

Applied Physics 1

Chapter: Properties of Matter

Exercise Set 3: Numerical Problems with Solutions

This set has only numerical problems of the chapter **Properties of Matter**, each solved step by step. All problems are new and do not repeat Set 1 or Set 2. They are grouped as Elasticity, Surface Tension, Viscosity and Hydrodynamics.

Method for every numerical: write the given data in SI units, write the formula, substitute the values, calculate step by step and give the answer with its unit. Take $g = 9.8 \text{ m/s}^2$ and $\pi = 3.14$ unless stated otherwise.

Formulas Used in this Set

Topic	Formulas
Elasticity	Stress = F/A ; strain = $\Delta L/L$; $Y = FL / (A\Delta L)$; $K = PV / \Delta V$; $G = (F/A) / \theta$; factor of safety = breaking stress / working stress
Surface tension	$T = F/l = W/\Delta A$; capillary rise $h = 2T \cos\theta / (r \rho g)$
Viscosity	$F = \eta A (dv/dx)$; Stokes' drag $F = 6\pi \eta r v$; terminal velocity $v = 2 r^2 (\rho - \sigma) g / (9 \eta)$; 1 poise = 0.1 Pa·s
Hydrodynamics	$Re = \rho v D / \eta$; $A_1 v_1 = A_2 v_2$; $Q = A v$; $P + \frac{1}{2}\rho v^2 + \rho gh = \text{constant}$

A. Elasticity

N1. A rod of length 1.5 m and cross-section 4 cm^2 is compressed by a force of $2 \times 10^4 \text{ N}$. Find the stress, strain and decrease in length. ($Y = 1 \times 10^{11} \text{ N/m}^2$)

Given: $L = 1.5 \text{ m}$, $A = 4 \text{ cm}^2 = 4 \times 10^{-4} \text{ m}^2$, $F = 2 \times 10^4 \text{ N}$, $Y = 10^{11} \text{ N/m}^2$

Formula: Stress = F / A ; strain = stress / Y ; $\Delta L = \text{strain} \times L$

Solution:

- Stress = $2 \times 10^4 / 4 \times 10^{-4} = 5 \times 10^7 \text{ N/m}^2$
- Strain = $5 \times 10^7 / 10^{11} = 5 \times 10^{-4}$
- $\Delta L = 5 \times 10^{-4} \times 1.5 = 7.5 \times 10^{-4} \text{ m}$

Answer: Stress = $5 \times 10^7 \text{ N/m}^2$, strain = 5×10^{-4} , decrease in length = 0.75 mm.

N2. A lift of mass 500 kg hangs from a steel cable of length 20 m and radius 1 cm. Find the elongation of the cable. ($Y = 2 \times 10^{11} \text{ N/m}^2$; neglect the weight of the cable)

Given: $m = 500 \text{ kg}$, $L = 20 \text{ m}$, $r = 0.01 \text{ m}$, $Y = 2 \times 10^{11} \text{ N/m}^2$

Formula: $\Delta L = F L / (A Y)$

Solution:

- $F = mg = 500 \times 9.8 = 4900 \text{ N}$
- $A = \pi r^2 = 3.14 \times (0.01)^2 = 3.14 \times 10^{-4} \text{ m}^2$
- $\Delta L = (4900 \times 20) / (3.14 \times 10^{-4} \times 2 \times 10^{11}) = 98000 / 6.28 \times 10^7$
- $\Delta L = 1.56 \times 10^{-3} \text{ m}$

Answer: Elongation = 1.56 mm.

N3. A wire of length 2 m and diameter 0.8 mm is stretched by 1 mm when a load of 5 kg is hung from it. Find the Young's modulus of the material.

Given: $L = 2 \text{ m}$, $r = 0.4 \times 10^{-3} \text{ m}$, $\Delta L = 10^{-3} \text{ m}$, $m = 5 \text{ kg}$

Formula: $Y = F L / (A \Delta L)$

Solution:

- $F = 5 \times 9.8 = 49 \text{ N}$
- $A = 3.14 \times (0.4 \times 10^{-3})^2 = 5.02 \times 10^{-7} \text{ m}^2$
- $Y = (49 \times 2) / (5.02 \times 10^{-7} \times 10^{-3}) = 98 / 5.02 \times 10^{-10}$
- $Y = 1.95 \times 10^{11} \text{ N/m}^2$

Answer: $Y = 1.95 \times 10^{11} \text{ N/m}^2$.

N4. The breaking stress of a steel wire is $7.5 \times 10^8 \text{ N/m}^2$. Find the maximum load it can carry if its radius is 1 mm.

Given: Breaking stress $= 7.5 \times 10^8 \text{ N/m}^2$, $r = 10^{-3} \text{ m}$

Formula: Maximum load $F = \text{breaking stress} \times A$

Solution:

- $A = 3.14 \times (10^{-3})^2 = 3.14 \times 10^{-6} \text{ m}^2$
- $F = 7.5 \times 10^8 \times 3.14 \times 10^{-6} = 2355 \text{ N}$
- Mass $= F / g = 2355 / 9.8 = 240 \text{ kg}$

Answer: Maximum load $= 2355 \text{ N}$ (about 240 kg).

N5. Find the decrease in volume of 500 cm^3 of oil when the pressure on it is increased by $8 \times 10^6 \text{ N/m}^2$. (K for oil $= 1.6 \times 10^9 \text{ N/m}^2$)

Given: $V = 500 \text{ cm}^3$, $\Delta P = 8 \times 10^6 \text{ N/m}^2$, $K = 1.6 \times 10^9 \text{ N/m}^2$

Formula: $K = \Delta P \times V / \Delta V$, so $\Delta V = \Delta P \times V / K$

Solution:

- $\Delta V = (8 \times 10^6 \times 500) / (1.6 \times 10^9) = 4 \times 10^9 / 1.6 \times 10^9$
- $\Delta V = 2.5 \text{ cm}^3$

Answer: Decrease in volume $= 2.5 \text{ cm}^3$.

N6. A rivet of cross-section 3 cm^2 is under a shearing force of $6 \times 10^4 \text{ N}$. Find the shear stress and the angle of shear. ($G = 8 \times 10^{10} \text{ N/m}^2$)

Given: $A = 3 \times 10^{-4} \text{ m}^2$, $F = 6 \times 10^4 \text{ N}$, $G = 8 \times 10^{10} \text{ N/m}^2$

Formula: Shear stress $= F / A$; $\theta = \text{shear stress} / G$

Solution:

- Shear stress $= 6 \times 10^4 / 3 \times 10^{-4} = 2 \times 10^8 \text{ N/m}^2$
- $\theta = 2 \times 10^8 / 8 \times 10^{10} = 2.5 \times 10^{-3} \text{ rad}$

Answer: Shear stress $= 2 \times 10^8 \text{ N/m}^2$; angle of shear $= 2.5 \times 10^{-3} \text{ rad}$.

B. Surface Tension

N7. A thin metal ring of radius 3 cm is gently lifted from the surface of water. Find the extra force needed to pull it free of the water surface due to surface tension. ($T = 0.072 \text{ N/m}$; the ring touches the water along both its inner and outer circumference)

Given: $r = 0.03 \text{ m}$, $T = 0.072 \text{ N/m}$

Formula: $F = T \times (\text{total length in contact}) = T \times 2 \times (2\pi r)$

Solution:

- Total length $= 2 \times 2 \times 3.14 \times 0.03 = 0.377 \text{ m}$
- $F = 0.072 \times 0.377 = 2.71 \times 10^{-2} \text{ N}$

Answer: Extra force $= 2.71 \times 10^{-2} \text{ N}$.

N8. Find the work done in blowing a soap bubble of radius 3 cm. ($T = 0.03 \text{ N/m}$)

Given: $r = 0.03 \text{ m}$, $T = 0.03 \text{ N/m}$; a soap bubble has two surfaces

Formula: $W = T \times \text{increase in area} = T \times 2 \times 4\pi r^2$

Solution:

- Area of one surface $= 4 \times 3.14 \times (0.03)^2 = 1.13 \times 10^{-2} \text{ m}^2$
- Increase in area (two surfaces) $= 2 \times 1.13 \times 10^{-2} = 2.26 \times 10^{-2} \text{ m}^2$
- $W = 0.03 \times 2.26 \times 10^{-2} = 6.78 \times 10^{-4} \text{ J}$

Answer: $W = 6.78 \times 10^{-4} \text{ J}$.

N9. 27 identical water drops, each of radius 1 mm, combine to form one big drop. Find the energy released. ($T = 0.072 \text{ N/m}$)

Given: $r = 10^{-3} \text{ m}$, $n = 27$, $T = 0.072 \text{ N/m}$

Formula: Equal volume: $R^3 = 27 r^3$; energy released $= T \times \text{decrease in area}$

Solution:

- $R = 3r = 3 \times 10^{-3} \text{ m}$
- Decrease in area $= 27 \times 4\pi r^2 - 4\pi R^2 = 4\pi (27 \times 10^{-6} - 9 \times 10^{-6})$
- $= 12.56 \times 18 \times 10^{-6} = 2.26 \times 10^{-4} \text{ m}^2$
- Energy released $= 0.072 \times 2.26 \times 10^{-4} = 1.63 \times 10^{-5} \text{ J}$

Answer: Energy released $= 1.63 \times 10^{-5} \text{ J}$.

N10. Two capillary tubes of radii 0.2 mm and 0.6 mm are dipped vertically in water. Find the difference in the heights of water in them. ($T = 0.072 \text{ N/m}$, $\theta = 0^\circ$, $\rho = 1000 \text{ kg/m}^3$)

Given: $r_1 = 0.2 \times 10^{-3} \text{ m}$, $r_2 = 0.6 \times 10^{-3} \text{ m}$, $T = 0.072 \text{ N/m}$

Formula: $h = 2T / (r \rho g)$

Solution:

- $h_1 = (2 \times 0.072) / (0.2 \times 10^{-3} \times 1000 \times 9.8) = 0.144 / 1.96 = 0.0735 \text{ m}$
- $h_2 = 0.144 / (0.6 \times 10^{-3} \times 1000 \times 9.8) = 0.144 / 5.88 = 0.0245 \text{ m}$
- Difference $= 0.0735 - 0.0245 = 0.049 \text{ m}$

Answer: Difference in heights $= 4.9 \text{ cm}$ (the narrower tube has the higher rise).

N11. A liquid of surface tension 0.05 N/m and density 900 kg/m³ makes an angle of contact of 30° with glass. Find its rise in a capillary tube of radius 0.3 mm.

Given: $T = 0.05 \text{ N/m}$, $\rho = 900 \text{ kg/m}^3$, $\theta = 30^\circ$, $\cos 30^\circ = 0.866$, $r = 0.3 \times 10^{-3} \text{ m}$

Formula: $h = 2T \cos \theta / (r \rho g)$

Solution:

- Numerator = $2 \times 0.05 \times 0.866 = 0.0866$
- Denominator = $0.3 \times 10^{-3} \times 900 \times 9.8 = 2.646$
- $h = 0.0866 / 2.646 = 3.27 \times 10^{-2} \text{ m}$

Answer: $h = 3.27 \text{ cm}$.

N12. Water rises to 6 cm in a capillary tube of diameter 0.5 mm with zero angle of contact. Find the surface tension of water. ($\rho = 1000 \text{ kg/m}^3$)

Given: $h = 0.06 \text{ m}$, $r = 0.25 \times 10^{-3} \text{ m}$, $\theta = 0^\circ$, $\rho = 1000 \text{ kg/m}^3$

Formula: $h = 2T \cos \theta / (r \rho g)$, so $T = h r \rho g / (2 \cos \theta)$

Solution:

- $T = (0.06 \times 0.25 \times 10^{-3} \times 1000 \times 9.8) / (2 \times 1)$
- $T = 0.147 / 2 = 0.0735 \text{ N/m}$

Answer: Surface tension = 0.0735 N/m.

C. Viscosity

N13. Two parallel plates are 1.5 mm apart with oil of viscosity 0.9 Pa·s between them. The lower plate is fixed and the upper plate, of area 0.4 m², moves at 0.25 m/s. Find the force needed to move the upper plate.

Given: $dx = 1.5 \times 10^{-3} \text{ m}$, $\eta = 0.9 \text{ Pa·s}$, $A = 0.4 \text{ m}^2$, $v = 0.25 \text{ m/s}$

Formula: $F = \eta A v / dx$

Solution:

- $F = (0.9 \times 0.4 \times 0.25) / (1.5 \times 10^{-3})$
- $F = 0.09 / 1.5 \times 10^{-3} = 60 \text{ N}$

Answer: $F = 60 \text{ N}$.

N14. A glass bead of radius 0.1 mm settles in water. Find its terminal velocity. ($\rho_{\text{glass}} = 2500 \text{ kg/m}^3$, $\rho_{\text{water}} = 1000 \text{ kg/m}^3$, $\eta = 10^{-3} \text{ Pa·s}$)

Given: $r = 10^{-4} \text{ m}$, $\rho = 2500 \text{ kg/m}^3$, $\sigma = 1000 \text{ kg/m}^3$, $\eta = 10^{-3} \text{ Pa·s}$

Formula: $v = 2 r^2 (\rho - \sigma) g / (9 \eta)$

Solution:

- $v = (2 \times 10^{-8} \times 1500 \times 9.8) / (9 \times 10^{-3})$
- $v = 2.94 \times 10^{-4} / 9 \times 10^{-3}$
- $v = 3.27 \times 10^{-2} \text{ m/s}$

Answer: Terminal velocity = 3.27 cm/s.

N15. For the glass bead of Problem 14, show that the viscous drag at terminal velocity equals the apparent weight of the bead in water.

Given: $r = 10^{-4}$ m, $\rho = 2500$, $\sigma = 1000$ kg/m³, $\eta = 10^{-3}$ Pa·s, $v = 3.27 \times 10^{-2}$ m/s

Formula: Drag $F = 6\pi \eta r v$; apparent weight = weight – upthrust = $(4/3)\pi r^3 (\rho - \sigma) g$

Solution:

- $F = 6 \times 3.14 \times 10^{-3} \times 10^{-4} \times 3.27 \times 10^{-2} = 6.15 \times 10^{-8}$ N
- Apparent weight = $(4/3) \times 3.14 \times (10^{-4})^3 \times 1500 \times 9.8 = 4.19 \times 10^{-12} \times 14700 = 6.15 \times 10^{-8}$ N
- Both are equal, so the net force is zero and the bead moves with constant velocity.

Answer: Drag = apparent weight = 6.15×10^{-8} N.

N16. An air bubble of radius 1 mm rises in oil of density 900 kg/m³ and viscosity 0.25 Pa·s. Find its terminal velocity. (Density of air = 1.2 kg/m³)

Given: $r = 10^{-3}$ m, $\rho = 1.2$ kg/m³, $\sigma = 900$ kg/m³, $\eta = 0.25$ Pa·s

Formula: $v = 2 r^2 (\rho - \sigma) g / (9 \eta)$; the negative sign shows motion upward

Solution:

- $\rho - \sigma = 1.2 - 900 = -898.8$ kg/m³
- $|v| = (2 \times 10^{-6} \times 898.8 \times 9.8) / (9 \times 0.25) = 1.76 \times 10^{-2} / 2.25$
- $|v| = 7.83 \times 10^{-3}$ m/s

Answer: Terminal velocity = 7.83×10^{-3} m/s (0.78 cm/s), upward.

N17. Two layers of a liquid 4 mm apart move with a speed difference of 0.2 m/s. A force of 0.5 N acts on an area of 0.1 m² of a layer. Find the velocity gradient and the coefficient of viscosity.

Given: $dx = 4 \times 10^{-3}$ m, $dv = 0.2$ m/s, $F = 0.5$ N, $A = 0.1$ m²

Formula: Velocity gradient = dv / dx ; $\eta = F / (A \times dv/dx)$

Solution:

- $dv/dx = 0.2 / 4 \times 10^{-3} = 50$ s⁻¹
- $\eta = 0.5 / (0.1 \times 50) = 0.5 / 5 = 0.1$ Pa·s

Answer: Velocity gradient = 50 s⁻¹; $\eta = 0.1$ Pa·s (= 1 poise).

N18. The coefficient of viscosity of glycerine is 8.5 poise. Convert it into SI units and find the drag on a sphere of radius 1.5 mm moving at 0.02 m/s in it.

Given: $\eta = 8.5$ poise, $r = 1.5 \times 10^{-3}$ m, $v = 0.02$ m/s

Formula: 1 poise = 0.1 Pa·s; $F = 6\pi \eta r v$

Solution:

- $\eta = 8.5 \times 0.1 = 0.85$ Pa·s
- $F = 6 \times 3.14 \times 0.85 \times 1.5 \times 10^{-3} \times 0.02$
- $F = 16.01 \times 1.5 \times 10^{-3} \times 0.02 = 4.8 \times 10^{-4}$ N

Answer: $\eta = 0.85$ Pa·s; drag = 4.8×10^{-4} N.

D. Hydrodynamics

N19. Oil of density 850 kg/m^3 and viscosity $0.12 \text{ Pa}\cdot\text{s}$ flows at 0.8 m/s through a pipe of diameter 4 cm . Find the Reynolds number and the type of flow.

Given: $\rho = 850 \text{ kg/m}^3$, $\eta = 0.12 \text{ Pa}\cdot\text{s}$, $v = 0.8 \text{ m/s}$, $D = 0.04 \text{ m}$

Formula: $Re = \rho v D / \eta$

Solution:

- $Re = (850 \times 0.8 \times 0.04) / 0.12 = 27.2 / 0.12$
- $Re = 227$

Answer: $Re = 227$, which is less than 2000, so the flow is streamline.

N20. Water flows at 0.4 m/s in a pipe. Find the diameter of the pipe at which the flow becomes unstable ($Re = 2000$). ($\rho = 1000 \text{ kg/m}^3$, $\eta = 10^{-3} \text{ Pa}\cdot\text{s}$)

Given: $v = 0.4 \text{ m/s}$, $Re = 2000$, $\rho = 1000 \text{ kg/m}^3$, $\eta = 10^{-3} \text{ Pa}\cdot\text{s}$

Formula: $Re = \rho v D / \eta$, so $D = Re \eta / (\rho v)$

Solution:

- $D = (2000 \times 10^{-3}) / (1000 \times 0.4) = 2 / 400$
- $D = 5 \times 10^{-3} \text{ m}$

Answer: $D = 5 \text{ mm}$. For pipes wider than this, the flow at 0.4 m/s is no longer streamline.

N21. Water flows at 1.5 m/s through a pipe of diameter 8 cm . Find the volume of water delivered per minute in litres and the mass flow rate.

Given: $D = 0.08 \text{ m}$ so $r = 0.04 \text{ m}$, $v = 1.5 \text{ m/s}$, $\rho = 1000 \text{ kg/m}^3$

Formula: $Q = A v$; mass flow rate $= \rho Q$

Solution:

- $A = 3.14 \times (0.04)^2 = 5.02 \times 10^{-3} \text{ m}^2$
- $Q = 5.02 \times 10^{-3} \times 1.5 = 7.54 \times 10^{-3} \text{ m}^3/\text{s}$
- Volume per minute $= 7.54 \times 10^{-3} \times 60 = 0.452 \text{ m}^3 = 452 \text{ litres}$
- Mass flow rate $= 1000 \times 7.54 \times 10^{-3} = 7.54 \text{ kg/s}$

Answer: $Q = 7.54 \times 10^{-3} \text{ m}^3/\text{s} = 452 \text{ litres per minute}$; mass flow rate $= 7.54 \text{ kg/s}$.

N22. Blood flows at 0.4 m/s in an artery of radius 3 mm which branches into 1000 capillaries, each of radius 0.4 mm . Find the speed of blood in each capillary.

Given: $r_1 = 3 \times 10^{-3} \text{ m}$, $v_1 = 0.4 \text{ m/s}$, $N = 1000$, $r_2 = 0.4 \times 10^{-3} \text{ m}$

Formula: $A_1 v_1 = N A_2 v_2$; $A \propto r^2$

Solution:

- $v_2 = v_1 r_1^2 / (N r_2^2)$
- $v_2 = 0.4 \times (3 \times 10^{-3})^2 / (1000 \times (0.4 \times 10^{-3})^2) = 0.4 \times 9 \times 10^{-6} / 1.6 \times 10^{-4}$
- $v_2 = 2.25 \times 10^{-2} \text{ m/s}$

Answer: Speed in each capillary $= 2.25 \text{ cm/s}$ (much slower than in the artery).

N23. A horizontal pipe has a cross-section of 40 cm^2 at the wide part and 10 cm^2 at the narrow part. Water flows at 6 m/s in the narrow part. Find the speed in the wide part and the pressure difference between the two parts.

Given: $A_1 = 40 \text{ cm}^2$, $A_2 = 10 \text{ cm}^2$, $v_2 = 6 \text{ m/s}$, $\rho = 1000 \text{ kg/m}^3$

Formula: $A_1 v_1 = A_2 v_2$; $P_1 - P_2 = \frac{1}{2} \rho (v_2^2 - v_1^2)$

Solution:

- $v_1 = A_2 v_2 / A_1 = 10 \times 6 / 40 = 1.5 \text{ m/s}$
- $P_1 - P_2 = \frac{1}{2} \times 1000 \times (6^2 - 1.5^2) = 500 \times (36 - 2.25)$
- $P_1 - P_2 = 500 \times 33.75 = 16875 \text{ N/m}^2$

Answer: $v_1 = 1.5 \text{ m/s}$; pressure difference = $1.69 \times 10^4 \text{ N/m}^2$ (higher in the wide part).

N24. A tank is filled with water. A small hole is made 2.5 m below the water surface and 1.6 m above the ground. Find the speed of the water leaving the hole and the horizontal distance from the tank where the jet strikes the ground.

Given: $h = 2.5 \text{ m}$ (depth of hole), $H = 1.6 \text{ m}$ (height of hole above ground)

Formula: $v = \sqrt{2 g h}$; time of fall $t = \sqrt{2H / g}$; range $R = v t$

Solution:

- $v = \sqrt{2 \times 9.8 \times 2.5} = \sqrt{49} = 7 \text{ m/s}$
- $t = \sqrt{2 \times 1.6 / 9.8} = \sqrt{0.3265} = 0.571 \text{ s}$
- $R = v t = 7 \times 0.571 = 4.0 \text{ m}$

Answer: Speed of efflux = 7 m/s ; horizontal range = 4.0 m .

N25. Air flows over the top of an aeroplane wing at 120 m/s and under it at 100 m/s . Find the pressure difference and the lift force on the wing if its area is 20 m^2 . (Density of air = 1.3 kg/m^3)

Given: $v_{\text{top}} = 120 \text{ m/s}$, $v_{\text{bottom}} = 100 \text{ m/s}$, $\rho = 1.3 \text{ kg/m}^3$, $A = 20 \text{ m}^2$

Formula: $P_{\text{bottom}} - P_{\text{top}} = \frac{1}{2} \rho (v_{\text{top}}^2 - v_{\text{bottom}}^2)$; lift = $\Delta P \times A$

Solution:

- $\Delta P = \frac{1}{2} \times 1.3 \times (120^2 - 100^2) = 0.65 \times (14400 - 10000)$
- $\Delta P = 0.65 \times 4400 = 2860 \text{ N/m}^2$
- Lift = $2860 \times 20 = 57200 \text{ N}$

Answer: Pressure difference = 2860 N/m^2 ; lift = $5.72 \times 10^4 \text{ N}$.

N26. A horizontal venturimeter has a pipe area of 50 cm^2 and a throat area of 20 cm^2 . The pressure difference between the two sections is 12000 N/m^2 for water. Find the speed in the pipe and the flow rate.

Given: $A_1 = 5 \times 10^{-3} \text{ m}^2$, $A_2 = 2 \times 10^{-3} \text{ m}^2$, $\Delta P = 12000 \text{ N/m}^2$, $\rho = 1000 \text{ kg/m}^3$

Formula: $v_2 = v_1 (A_1/A_2)$; $\Delta P = \frac{1}{2} \rho (v_2^2 - v_1^2)$; $Q = A_1 v_1$

Solution:

- $A_1 / A_2 = 2.5$, so $v_2 = 2.5 v_1$
- $12000 = \frac{1}{2} \times 1000 \times v_1^2 (2.5^2 - 1) = 500 \times 5.25 \times v_1^2 = 2625 v_1^2$
- $v_1^2 = 12000 / 2625 = 4.57$, so $v_1 = 2.14 \text{ m/s}$
- $Q = A_1 v_1 = 5 \times 10^{-3} \times 2.14 = 1.07 \times 10^{-2} \text{ m}^3/\text{s}$

Answer: Speed in the pipe = 2.14 m/s ; flow rate = $1.07 \times 10^{-2} \text{ m}^3/\text{s}$ (10.7 litre/s).

N27. Water flows up through a pipe. At the lower section the diameter is 10 cm, the pressure is $2.5 \times 10^5 \text{ N/m}^2$ and the speed is 1 m/s. At the upper section, 4 m higher, the diameter is 5 cm. Find the pressure at the upper section.

Given: $D_1 = 10 \text{ cm}$, $D_2 = 5 \text{ cm}$, $P_1 = 2.5 \times 10^5 \text{ N/m}^2$, $v_1 = 1 \text{ m/s}$, $h = 4 \text{ m}$, $\rho = 1000 \text{ kg/m}^3$

Formula: $v_2 = v_1 (D_1/D_2)^2$; $P_2 = P_1 + \frac{1}{2}\rho (v_1^2 - v_2^2) - \rho g h$

Solution:

- $v_2 = 1 \times (10/5)^2 = 4 \text{ m/s}$
- $P_2 = 250000 + 500 \times (1 - 16) - 1000 \times 9.8 \times 4$
- $P_2 = 250000 - 7500 - 39200 = 203300 \text{ N/m}^2$

Answer: $P_2 = 2.03 \times 10^5 \text{ N/m}^2$.