WOMEN IN ENGINEERING 2021

MATHEMATICS CHALLENGE

Shannon Slipway Design

Introduction:

The Shannon is the newest class of all-weather lifeboat and can be launched in a variety of ways, from a pontoon in a harbour, down a beach by a special tractor and carriage system or direct from the station down a slipway.

When a slipway is used, it needs to be carefully designed so that when the Shannon launches, it doesn't slide down too fast and hit the water too hard, especially as there are often crew out on deck when it launches. If the angle of the slipway is too steep, the boat could travel too fast and hit the water too hard. If it's too shallow, the boat could take too long to hit the water or even get stuck on the slipway.

Your task is to help design the slipway from the station to the water, by looking at the forces acting on the boat and then calculating the best angle for the design so that the lifeboat enters the water at the right speed.

Remember that your crew are depending on you.

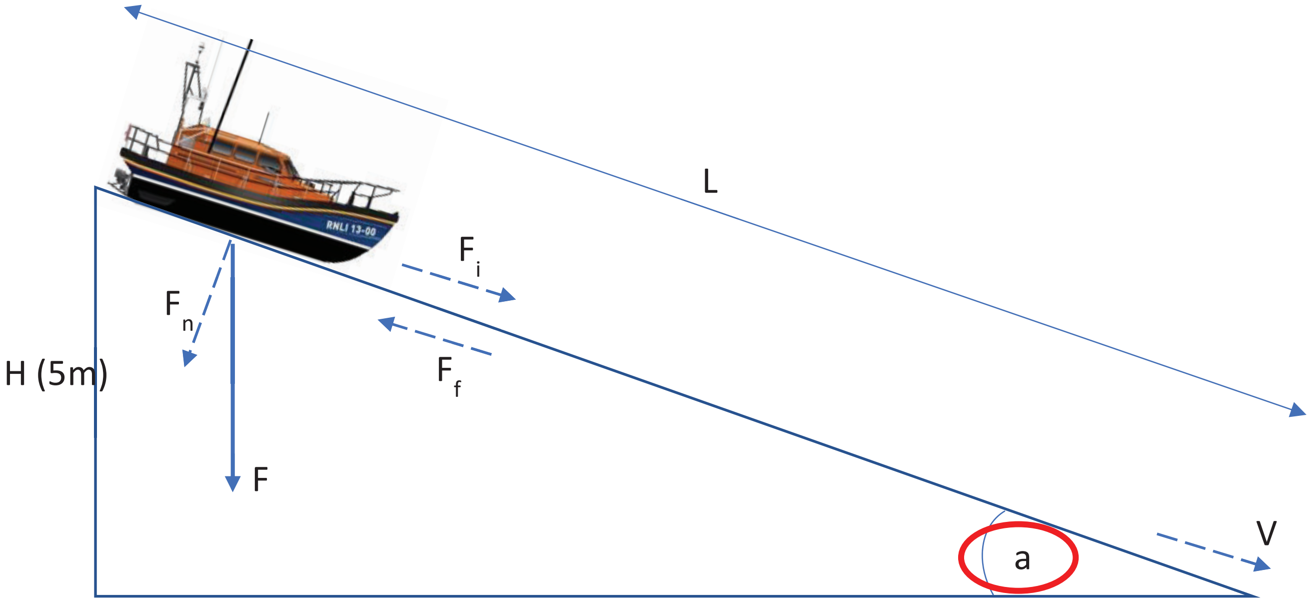
What you will need:

Activity sheet plus some extra paper for calculations

Pen or pencil

Scientific calculator with trigonometric (sin and cos) and square root functions

Method:



We're looking for the angle **a** of the slipway which is shown in the diagram but there are several factors to be included: the height of the station above the water (5m in this case), the forces acting on the lifeboat, the calculated length of the slipway and finally the speed of the lifeboat as it hits the water.

First, we need to look at the forces acting on the lifeboat. First is the force due to gravity.

Force due to gravity (F) = Mass of Shannon (kg) X Acceleration due to gravity (m/s^2)

For this calculation, we can use the following:

Mass of a Shannon - 18,000kg Acceleration due to gravity - 9.8 m/s^2

Next, we break that force down into its component parts, **F_i** and **F_n**.

- **F_i** is the force parallel to the slipway which causes it to slide down the slipway.
- **F_n** is the force holding the Shannon on the slipway.
- These vary depending on the angle of the slipway, **a**. If it's very steep, the boat has less force holding it onto the slipway, very shallow and there's not much force to make it slide down. We use trigonometry to do this.

Don't worry if you don't have a scientific calculator, there are some approximations of sin a and cos a shown below.

Firstly,

Parallel Force (F_i) = Force due to gravity (F) X sin a

Then also,

Perpendicular Force (F_n) = Force due to gravity (F) X cos a

(Tip: try somewhere between 5° and 15°)

With the perpendicular force **F_n**, we can work out what the effect of friction will be holding the Shannon back as it slides down the slipway. For this, we need the coefficient of friction **f**, which in this case, we will assume to be 0.03.

Frictional Force (F_f) = Perpendicular Force (F_n) X Coefficient of friction (f)

(The coefficient of friction will vary depending on a lot of factors including the materials used to make the slipway, its shape and even how wet it is.)

Now we can work out the total force less friction that is making the Shannon slide down the slipway.

Total Force = Parallel Force (F_i) − Frictional Force (F_f)

With this we can work out how quickly the Shannon will accelerate down the slipway.

Acceleration = Total Force / Mass of Shannon (kg)

A slightly more complicated calculation to work out how long the Shannon will be sliding down the slipway. To find this, we need to know how long the slipway is **L**. This is dependent on the height of the station above water **H** which we know is 5m and the angle of the slipway **a** and takes a little bit more trigonometry.

Length of slipway (L) = Height of station above water (H) X sin a

Knowing the length of the slipway means we can work out how long the Shannon will take to hit the water (watch out for that square root!).

Time to hit water = √ (2 X Length of slipway (L) / Acceleration)

Lastly, we can now calculate the speed at which the Shannon hits the water V.

Final velocity (V) = Acceleration X Time to hit water

But is it too fast? The velocity we've calculated is in metres per second. The engineers tell me that we want that to be no more than **9 m/s** which equates to around 17.5 knots in nautical terms. How close are you?

Could you try a different angle to get closer?

Reference: Sine and cosine table

Angle a	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°
sin a	0.087	0.105	0.122	0.139	0.156	0.174	0.191	0.208	0.225	0.242	0.259
cos a	0.996	0.995	0.993	0.990	0.988	0.985	0.982	0.978	0.974	0.970	0.966

What this teaches us:

These are some quite complex calculations which are normally covered in A-Level Maths. Well done if you've been successful in working them out.

We can always divide forces into different directions so that we can understand what's happening with the item experiencing the force. Trigonometry allows us to work out the calculations at different angles.

Some other questions for you to consider:

- The friction shown in the case above is pretty low but how might you get this even lower and how might parts of the lifeboat or slipway design affect the friction?
- With tides going in and out every day, can you think of problems this could cause in this calculation and in the overall design of the slipway?
- We have assumed a straight and flat slipway, what effect might curves in the slipway design have?
- If the station is positioned quite high up a rocky face, what limits might there be on the length of a slipway to ensure the lifeboat doesn't enter the water too fast? What ideas do you have for finding a solution for this issue?

The next step…….

The RNLI website rnli.org gives plenty of information on all our lifeboat fleet and you can find lots of videos on RNLI rescues on the RNLI YouTube channel.

This also includes information and videos on some of our big submersible tractors, not the mention the spectacular Shannon Launch & Recovery System (SLARS) tractor and carriage which is like a mobile slipway that can launch an 18 tonne Shannon off a beach, not to mention recover it out of the water and turn it around on the cradle ready for launch again.

Videos of launches

How this links to the RNLI:

My role in the RNLI is to understand the costs involved in building lifeboats and lifeboat stations. I am therefore keen that we find not only the best solution but also the one that is the best value for money so that we can put our donors' money to best use.

We can use these calculations to model the effect of launching a lifeboat down a slipway before we even build it, meaning less time and money involved in building and trialling prototypes at each station.

We would love to see how you got on with the challenge so please send any photos you don't mind us sharing on our webpage to womeninengineering@rnli.org.uk (please note that we will require consent to share these photos and an automated email will be sent requesting consent).