Solutions

Each answer shows the steps, then the **result**.

2.1

- drag **increases** as speed increases (zero at zero speed)

2.2

- **drag equals weight**, so the **resultant force is zero**

2.3

- just after release, drag is still zero, so $a = g \approx \mathbf{9.81}$ m s^{-2} (the maximum)

2.4

- gravitational potential energy → **thermal energy of the air**

3.1 B

- at terminal velocity the KE of the parachutist is **constant**, so PE is **not** converted to her KE
- it is converted to thermal energy of the air

3.2

- just after release only weight acts, so $a = g$
- as speed rises, drag increases
- so the resultant force and the acceleration **decrease**
- when drag = weight the resultant is zero and the speed is constant — **terminal velocity**

3.3

- the resultant force is **zero**
- no resultant force ⇒ no acceleration ⇒ velocity stays constant (Newton's first law)

3.4

- curve from the origin, steepest at the start
- bending and **flattening** to a horizontal line at the (labelled) terminal velocity

3.5

(a) her velocity **decreases** (she decelerates)

(b) the parachute greatly increases the **drag**, so drag now exceeds weight and the resultant is **upward**

- as she slows, drag falls until **drag** = **weight** again, giving a new, **lower** terminal velocity

3.6

(a) pressure is the **normal force per unit area**

(b) pressure in a liquid **increases with depth**

- so the upward force on the bottom of the sphere is greater than the downward force on its top; the difference is the upthrust

(c)

- arrow vertically **downwards** labelled *weight*
- arrow vertically **upwards** labelled *upthrust*
- arrow vertically **upwards** labelled *(viscous) drag*

(d) $r = 3.0 \times 10^{-3}$ m

$$V = \tfrac{4}{3}\pi r^3 = \tfrac{4}{3}\pi(3.0 \times 10^{-3}\ \text{m})^3 = 1.13 \times 10^{-7}\ \text{m}^3$$

$$U = \rho_{\text{oil}} V g = (900\ \text{kg m}^{-3})(1.13 \times 10^{-7}\ \text{m}^3)(9.81\ \text{m s}^{-2}) = \mathbf{1.0 \times 10^{-3}}\ \text{N}$$

(e) 6π has no units

$$\eta = \frac{D}{6\pi r v} = \frac{\text{kg m s}^{-2}}{\text{m} \times \text{m s}^{-1}} = \mathbf{kg\ m^{-1}\ s^{-1}}$$

(f)

$$W = \rho_{\text{steel}} V g = (7800\ \text{kg m}^{-3})(1.13 \times 10^{-7}\ \text{m}^3)(9.81\ \text{m s}^{-2}) = 8.7 \times 10^{-3}\ \text{N}$$

- at terminal velocity $W = U + D$, so $D = 8.7 \times 10^{-3}\ \text{N} - 1.0 \times 10^{-3}\ \text{N} = 7.7 \times 10^{-3}\ \text{N}$

$$v = \frac{D}{6\pi\eta r} = \frac{7.7 \times 10^{-3}\ \text{N}}{6\pi(0.20\ \text{Pa s})(3.0 \times 10^{-3}\ \text{m})} = \mathbf{0.68}\ \text{m s}^{-1}$$

(g) at rest, $v = 0$ so **drag is zero**; only weight and upthrust act

- resultant $= 8.7 \times 10^{-3}\ \text{N} - 1.0 \times 10^{-3}\ \text{N} = 7.7 \times 10^{-3}$ N **downwards**