ADVANCED CONNECTIONS | CYSYLLTIADAU PELLACH

PHYSICS MENTORING PROJECT | PROSIECT MENTORA FFISEG

PRE-TUTORIAL MATERIALS

SESSION 6: BEING A PHYSICIST

In this session, we will try to bring together a lot of what we have learned already. But first, lets go all the way back to the first session and see how we approach the Fermi problems.

TASK 1: FERMI PROBLEMS REVISITED

15 MINS

Take another look at the Fermi problems from Tutorial 1 below. As you go through them, ask yourself:

- **How would your approach change now** compared to the first session?
- Do you feel **more confident** in tackling them than you did the first time around?

1 How many Shreddies has the average 17-year-old eaten?

a List any assumptions you have made.
e.g. sizes of things, how often something happens, etc.

b Estimate the level of confidence you have in each assumption.

OR

2 Could you fit more monetary value in a backpack in 1p or 2p coins?

a List any assumptions you have made.
e.g. sizes of things, how often something happens, etc.

b Estimate the level of confidence you have in each assumption.

TASK 2: TERMINAL VELOCITY EXPERIMENT

20 MINS

Use everything you have learned so far to conduct an experiment investigating air resistance and terminal velocity.

BACKGROUND

Any object falling through a fluid medium (e.g. air) will will eventually **reach a specific velocity** that it cannot exceed, called the **terminal velocity.**

THE PHYSICS

The force due to drag (**air resistance**) **increases with velocity,** whilst the force due to gravity (**weight**) remains **constant.** So when the velocity is high enough, these two forces **cancel out.** Newton's 1st Law of Motion states that an object with no resultant force will not change its velocity - this is what happens when an object reaches terminal velocity.

The expressions for gravitational force (F_G) and drag force (F_D) are:

$$F_G = mg$$

$$F_D = \frac{1}{2} c_d \rho v^2 A$$

$\rho_2 =$ drag coefficient
$c_d =$ mass density of fluid (air)
$v^2 =$ velocity
$A =$ surface area

when $F_G = F_D$ ...

$$mg = \frac{1}{2} c_d \rho v^2 A$$

SESSION 6: BEING A PHYSICIST

EXPERIMENT TIME!

We're going to investigate this phenomenon using **cupcake cases.** You'll find the terminal velocities at different masses, and you can also try and find the drag coefficient that is specific to the cupcake case shape.

You can **drop the cases over a known distance, measure the time** it takes them to fall. **Assuming** terminal velocity is reached almost immediately, these values can be used to **calculate the terminal velocity.**

You can nestle **multiple** cases inside each other too to **change the mass** of the object without altering any other properties. You can **assume** that the mass of each case is **3.6×10^{-4} kg.**

TOP TIP
If you don't have this equipment, you can ask your Physics teacher to provide it and perform the experiment at your school/college!

Using the expression at the bottom of the previous page, we can then **plot a straight line graph** to help us find the drag coefficient.

What do you think needs to be plotted?

What are the biggest challenges of this experiment? How could it be improved?

Remember to keep a note of any uncertainties or possible sources of error!

BE SAFE!
Don't go anywhere unnecessarily high or precarious.

REMEMBER
Consider the equation to be in the form **y = mx (+c)**. What would m be in this case?

$$mg = \frac{1}{2} c_d \rho v^2 A$$

Mass density of air is 1.3 kgm^{-3}

TOP TIP
If you're confused about any steps involved in this experiment, see the upside down text at the bottom of this page

If finding the drag coefficient is too difficult, then just try to find the terminal velocities and plot a graph.

5. Plot a graph according to the information at the bottom of this page to find the drag coefficient
4. Continue like this, but we expect the terminal velocity to increase with mass so it may get quite difficult to measure t eventually!
3. Do this again, but put another cupcake case inside the first to double them mass
2. Drop a single cupcake case and measure the time it takes to fall the known distance. Make repeat readings
1. Find where you can conduct this experiment. The cupcake cases will have to fall a known distance and the time measured.

Plot mg on the y axis, and v on the x axis. The gradient would therefore be $\frac{1}{2} c_d \rho A$

OPTIONAL EXTRAS

FERMI PROBLEMS

What **experiments** could you design to confirm or deny the answers you got to the Fermi questions? What **equipment and resources** would you need? What would be your **variables** and **measurements?**

1 How many Shreddies has the average 17-year-old eaten?

2 Could you fit more monetary value in a backpack in 1p or 2p coins?

Try out some more Fermi problems:

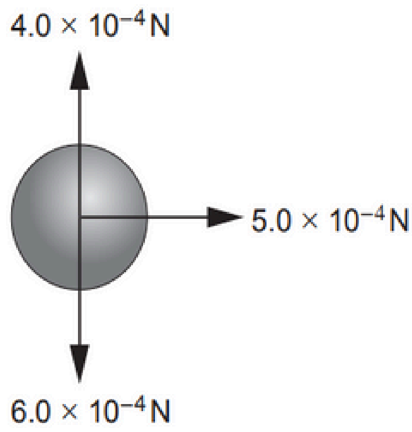
A How many blades of grass are there on a football pitch?

B How many times do you blink in a year?

EXAM PRACTICE

Try these exam questions:

2. *(a)* The forces acting on a hailstone falling in a horizontal cross-wind can be represented as in the diagram.



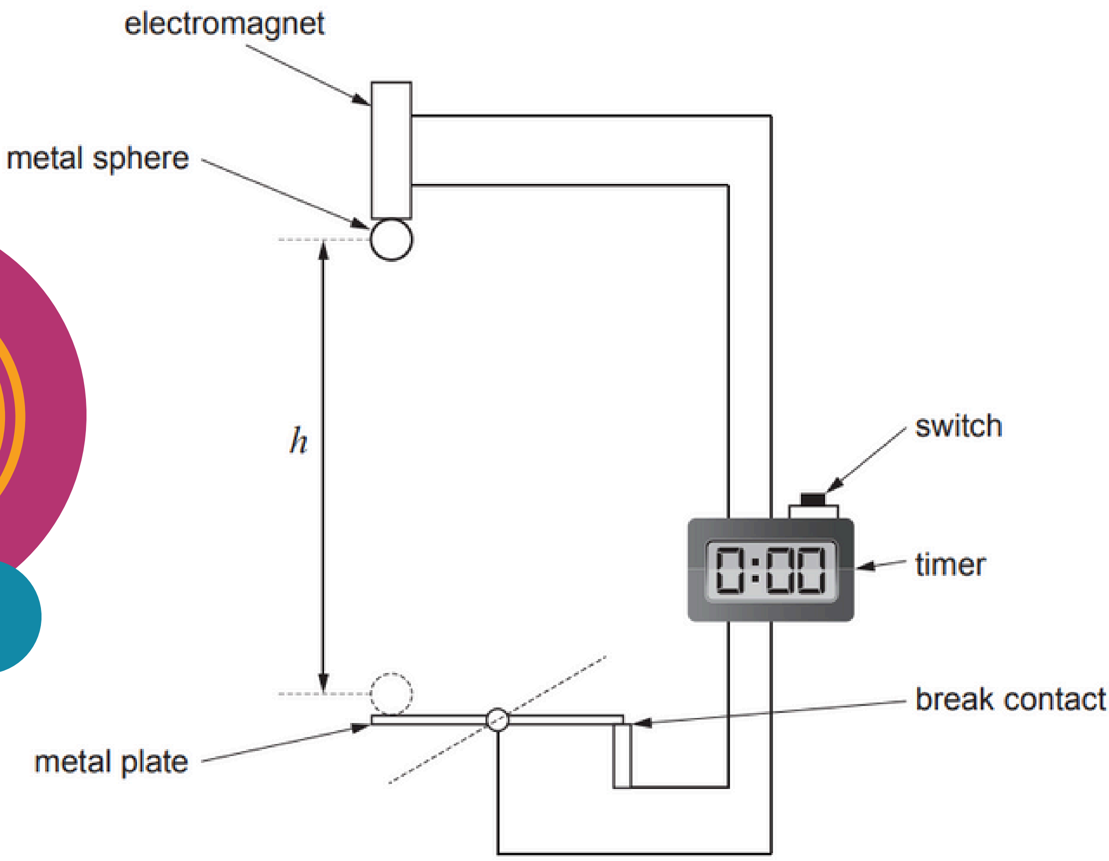
(i) Calculate the magnitude and direction of the resultant force acting on the hailstone. [3]

(ii) At a later time, the wind has stopped blowing and the hailstone falls at terminal velocity. In terms of forces, explain why the hailstone is at terminal velocity. [1]

OPTIONAL EXTRAS

EXAM PRACTICE CONT.

(b) Aled uses the following apparatus to measure the acceleration of free-fall, g.



When the switch is pressed, it starts the timer and disconnects the electromagnet, almost instantly releasing the metal sphere. When the sphere hits the metal plate it breaks the circuit, stopping the timer. The time taken for the metal sphere to fall through a range of different heights, h is measured.

(i) Aled is told that there is a very small time delay between the switch being pressed and the ball being released. This is a systematic error. The manufacturer states that the time delay is 0.05 s. State how Aled should account for the systematic error when taking readings. [1]

(ii) Aled records his **corrected results (i.e. with the systematic error accounted for)** in the table below. Complete the row for time squared, t^2 giving your answers to an appropriate number of significant figures. [2]

Drop height, h/m	0.40	0.80	1.20	1.60	2.00
Corrected time, t/s	0.27	0.41	0.48	0.58	0.64
Corrected time squared, t^2/s^2					