Experimental Question 1

Terminal velocity in a viscous liquid

An object falling in a liquid will eventually reach a constant velocity, called the *terminal velocity*. The aim of this experiment is to measure the terminal velocities of objects falling through glycerine.

For a sphere of radius r falling at velocity v through a viscous liquid, the viscous force F is given by $F = 6\pi\eta rv$. Here η is a property of the liquid called the *viscosity*. In this experiment you will measure the terminal velocity of metal cylinders (because cylinders are easier to make than spheres). The diameter of each cylinder is equal to its length, and we will assume the viscous force on such a cylinder is similar to the viscous force on a sphere of the same diameter, $2r$:

$$F_{cyl} = 6\pi\kappa\eta r^m v \tag{1}$$

where $\kappa = 1$, $m = 1$ for a sphere.

Preliminary

Calculation of terminal velocity (2 marks)

If ρ is the density of the culinder and ρ' is the density of the liquid, show that the terminal velocity v_T of the cylinder is given by

$$v_T = Cr^{3-m}(\rho - \rho') \tag{2}$$

where C is a constant and derive a expression for C.

Experiment

Use the equipment available to determine the numerical value of the exponent m (10 marks) and the density of glycerine (8 marks).

Notes

- For consistency, try to ensure that the cylinders fall in the same orientation, with the axis of the cylinder horizontal.
- The tolerances on the diameter and the length of the cylinders are 0.05 mm (you need not measure them yourself).
- There is a brass sieve inside the container that you should use to retrieve the metal cylinders. Important: make sure the sieve is in place before dropping objects into the glycerine, otherwise you will not be able to retrieve them for repeat measurements.
- When glycerine absorbs water from the atmosphere, it becomes less viscous. Ensure that the cylinder of glycerine is covered with the plastic film provided when not in use.
- Do not mix cylinders of different size and different material after the experiment.

Material	**Density (kgm^{-3})**
Aluminium	2.70×10^3
Titanium	4.54×10^3
Stainless steel	7.87×10^3
Copper	8.96×10^3