Solutions for Option B – Engineering physics

1. a) $\alpha = mg \times r = 3.0 \times 9.81 \times 0.75 = 22 \text{ rad s}^{-2}$
   b) torque $= F \times r = 0.5 \times MR^2 \times \alpha$
      
      $F = 30 \text{ N}$ gives $\alpha = \frac{30 \times 2}{7 \times 0.25} = 34 \text{ rad s}^{-2}$

2. a) conservation of angular momentum gives $I_1 \omega_1 = I_2 \omega_2$
    
    so $\omega_2 = \frac{2.85 \times 2.0}{1.5} = 3.8 \text{ rad s}^{-1}$
   b) rotational kinetic energy is $0.5 \times I \times \omega^2$
      
      so change in energy is $0.5 \times (1.5 \times 3.8^2) - (2.85 \times 2^2) = 5.1 \text{ J}$

3. a) work done $= \Gamma \theta$
      
      $\theta = 320 \text{ rads}$
      
      torque $= I \times \alpha = 5.3 \text{ N m}$
      
      work done $= 5.3 \times 320 = 1.7 \text{ kJ}$
   b) power $= \Gamma \omega = 4.4 \times 65 = 290 \text{ W}$

4. a) AB is isotherm (less steep than adiabat)
   b) area enclosed by three lines
   c) work done $= \text{area in part (b)} = 150 \text{ J}$
   d) in adiabatic change, $Q = 0$ so internal energy must increase during compression of gas so temperature will rise

5. a) $P = \frac{4.0 \times 10^5 \times 3.0}{5.0} = 2.4 \times 10^5 \text{ Pa}$
   b)

   ![Diagram of pressure-volume graph]
   
   c) (i) work done is area under curve
      
      (ii) adiabat is steeper so area enclosed would be smaller

6. a) change occurs at constant pressure
   b)

   ![Diagram with points A and B]
c) work done = area enclosed = 450 – 550 J

d) (i) Entropy of the universe always increases in real processes.
(ii) entropy inside refrigerator decreases but heat energy is lost to surroundings so overall entropy change is still positive

7. a) (i) 3.0 \times 10^{-4} \times 0.40 = 1.2 \times 10^{-4} m^3 s^{-1}
(ii) A_1v_1 = A_2v_2 so v_2 = \frac{3.0}{1.6} \times 0.40 = 0.75 m s^{-1}

b) flow is accelerated through the constriction so that the flow rate remains constant (conservation of mass)

8. a) pressure difference = \rho g \Delta z = 1.4 \times 10^4 \times 9.81 \times 0.08 = 11 kPa

b) \frac{v_2}{v_1} = \frac{A_1}{A_2} = 4

c) (i) Bernoulli: \frac{1}{2} \rho v^2 + P = \text{const}
so \Delta P = \frac{1}{2} \rho (v_2^2 - v_1^2) = \frac{1}{2} \rho (4v_1^2) - v_1^2 = \frac{15}{2} \rho v_1^2
rearrange to get v_1 = 1.35 m s^{-1}
(ii) flow rate = 8.0 \times 10^2 \times 1.35 \times 4.0 \times 10^{-2} = 43 kg s^{-1}

9. a) (i) continuity equation: Av = constant
so narrower pipe with smaller A will have faster flow
(ii) \frac{1}{2} \rho v^2 + P = \text{const}

b) (i) flow will increase in velocity through B so will decrease in pressure, causing a partial vacuum once it emerges into D
(ii) \Delta P = \frac{1}{2} \rho (v_d^2 - v_c^2)
since water at C is moving very slowly, can approximate v_d^2 - v_c^2 = v_d^2
so v_d = \sqrt{\frac{2 \times 55000}{1000}} = 10.5 m s^{-1}
(iii) flow rate = \pi \times (1.0 \times 10^{-3})^2 \times 10.5 = 3.3 \times 10^{-5} m^3 s^{-1}

10. a) (i) spring constant k = \frac{2.0}{0.05} = 40 N m^{-1}
\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{40}{0.5}} = 8.9 rad s^{-1}
T = \frac{2\pi}{\omega} = 0.70 s

(ii) x

b) resonant frequency is \frac{1}{T} = 1.4 Hz
(i) driving frequency less than resonant frequency so system undergoes light damping i.e. amplitude decreases with each oscillation
(ii) system undergoes resonance, oscillates at maximum amplitude
11. a) resonance
   
   b) system at resonance vibrates with maximum amplitude so bridge will oscillate from side to side
   
   c) add loads to bridge to make it heavier; use different materials with higher resonant frequency

12. a) (i) vibrations that occur when regularly changing external force is applied to a system, resulting in system vibrating at the driving frequency

   (ii) if driving frequency is the same as the natural frequency of the system, it will vibrate at maximum amplitude

   b) (i) Damping is when the amplitude of an oscillating system decreases over time due to energy being lost over time.

   (ii) degree of damping affects the system’s resonant response