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Edexcel, OCR

A Level

A Level Physics

MECHANICS: Fluids (Answers)

Name:

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Total Marks: /30

1. This question tackles the drag force experienced when an object falls freely through a fluid.

Total for Question 1: 10

(a) What is the cause of drag in fluids? [1]

> **Solution:** Friction.

(b) State three factors affect the magnitude of the drag force. [3]

> **Solution:** The object's speed, shape, roughness/texture. The fluid's density, viscosity.

(c) Draw a free-body diagram for a sinking object at each of the following points during its descent: [3]

i. The instant it is released.
ii. As it is accelerating.
iii. When it is travelling at its terminal velocity.

Be sure to label any forces indicated.

> **Solution:** (i) One arrow, directed downwards and labelled mg.
> (ii) As for (i) but with an additional arrow of a smaller size pointing upwards, labelled D (or drag force).
> (iii) The two forces should now be of equal magnitude but point in opposite directions.

(d) For each of the cases in Part c, express the net acceleration in terms of *m, g and D* - the object's mass, the acceleration due to gravity and the drag force, respectively. [3]

> **Solution:** (i) Net force $= mg \rightarrow a = g$
> (ii) Net force $= mg - D \rightarrow a = \frac{mg-D}{m}$
> (iii) Net force $= 0 \rightarrow a = 0$

2. Stokes' Law describes viscous drag acting on an object travelling at low speeds. From it, the following expression can be derived for a small sphere dropping through a viscous fluid:

$$v_{terminal} = \frac{2r^2 g(\rho_s - \rho_f)}{9\eta}$$

where r, ρ_s, ρ_f and η represent the sphere's radius, the densities of the sphere and the fluid and the fluid's viscosity, respectively. Sketch graphs showing the form of the following for positive values of all quantities:

Total for Question 2: 9

(a) $v_{terminal}$ vs η [2]

Solution: $y \propto \frac{1}{x}$ - symmetric about the line $y = x$

(b) $v_{terminal}$ vs r [2]

Solution: $y \propto x^2$ - a simple concave-up quadratic.

(c) $v_{terminal}$ vs $(\rho_s - \rho_f)$ [2]

Solution: $y \propto x$ - a straight line with positive gradient.

(d) Briefly outline a simple experiment that could be used to determine a fluid's viscosity. Assume that any spheres' radii and the fluid's density are known. [3]

Solution: Measure $v_{terminal}$ for many spheres of different radii.
Plot a graph of $v_{terminal}$ against r^2
The gradient will be $\frac{2g(\rho_s - \rho_f)}{9\eta}$, from which η can be calculated.

3. Here, you will explore the factors that affect buoyancy in fluids.

Total for Question 3: 11

(a) Explain why fluids exert a pressure. [1]

Solution: Molecules' bombardment of the exterior walls.

(b) Show that this pressure is $h\rho g$ for a vertical cylinder of length h and cross-sectional area A. [3]

Solution: Force at base = weight = $(\rho V)g = \rho A h g$
Pressure = force/area = $\frac{\rho A h g}{A} = h\rho g$

(c) State Archimedes' Principle. [1]

Solution: Upthrust exerted on a body immersed in a fluid is equal to the weight of the fluid it displaces.

(d) By considering a cuboid of thickness x buried with its top surface at a depth h, show that the upthrust will be $Ax\rho g$, where A is the area of its upper surface. [3]

Solution: Force at top surface $= h\rho gA$
Force at bottom $= (h+x)\rho gA$
Upwards resultant $= x\rho gA$

(e) Icebergs typically float with 90% of their volume beneath the water. Given that $\rho_{water} = 1000\ \text{kgm}^{-3}$, use Archimedes Principle to calculate the density of the ice. [3]

Solution: 900 kgm^{-3}