

Solutions

2.1 $\rho = \frac{m}{V}$: $\rho = \frac{0.054 \text{ kg}}{20 \times 10^{-6} \text{ m}^3} = 2.7 \times 10^3 \text{ kg m}^{-3}$.

2.2 Upthrust = weight of displaced fluid = $mg = 0.040 \text{ kg} \times 9.81 \text{ N kg}^{-1} = 0.39 \text{ N}$.

2.3 Small sphere; low speed / laminar flow, no turbulence; (and viscosity depends on temperature, so the temperature must be steady).

2.4 Just below the surface the ball is still accelerating, so the speed is not constant; the measured time must be at constant terminal velocity, or $v = \frac{s}{t}$ gives the wrong value.

3.1 D. Upthrust equals the weight of the displaced liquid – the weight, not its volume or its mass. A and C confuse volume with weight; B is a volume, not a force.

3.2 B. Viscosity falls as the oil warms, so drag is less at the same speed and the terminal velocity is higher, so the time is shorter. A reverses the temperature effect; C is wrong on density; D confuses expansion with weight.

3.3 (a) $v = \frac{s}{t} = \frac{0.250 \text{ m}}{1.8 \text{ s}} = 0.139 \text{ m s}^{-1}$; $F = 6\pi\eta rv \Rightarrow \eta = \frac{F}{6\pi rv}$; $\eta = \frac{8.4 \times 10^{-5} \text{ N}}{6\pi \times 0.80 \times 10^{-3} \text{ m} \times 0.139 \text{ m s}^{-1}}$
0.040 Pa s. (b) The ball's mass (or weight) and the oil's density. The diameter is already given, so the displaced volume is known: use $mg = \rho_{oil}Vg + F_{drag}$ to check the force balance.

3.4 Fully submerged at constant speed: tension $T = W - U$, with U the upthrust. As the submarine emerges, the displaced volume falls, so the upthrust falls, and the tension rises. Once fully out of the water there is no upthrust, so $T = W$ and stays there.