Sea and Learn – Lesson Plan: Forces and Cannons

Key Stage: Four (Double Science)
National Curriculum Links: Sc4 2f
Main Subject Focus: Science

Learning Outcomes:

Children will:

- Know the difference between balanced and unbalanced forces.
- Know that unbalanced forces can cause motion
- Know how a cannon works
- Understand the quantitative relationship between force, mass and acceleration
- Understand Newton's Third Law of Motion

Resources Required:

- 'Alka Seltzer' tablets
- 35mm film containers (ones where the lids clip to the inside of the container)
- 'Making an Alka Seltzer cannon' worksheet
- 'Ready, Aim, Fire!' information sheet
- Sellotape
- Scissors
- Drinking straws
- Small plastic beakers and droppers/plastic pipettes
- Iron shot borrowed from PE department

Lesson Structure:

1. Briefly revisit balanced and unbalanced forces.
2. Get out the iron shot. Explain that this would have been the size of a smallish cannonball that would have been fired by a Royal Navy ship of the 17th to 19th centuries. Get the group to consider the forces involved in firing the shot. How does a cannon generate these forces? (See Teacher's Notes)
3. Explain how a cannon works using the diagram provided on the 'Ready, Aim, Fire!' Information sheets.
4. Using the cannon as an example get the class to consider how the force needed to move a cannon ball at a given rate of acceleration might vary with the mass of the cannon ball (necessary force increases with mass). Consider how the force needed to move a cannon ball of fixed mass might vary with rate of acceleration (necessary force increases with acceleration). Also consider how acceleration varies with mass for a given force applied (acceleration decreases as mass increases). From

these considerations your class (with appropriate prompts) should be able to deduce that *F=ma*.

5. Ask the class what happens when a cannon is fired – hopefully someone will mention recoil and this is a perfect lead in to a discussion of Newton's Third Law of Motion.
6. Go through construction details for the 'Alka-Seltzer' cannon. Demonstrate the cannon.
7. Get pupils to build their own cannons (See Worksheet 1). As they do this ask them to think about how they could calculate the force exerted on the film pot lid and to write down a list of experimental measurements they would need to make in order to do this.
8. Have a 'shoot – off' to find the cannon with the greatest range.
9. Summarise learning points.

Extension/Homework Ideas:

- Suggest improvements to the design of your cannon to improve its range.
- Firing a cannon was a risky business for the gun crew, particularly if they didn't follow the proper drill. Look at the firing drill in the 'Ready, Aim, Fire!' worksheet and explain how each step is designed to keep the gun crew safe.
- Write an experimental procedure for finding the force exerted on the film pot lid. Paying special attention to any errors that might occur.

Sea and Learn – Teacher's Notes (1)

When deducing F=ma for higher ability pupils it might be possible to explore this graphically by plotting example graphs of the straight line relationships between force and mass and force and acceleration and the inverse relationship between acceleration and mass.

If practical or appropriate pupils could be taken outside and a volunteer could be asked to throw the shot. Compare this with a typical 5½-inch cannon of the mid 18th century, which could fire a 20lb (9kg) shot some 2650 yards (2423 metres) with a muzzle velocity of 590 mph (264m/s). Ask for ideas as to how big a force would be needed to propel the shot (a rough value can be obtained by calculating the kinetic energy of the shot as it leaves the muzzle and then plugging this answer into '*work = force x distance*' where distance is the length of the barrel.

The 'Alka-Seltzer' Cannon

The 'Alka-Seltzer' Cannon uses the same principle as the real thing but is considerably safer.

The film container needs to be filled about one third full of water (warm for a quick fire, cold for a slower reaction). Then add approximately one third of an 'Alka-Seltzer' tablet and quickly clip the lid in place. Stand back and wait.

The exact time the cannon takes to fire will depend on the temperature of the water and whether there is enough 'Alka-Seltzer' present. Pupils will often make the mistake of thinking 'the more Alka-Seltzer I put in, the further my cannon will fire'. This is not true because the lid of the film pot will blow off when the force from the pressure inside the pot overcomes the friction force holding the lid on. The force necessary is the same regardless of how much 'Alka-Seltzer' is put in the pot. If an excess of 'Alka-Seltzer' is put in the pot all that will happen is the lid will shoot the same distance as before but there will be lots of undissolved 'Alka-Seltzer' left in the pot.

For the purposes of time management it is best to get pupils to form a line behind their cannons and to let them off simultaneously. Ensure that pupils have scratched their initials into their lids so that they can be identified to find the longest range. There can also be categories for 'quickest firing' and 'longest firing'.

As the teacher, you could take on the role of 'gun captain' and issue the necessary orders for firing. For example; 'Load cannons with water'
'Insert Alka Seltzer and stoppper'
'Stand back and await firing'

Sea and Learn – Teacher's Notes (2)

The force exerted on the film pot lid can be calculated in the following way.

- Weigh the film pot lid on a pair of sensitive scales.
- Set up the cannon ready to fire, with a motion sensor rigged up directly facing the mouth of the cannon.
- Fire the cannon.
- Take a reading for the 'muzzle velocity' of the cannon – this will be the peak velocity recorded by the motion sensor.
- Repeat this a number of times to get an average reading
- Use this velocity value and the measured mass of the film pot lid to calculate the kinetic energy of the lid. The kinetic energy of the lid will be equivalent to the work done by the pressurised gas in the film pot on the lid. This work done is given by force (on the lid) multiplied by distance that the force is exerted over. This distance will **not** be the length of the film pot, it will be the length of the film pot with which the lid is in contact before it launches from the 'barrel'. This is only likely to be a few millimetres.

Rearranging this relationship will give a value for force exerted on the lid and from this the acceleration of the lid can also be calculated.

It is worth noting that the major error introduced in this procedure is likely to be the measurement of the distance element. This is because the distance in question is small and the exact distance to be measured is a little subjective. Even a small discrepancy in distance measured is therefore going to be a large percentage error.

It is also appreciated that motion sensors will generally be able to measure the acceleration directly. This method can be used with lower ability groups to show the relationship between velocity and acceleration. It can also be used to provide a check for results obtained from the method above.

Safety:

Alka-Seltzer is a medicine. It should not be handed out to pupils in any quantity. Pupils should construct their cannons and only when they are ready to fire should they be given their one third tablet. They should be given clear instructions that the 'Alka-Seltzer' is not for consumption.

Goggles and lab coats are recommended. Make sure that pupils are standing behind their cannons when they fire and that no one else is standing in front of them. The cannons can fire their lids more than 10 feet in the right conditions and although they are unlikely to cause any impact injuries there is a slight risk that flying lids or 'spray' from the cannons may get into unguarded eyes.

Sea and Learn – Information Sheet (1)

Ready, Aim, Fire!

To fire a cannon the correct amount of gunpowder was poured into a cloth bag, this bag full of gunpowder was known as a cartridge. This was rammed down the cannon barrel behind a plug or 'wad' of wood or cloth. The shot was then put in the barrel and rammed firmly back against the wad. Meanwhile the gun captain would pour some gunpowder into the touch hole or vent. When the order to fire was given the gunner would bring up a slow burning match or red hot rod and place it on the touch hole. This would ignite the gunpowder trail, which then burnt quickly down to the charge and ignited it.

When the charge ignited, the pressure in the chamber of the cannon would increase very quickly. The wadding would contain the pressure for a very short period of time and then act as a piston to push the shot out of the barrel.

The shot would start to move when the pressure in the chamber of the cannon could produce enough force to overcome the friction force caused by contact of the shot and wadding with the inside of the barrel and the weight of the shot.

At the time of the battle of Trafalgar, HMS Victory was armed with 104 guns.

The guns were of a number of different sizes and were known by the weight of the cannonball they fired. For example, a 32 pounder would fire a cannon ball weighing 32 pounds.

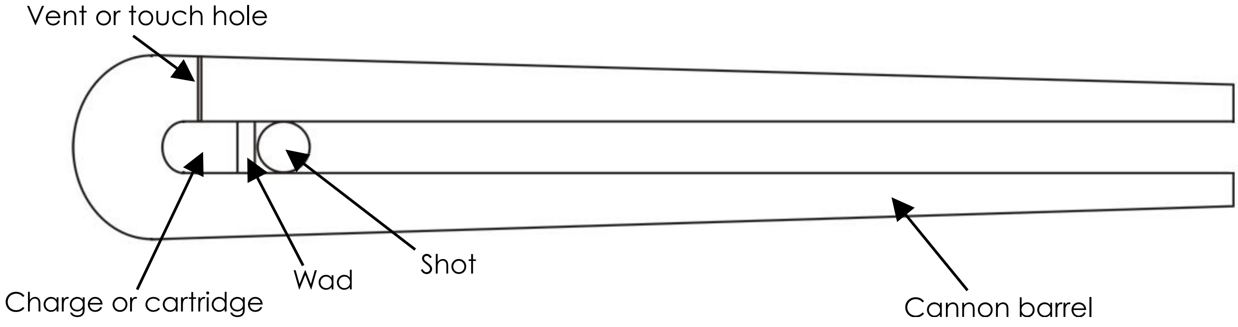
The table below shows what types of cannons were on board HMS Victory at the battle of Trafalgar.

Location	Number	Size	Weight of Shot in pounds (kgms)
Lower Gun Deck	30	32 pounders (long)	32 pounds (14.48 kg)
Middle Gun Deck	28	24 pounders (long)	24 pounds (10.86 kg)
Upper Gun Deck	30	12 pounders (long)	12 pounds (5.43 kg)
Quarter Gun Deck	12	12 pounders (short)	12 pounds (5.43 kg)
Forecastle	2 2	12 pounders (medium) 64 pounder carronades	12 pounds (5.43 kg) 64 pounds (28.96 kg)

The total weight of a broadside was 1148 pounds (519 kg).

Sea and Learn – Information Sheet (2)

Cross-Section of a Cannon:



Firing these guns was a complex and dangerous operation. Gun crews would be working in cramped conditions with explosives and extremely heavy machinery. To make things worse they would also be under enemy fire. Despite all of this they would have to clean, load, aim and fire a cannon in two to five minutes. The very best crews could do it in 90 seconds.

Sea and Learn – Information Sheet (3)

A six-man gun crew would be referred to by numbers to make any orders given as clear as possible.

One	The gun captain who primed, aimed and fired the gun.
Two	Turned and raised the gun barrel
Three	Was responsible for loading the gun
Four	Damped down any sparks before reloading
Five	Helped to move the gun barrel and passed ammunition
Six	The powder monkey delivered fresh gunpowder. Powder monkeys could be as young as 10 years old.

The process of firing a cannon is given below.

Step 1

After having fired the cannon the crew cleaned the gun, swabbing out the barrel with a damp cloth to put out any embers that might still be in the barrel.

Step 2

A bag of powder was then pushed down the barrel with a ramrod, followed by wadding to hold it in place. The shot was then rammed in.

Step 3

The gun captain used a long thin tool with a point on the end called a 'vent pricker' to push down the vent and prick the bag of powder, exposing the gunpowder. This tool was made from copper. A quill filled with gunpowder was then inserted as a fuse.

Step 4

The gun crew used handspikes and ropes to lever the cannon into position.

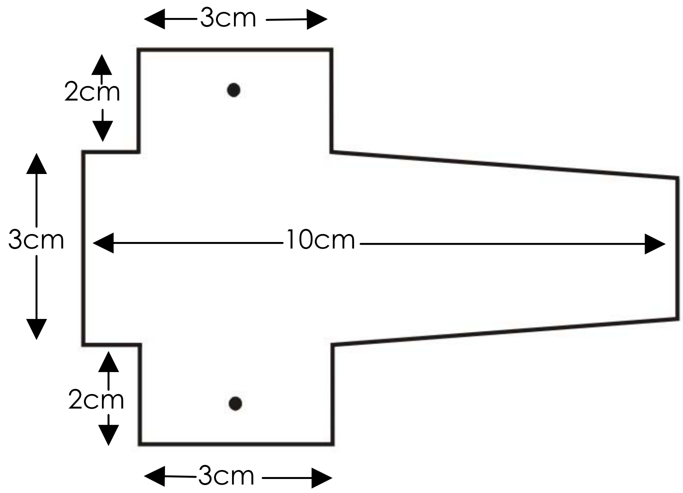
Step 5

The gun captain lit the fuse. As soon as the fuse was lit the gun crew jumped out of the way of the cannon and covered their ears with their hands. Firing would cause the heavy cannon to recoil violently. To stop it crashing into the gun crews on the other side of the gun deck it was restrained with ropes and pulleys. Without restraints a 32 pounder cannon, which weighed 7280 pounds (3276 kg) would recoil up to 50 feet (about 15m).

Sea and Learn – Worksheet (1)

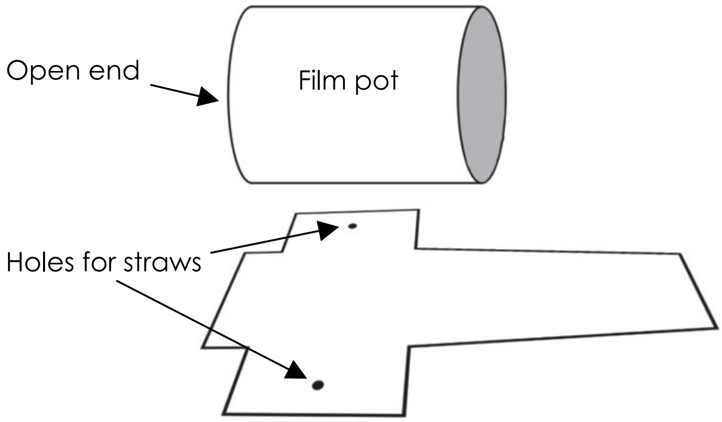
Making an 'Alka Seltzer' Cannon

1. Using a ruler and pencil mark out the shape below on a piece of stiff card



2. Using a pencil, carefully make holes where the black dots are. The holes should be just the right size to allow the drinking straw to fit fairly tightly.

3. Fix your film container in position with some sellotape. Make sure that the open end of the container points towards B in the diagram above. Make sure that the lip of the container sticks out slightly over the edge of the card base. Do not cover the holes you have made for the straws with sellotape or you will have to make them again.



4. Cut your straw into two pieces. Poke one piece through each hole. By adjusting the length of the straw poking through the hole you can adjust the elevation of your cannon. You may find that when you have water in the barrel the cannon may over balance. To stop this just put a piece of blu-tac on tail of your cannon and stick a small coin or other weight onto it.

5. You are now ready to fire, so wait for instructions from your gun captain.