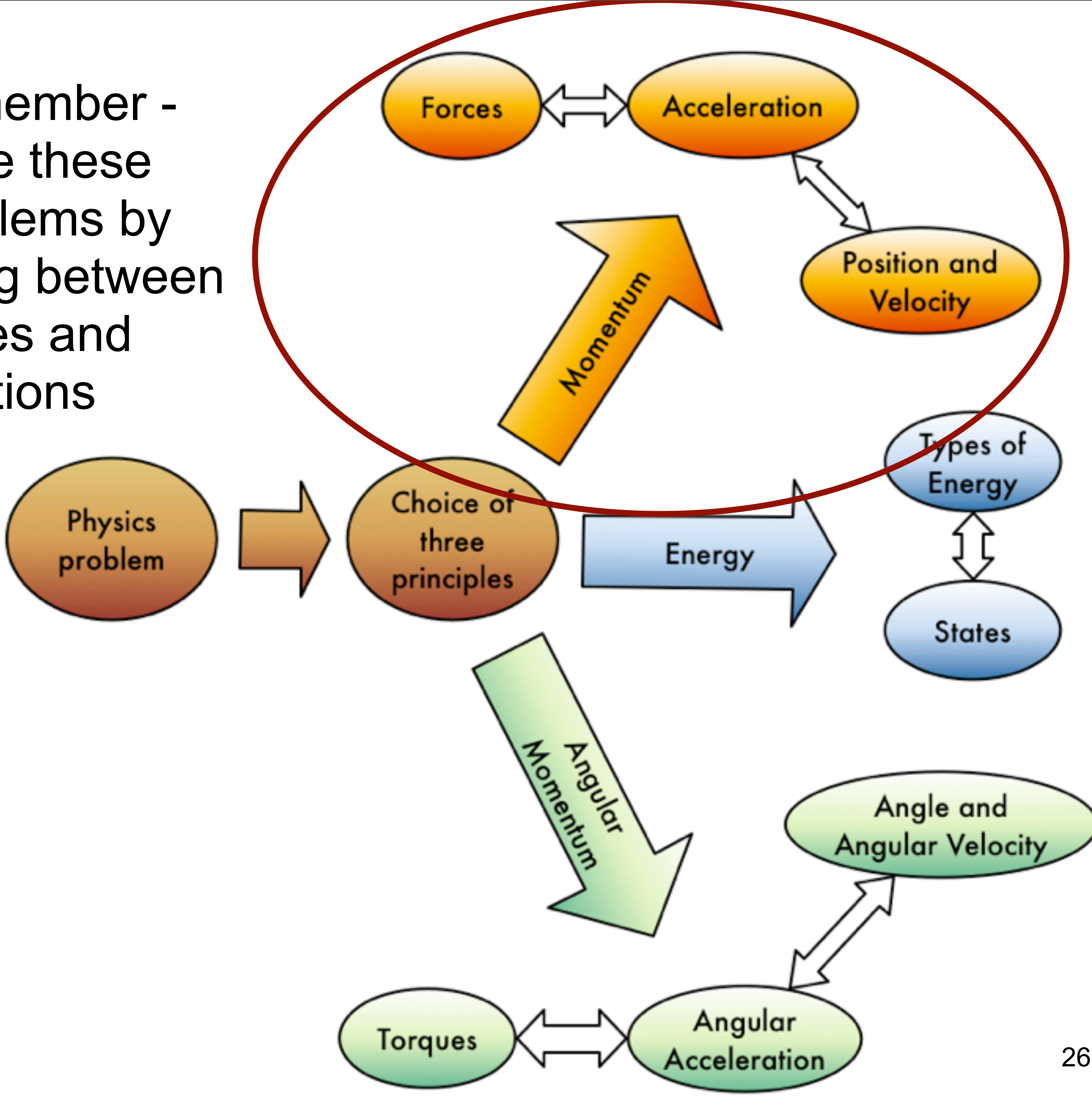
- Energy is mgh, h is a length (m) and so energy has dimensions

$$\frac{kg\ m^2}{s^2}$$

Back to Force/ Momentum

We will spend around 3 weeks on this principle

Remember - solve these problems by going between forces and positions



Special Cases

- Remember - there were a small number of special cases in which you can solve these problems mathematically.
- Most of the time you need a computer.
- We've talked about one special case - constant force. This leads to projectile motion.

Motion in a Circle, at constant speed.

- We'll now come to the second special case - motion in a circle at a constant speed.
- Then on to a third case - oscillation.
- And then we'll do the general case - where you need a computer.

Motion in a Circle

At a uniform speed.

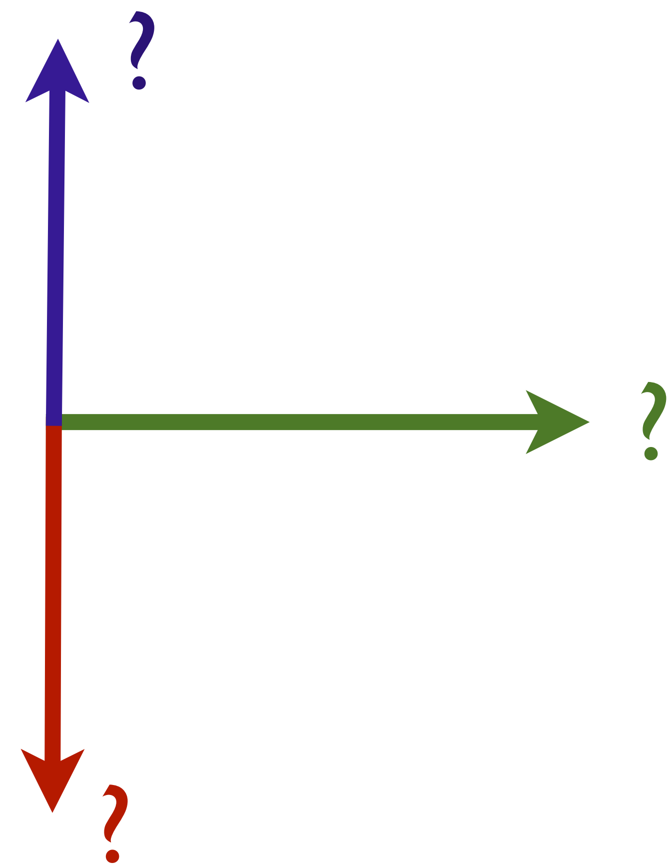
Clicker Question

- A car rounds a curve while maintaining a constant speed. Is there a net force on the car as it rounds the curve?

The Answer

- Yes.
- Velocity is a vector. It has a magnitude and a direction.
- A change in either the magnitude or the direction is a change in the vector.
- Any change in velocity is acceleration
- Any acceleration requires a force

Clicker Question



- In what direction is the force?

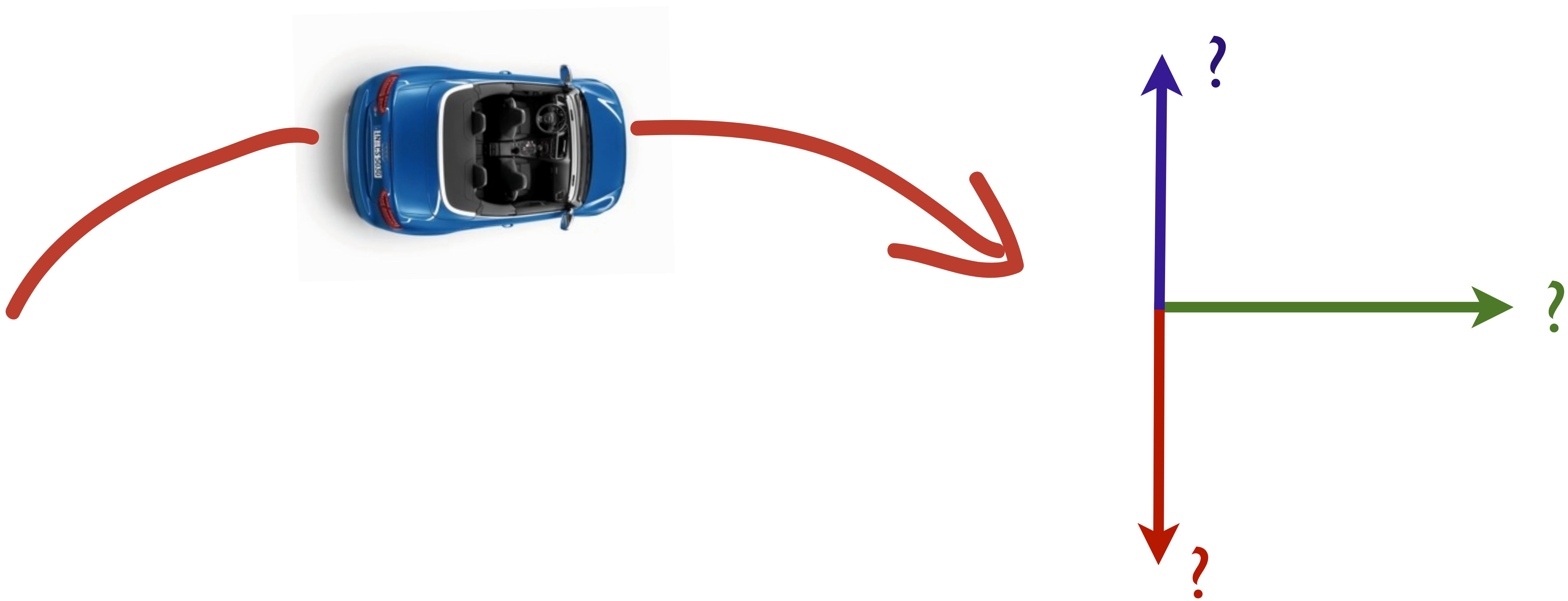
Let's see

- Try out the spaceship simulator here:
- http://tiny.cc/dzxaq
- (Click on today's lecture)
- It is the web page with today's course notes: full address
- http://www.mso.anu.edu.au/~pfrancis/phys1101/Lectures/

In what direction...

- do you have to apply a force to the rocket to make it go in a circle?

Clicker Question again



- In what direction is the force?

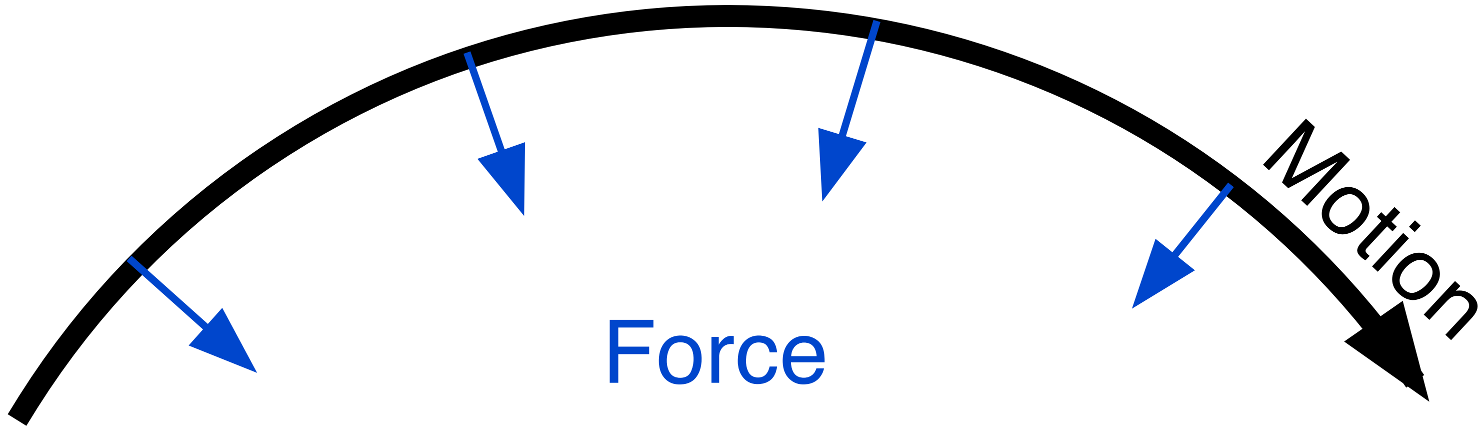
Answer

- The force has to point towards the centre of the circle.

Centripetal Force

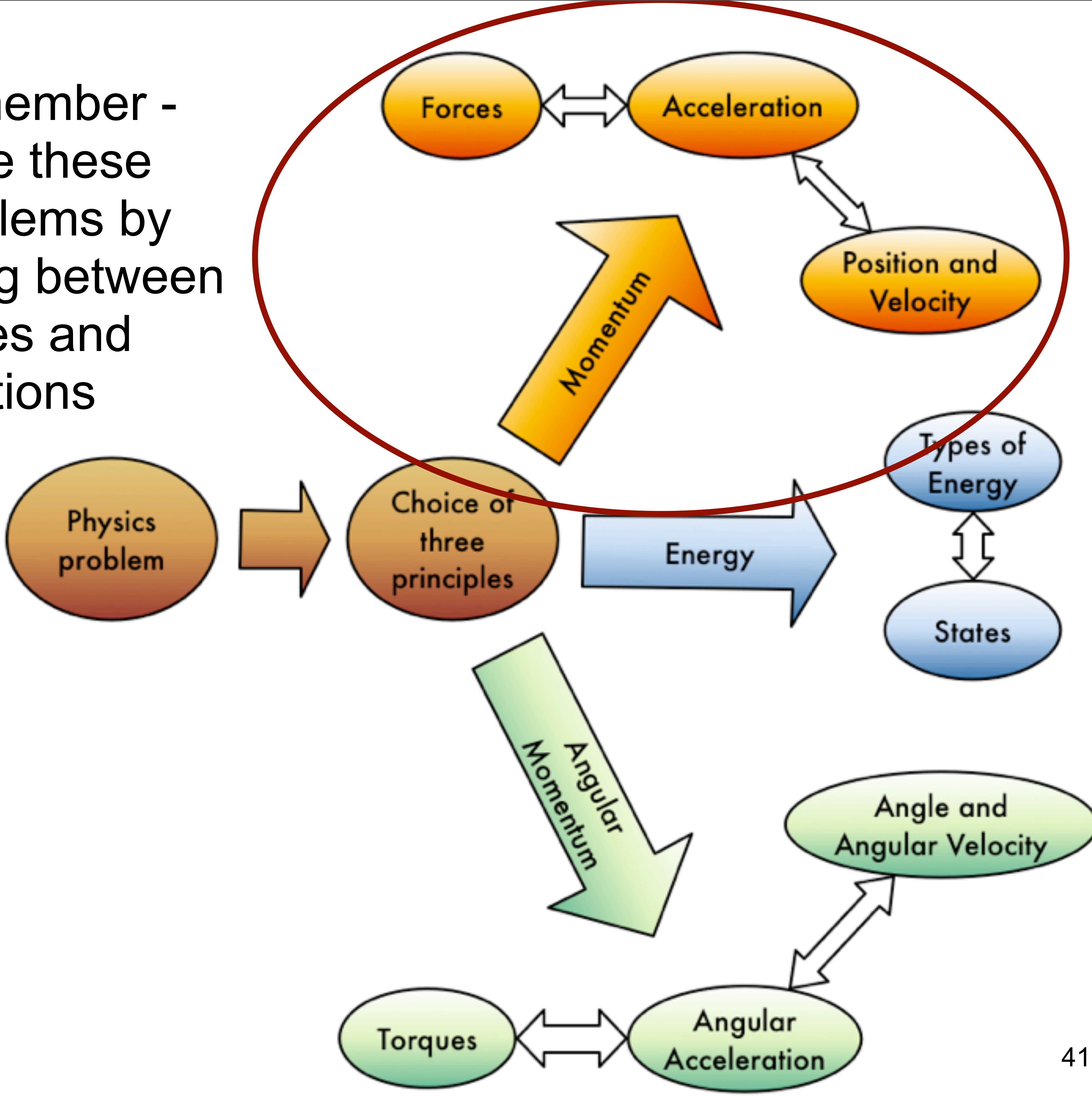
- If an object is moving in a circle, there must be a force pushing it towards the centre of the circle.
- The motion by itself does not magically provide such a force.
- Something outside must do it, like friction with a road, gravity, or a piece of elastic.

This is our special case



- A force that is constant in strength, but always points at right-angles to the direction of motion.
- Result - motion in a circle.

Remember - solve these problems by going between forces and positions



Both Ways

- From force to motion - a sideways force leads to circular motion
- From motion to force - if an object is moving in a circle, the net force must be sideways

Examples

- The Earth goes in a circle around the sun: The force towards the centre is provided by gravity.
- A car goes around a corner, the force is provided by friction between the tires and the road.
- The tips of a helicopter blade travel in circles, held in place by elastic forces within the blade

If something is moving in a circle

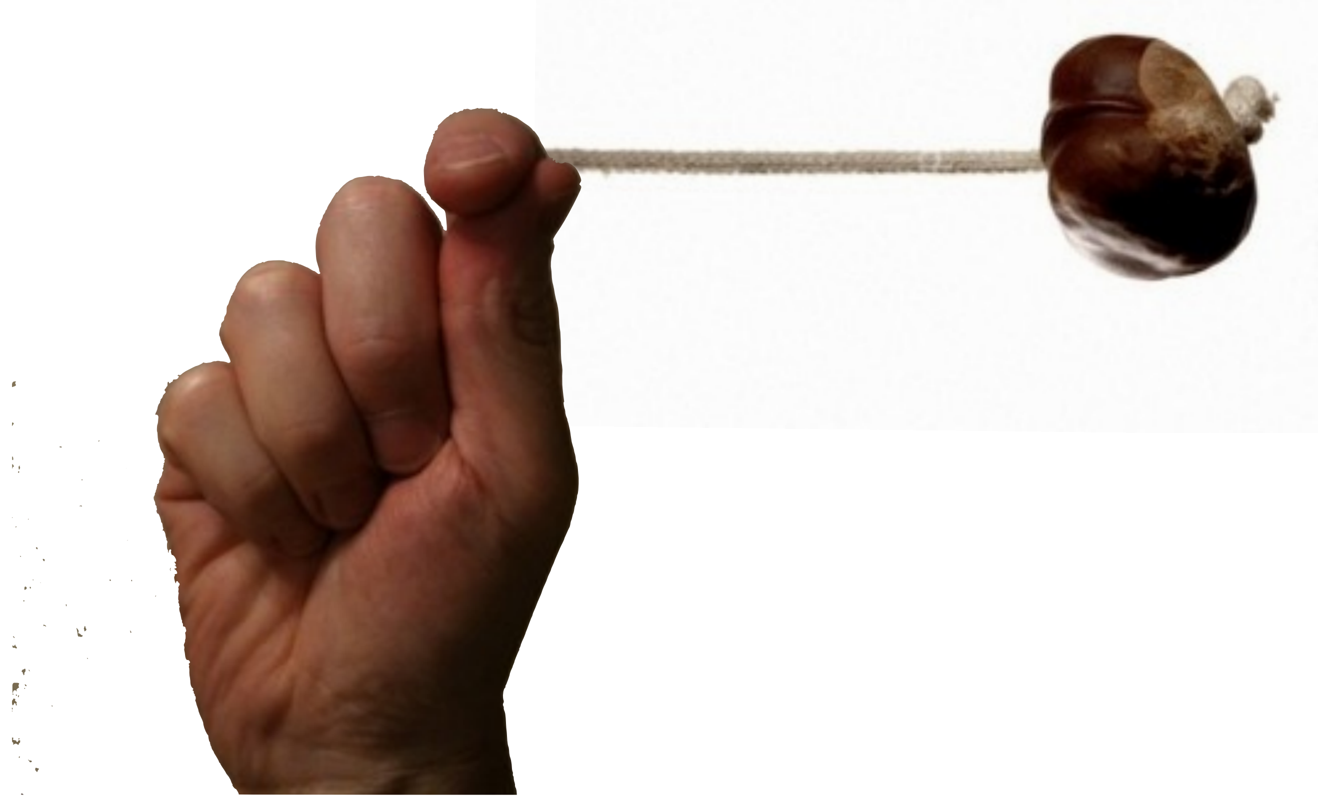
- There MUST be a net force towards the centre.
- It could be any sort of force - that’s up to you to find out.
- This force that must exist towards the centre is called a “Centripetal force”
- Which just means a force which points towards the centre...

The force must have a magnitude of...

$$\frac{mv^2}{r}$$

where m is the mass of the object, v is its speed, and r is the radius of the circle in which it is moving.

How to use this



- A boy is spinning a conker around his head, on the end of a light-weight string.
- What is the tension in the string? $\frac{mv^2}{r}$
- If it was anything else, the conker wouldn't be moving in a circle

At the space station

1. Gravity is almost the same as at the Earth's surface
2. Gravity is much weaker but not zero
3. There is no gravity
4. It depends on whether you are inside or outside
5. It depends on the position of the moon

Gravitational Force

- Force between two objects due to gravity is given by Newton's Law:

$$F = \frac{GMm}{r^2}$$

where M and m are the masses of the two objects interacting, r is the distance between their centres, and G is a constant (6.67×10^{-11} N m^2 kg^{-2})

The Answer

- The space station orbits around 800 km above the Earth's surface.
- So r in this equation changes from the radius of the Earth (6400 km) to 7200 km.
- Ratio is 7200/6400 = 1.125
- Force goes as inverse square of distance, so ratio of forces is $F = \frac{1}{1.125^2} = 0.79 = 79\%$

So not very different...

Why then do you feel weightless?

- You and everything around you are accelerating equally, so you see no relative movement.

Why doesn't it fall down?

- Because of its rapid sideways motion.
- It goes so fast that this gravitational force is just enough to keep it moving in a circle of radius 7200 km.
- How fast is this?
- Gravity is supplying the centripetal force