

APPLIED PHYSICS 1

Chapter: Work, Power and Energy

SET 3: Proofs and Numerical Problems with Solution Steps

(New questions, not repeated from Sets 1 and 2)

Contents

1. **Part A:** 9 derivations and “Show that” problems (engineering applications)
2. **Part B:** 36 numerical problems, including multi-step exam-type problems

Reminders

- Take $g = 9.8 \text{ m/s}^2$ unless stated otherwise.
- Useful: $v^2 = u^2 + 2as$, $F = ma$, $W = F d \cos\theta$, $F = \mu R$, $KE = \frac{1}{2} mv^2$, $PE = mgh$, $P = W / t = F v$.
- Water: density = 1000 kg/m^3 , so $1 \text{ m}^3 = 1000 \text{ kg}$.

PART A: DERIVATIONS AND SHOW THAT

A1. A body of mass m is pulled on a rough horizontal surface by a rope making angle θ above the horizontal. Show that the force needed to move it uniformly is $F = \mu mg / (\cos\theta + \mu \sin\theta)$. (6 marks)

1. Forces: weight mg (down), normal reaction N (up), pull F at angle θ , friction $f = \mu N$ (backward).
2. Vertical equilibrium: $N + F \sin\theta = mg$, so $N = mg - F \sin\theta$.
3. Horizontal (uniform motion): $F \cos\theta = \mu N = \mu (mg - F \sin\theta)$.
4. $F \cos\theta + \mu F \sin\theta = \mu mg$, so $F (\cos\theta + \mu \sin\theta) = \mu mg$.
5. Therefore **$F = \mu mg / (\cos\theta + \mu \sin\theta)$** .
6. Note: pulling at an angle reduces the normal reaction. F is least when $\tan\theta = \mu$ (θ = angle of friction), giving $F_{\min} = mg \sin\phi$.

A2. Show that the stopping distance of a vehicle moving with speed u on a road with coefficient of friction μ is $s = u^2 / 2\mu g$. (4 marks)

1. Braking (locked wheels) friction force $f = \mu mg$ opposes the motion.
2. Work-energy theorem: work done by friction = change in KE, so $-\mu mg s = 0 - \frac{1}{2} mu^2$.
3. $\mu mg s = \frac{1}{2} mu^2$, and mass cancels.
4. **$s = u^2 / 2\mu g$** . The distance is proportional to u^2 : doubling the speed quadruples the stopping distance. It is independent of mass.

A3. A body is projected up a rough incline with speed u . Show that the distance it travels up before stopping is $s = u^2 / [2g (\sin\theta + \mu \cos\theta)]$. (5 marks)

1. Forces opposing the motion up the plane: $mg \sin\theta$ and friction $\mu mg \cos\theta$.
2. Retardation $a = (mg \sin\theta + \mu mg \cos\theta) / m = g (\sin\theta + \mu \cos\theta)$.
3. From $v^2 = u^2 - 2as$ with $v = 0$: $s = u^2 / 2a$.
4. **$s = u^2 / [2g (\sin\theta + \mu \cos\theta)]$** .

5. Check by energy: $\frac{1}{2} \mu u^2 = (mg \sin\theta + \mu mg \cos\theta) s$ gives the same result. For $\mu = 0$, $s = u^2 / (2g \sin\theta)$.

A4. Show that a body released from rest on a rough incline of length d reaches the bottom with speed $v = \sqrt{[2gd (\sin\theta - \mu \cos\theta)]}$. (4 marks)

1. Acceleration down the plane: $a = g (\sin\theta - \mu \cos\theta)$.
2. $v^2 = u^2 + 2ad$ with $u = 0$ gives $v^2 = 2ad$.
3. $v = \sqrt{[2gd (\sin\theta - \mu \cos\theta)]}$.
4. Putting $\mu = 0$ gives $v = \sqrt{(2gd \sin\theta)} = \sqrt{(2gh)}$, the smooth-plane result.

A5. Show that the loss of mechanical energy of a body sliding down a rough incline equals the work done against friction, $\mu mg \cos\theta \times d$. (5 marks)

1. Loss of PE over length d : $mg h = mg d \sin\theta$.
2. Gain in KE (net force $\times d$): $(mg \sin\theta - \mu mg \cos\theta) d$.
3. Loss of mechanical energy = loss of PE – gain in KE = $mg d \sin\theta - (mg \sin\theta - \mu mg \cos\theta) d$.
4. = $\mu mg \cos\theta \times d$, which is the work done against friction.
5. This energy appears as heat at the surfaces; total energy (including heat) is conserved.

A6. Show that the power required to pump water of discharge Q (m^3/s) to a height h is $P = \rho g Q h$. (4 marks)

1. Mass of water lifted per second = density $\times$ volume per second = ρQ .
2. Work done per second = (mass per second) $\times g \times h = \rho Q g h$.
3. Work per second is power, so $P = \rho g Q h$.
4. For water $\rho = 1000 \text{ kg/m}^3$, so $P = 9800 Q h$ (watt). If pump efficiency is η , input power = P / η .

A7. Show that a vehicle of engine power P moving at its maximum speed against a constant resistance R satisfies $P = R v_{\text{max}}$. (3 marks)

1. Engine (tractive) force F gives power $P = F v$.
2. At maximum speed there is no acceleration, so the net force is zero: $F = R$.
3. Hence $P = R v_{\text{max}}$, i.e. $v_{\text{max}} = P / R$. At speeds below this the extra force $F - R$ produces acceleration.

A8. Show that the work done by gravity depends only on the vertical height and not on the path followed. (5 marks)

1. Divide any path into very small straight segments. Let one segment of length Δl make angle θ with the horizontal.
2. Work by gravity on this segment (smooth path) = $mg \sin\theta \times \Delta l = mg \Delta h$, since $\Delta l \sin\theta = \Delta h$ (the height change).
3. Adding all segments: $W = mg \Sigma \Delta h = mg h$, where h is the total height difference between start and end.
4. Hence $W = mgh$ for every path (straight, curved, or incline of any angle). A force with this property is called a **conservative force** and allows a PE to be defined.

A9. Show that 1 electron-volt = 1.6×10^{-19} J. (2 marks)

1. 1 eV is the energy gained by an electron (charge $e = 1.6 \times 10^{-19} \text{ C}$) accelerated through a potential difference of 1 volt.

2. Energy = charge $\times$ potential difference = $1.6 \times 10^{-19} \text{ C} \times 1 \text{ V} = \mathbf{1.6 \times 10^{-19} \text{ J}}$.

Poly Notes Hub

PART B: NUMERICAL PROBLEMS

B1. Work

W1. A 10 kg block is pulled 6 m along the floor by a rope with tension 40 N at 30° above the horizontal. Friction is 15 N. Find the work done by the rope, by friction, and the net work.

Given: $T = 40 \text{ N}$, $\theta = 30^\circ$, $d = 6 \text{ m}$, $f = 15 \text{ N}$

Solution:

$$\text{Work by rope} = T d \cos\theta = 40 \times 6 \times 0.866 = 207.8 \text{ J}$$

$$\text{Work by friction} = -f d = -15 \times 6 = -90 \text{ J}$$

$$\text{Net work} = 207.8 - 90 = 117.8 \text{ J}$$

Answer: Rope: **207.8 J**; friction: **-90 J**; net: **117.8 J**

W2. A crane lifts 200 kg of bricks to a height of 15 m. Find the work done.

Given: $m = 200 \text{ kg}$, $h = 15 \text{ m}$

Solution:

$$W = mgh = 200 \times 9.8 \times 15 = 29400 \text{ J}$$

Answer: **29400 J**

W3. A 0.1 kg ball is thrown up at 20 m/s. Find the work done by gravity until the ball reaches its highest point.

Given: $m = 0.1 \text{ kg}$, $u = 20 \text{ m/s}$

Solution:

$$\text{Maximum height } h = u^2 / 2g = 400 / 19.6 = 20.4 \text{ m}$$

$$\text{Gravity is opposite to displacement: } W = -mgh = -0.1 \times 9.8 \times 20.4 = -20 \text{ J}$$

$$\text{Check: equals the loss of KE, } \frac{1}{2} \times 0.1 \times 400 = 20 \text{ J}$$

Answer: **-20 J**

W4. A force of 12 N acts at 45° to the displacement of 5 m. Find the work done.

Given: $F = 12 \text{ N}$, $\theta = 45^\circ$, $d = 5 \text{ m}$

Solution:

$$W = 12 \times 5 \times \cos 45^\circ = 60 \times 0.7071 = 42.4 \text{ J}$$

Answer: **42.4 J**

W5. A 70 kg man climbs an 8 m long ladder inclined at 60° to the ground. Find the work done against gravity.

Given: $m = 70 \text{ kg}$, $L = 8 \text{ m}$, $\theta = 60^\circ$

Solution:

$$\text{Vertical height } h = L \sin 60^\circ = 8 \times 0.866 = 6.93 \text{ m}$$

$$W = mgh = 70 \times 9.8 \times 6.93 = 4753 \text{ J}$$

Answer: **≈ 4753 J**

B2. Friction

F1. A 20 kg block ($\mu = 0.25$) is pulled uniformly by a rope at 30° above the horizontal. Find the pull.

Given: $m = 20 \text{ kg}$, $\mu = 0.25$, $\theta = 30^\circ$

Solution:

$$F = \mu mg / (\cos\theta + \mu \sin\theta)$$

$$\mu mg = 0.25 \times 196 = 49 \text{ N}$$

$$\text{Denominator} = 0.866 + 0.25 \times 0.5 = 0.991$$

$$F = 49 / 0.991 = 49.4 \text{ N}$$

Answer: 49.4 N (a horizontal pull would need 49 N; here N is reduced to 171.5 N)

F2. A car travelling at 54 km/h brakes with locked wheels on a road with $\mu = 0.5$. Find the stopping distance.

Given: $u = 54 \text{ km/h} = 15 \text{ m/s}$, $\mu = 0.5$

Solution:

$$s = u^2 / 2\mu g = 225 / (2 \times 0.5 \times 9.8)$$

$$s = 225 / 9.8 = 23.0 \text{ m}$$

Answer: 23 m

F3. A truck must stop within 40 m on a road with $\mu = 0.4$. Find the maximum safe speed.

Given: $s = 40 \text{ m}$, $\mu = 0.4$

Solution:

$$u^2 = 2\mu g s = 2 \times 0.4 \times 9.8 \times 40 = 313.6$$

$$u = 17.7 \text{ m/s} = 17.7 \times 3.6 = 63.8 \text{ km/h}$$

Answer: 17.7 m/s (63.8 km/h)

F4. A 12 kg block is pulled by a horizontal force of 60 N on a floor with $\mu = 0.3$. Find its acceleration.

Given: $m = 12 \text{ kg}$, $F = 60 \text{ N}$, $\mu = 0.3$

Solution:

$$\text{Friction } f = \mu mg = 0.3 \times 12 \times 9.8 = 35.28 \text{ N}$$

$$\text{Net force} = 60 - 35.28 = 24.72 \text{ N}$$

$$a = F_{\text{net}} / m = 24.72 / 12 = 2.06 \text{ m/s}^2$$

Answer: 2.06 m/s²

F5. A box rests on a truck bed ($\mu_s = 0.35$). Find the maximum acceleration of the truck for which the box does not slip.

Given: $\mu = 0.35$

Solution:

The only horizontal force on the box is friction: $\mu mg = ma$

$$a_{\text{max}} = \mu g = 0.35 \times 9.8 = 3.43 \text{ m/s}^2$$

Answer: 3.43 m/s²

F6. A 500 N body needs a 150 N force to start moving on a floor. A 300 N load is then placed on it. Find the new force needed.

Given: $W_1 = 500 \text{ N}$, $F_1 = 150 \text{ N}$

Solution:

$$\mu = F_1 / R_1 = 150 / 500 = 0.3$$

$$\text{New normal reaction } R_2 = 500 + 300 = 800 \text{ N}$$

$$F_2 = \mu R_2 = 0.3 \times 800 = 240 \text{ N}$$

Answer: 240 N

B3. Rough Inclined Plane

I1. A block is projected up a plane inclined at 30° with speed 10 m/s. If $\mu = 0.2$, how far up does it go?

Given: $u = 10 \text{ m/s}$, $\theta = 30^\circ$, $\mu = 0.2$

Solution:

$$a = g (\sin\theta + \mu \cos\theta) = 9.8 (0.5 + 0.2 \times 0.866) = 9.8 \times 0.6732 = 6.60 \text{ m/s}^2$$

$$s = u^2 / 2a = 100 / 13.2 = 7.58 \text{ m}$$

Answer: 7.58 m

I2. A body is released from rest at the top of a 10 m long plane inclined at 30° with $\mu = 0.1$. Find its speed at the bottom.

Given: $d = 10 \text{ m}$, $\theta = 30^\circ$, $\mu = 0.1$

Solution:

$$a = g (\sin\theta - \mu \cos\theta) = 9.8 (0.5 - 0.0866) = 4.05 \text{ m/s}^2$$

$$v^2 = 2ad = 2 \times 4.05 \times 10 = 81.0$$

$$v = 9.0 \text{ m/s}$$

Answer: 9.0 m/s

I3. A 5 kg body slides 8 m down a rough plane inclined at 30° with $\mu = 0.2$. Find the mechanical energy lost.

Given: $m = 5 \text{ kg}$, $d = 8 \text{ m}$, $\theta = 30^\circ$, $\mu = 0.2$

Solution:

$$\text{Energy lost} = \mu mg \cos\theta \times d$$

$$= 0.2 \times 5 \times 9.8 \times 0.866 \times 8 = 67.9 \text{ J}$$

Answer: 67.9 J (converted to heat)

14. Find the work done in pulling a 40 kg body 6 m up a plane inclined at 30° with $\mu = 0.15$.

Given: $m = 40 \text{ kg}$, $d = 6 \text{ m}$, $\theta = 30^\circ$, $\mu = 0.15$

Solution:

$$mg = 392 \text{ N}; mg \sin\theta = 196 \text{ N}$$

$$\mu mg \cos\theta = 0.15 \times 392 \times 0.866 = 50.9 \text{ N}$$

$$F = 196 + 50.9 = 246.9 \text{ N}$$

$$W = 246.9 \times 6 = 1481 \text{ J}$$

Answer: $\approx 1481 \text{ J}$

15. A 10 kg body is on a plane inclined at 30° with $\mu = 0.2$. Find (i) the minimum force up the plane to prevent it sliding down, (ii) the force up the plane to move it up uniformly.

Given: $m = 10 \text{ kg}$, $\theta = 30^\circ$, $\mu = 0.2$

Solution:

$$mg \sin\theta = 49 \text{ N}; \mu mg \cos\theta = 0.2 \times 98 \times 0.866 = 16.97 \text{ N}$$

$$(i) \text{ Friction helps to hold: } F = 49 - 16.97 = 32.03 \text{ N}$$

$$(ii) \text{ Friction opposes upward motion: } F = 49 + 16.97 = 65.97 \text{ N}$$

Answer: (i) **32.0 N**; (ii) **66.0 N**

16. A body slides down a 30° incline with acceleration 3 m/s^2 . Find μ .

Given: $\theta = 30^\circ$, $a = 3 \text{ m/s}^2$

Solution:

$$a = g(\sin\theta - \mu \cos\theta), \text{ so } 3 = 9.8(0.5 - 0.866\mu)$$

$$0.5 - 0.866\mu = 0.3061$$

$$\mu = 0.1939 / 0.866 = 0.224$$

Answer: $\mu \approx 0.224$

17. A 150 kg load is pushed up a 4 m ramp rising 1 m with $\mu = 0.2$. Find the force and work done.

Given: $m = 150 \text{ kg}$, $d = 4 \text{ m}$, $h = 1 \text{ m}$, $\mu = 0.2$

Solution:

$$\sin\theta = 1/4 = 0.25, \cos\theta = 0.968; mg = 1470 \text{ N}$$

$$F = 1470 \times 0.25 + 0.2 \times 1470 \times 0.968 = 367.5 + 284.7 = 652.2 \text{ N}$$

$$W = 652.2 \times 4 = 2609 \text{ J}$$

Answer: $F = 652 \text{ N}$; $W = \approx 2609 \text{ J}$

B4. Energy

E1. Find the kinetic energy of a 6000 kg bus moving at 36 km/h.

Given: $m = 6000 \text{ kg}$, $v = 36 \text{ km/h} = 10 \text{ m/s}$

Solution:

$$KE = \frac{1}{2} \times 6000 \times 100 = 300000 \text{ J}$$

Answer: 300 kJ

E2. A 2 kg mass is thrown vertically downward at 10 m/s from a height of 20 m. Find its speed on reaching the ground.

Given: $m = 2 \text{ kg}$, $u = 10 \text{ m/s}$, $h = 20 \text{ m}$

Solution:

$$\text{Total initial energy} = \frac{1}{2} \times 2 \times 100 + 2 \times 9.8 \times 20 = 100 + 392 = 492 \text{ J}$$

$$\text{At ground: } \frac{1}{2} \times 2 \times v^2 = 492, \text{ so } v^2 = 492$$

$$v = 22.2 \text{ m/s}$$

Answer: 22.2 m/s

E3. A 5 kg hammer falls 0.8 m onto a nail and drives it 2 cm into wood. Find the speed on impact and the average force on the nail (neglect the weight during penetration).

Given: $m = 5 \text{ kg}$, $h = 0.8 \text{ m}$, $s = 0.02 \text{ m}$

Solution:

$$v = \sqrt{2gh} = \sqrt{15.68} = 3.96 \text{ m/s}$$

$$KE \text{ at impact} = mgh = 5 \times 9.8 \times 0.8 = 39.2 \text{ J}$$

$$F \times s = KE, \text{ so } F = 39.2 / 0.02 = 1960 \text{ N}$$

Answer: $v = 3.96 \text{ m/s}$; $F = 1960 \text{ N}$

E4. A 60 kg skier slides down from a height of 40 m. Find the speed at the bottom (i) without friction, (ii) if 6000 J is lost to friction.

Given: $m = 60 \text{ kg}$, $h = 40 \text{ m}$

Solution:

$$(i) v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 40} = \sqrt{784} = 28 \text{ m/s}$$

$$(ii) KE = mgh - \text{loss} = 60 \times 9.8 \times 40 - 6000 = 23520 - 6000 = 17520 \text{ J}$$

$$v = \sqrt{2 \times 17520 / 60} = \sqrt{584} = 24.2 \text{ m/s}$$

Answer: (i) 28 m/s; (ii) 24.2 m/s

E5. A 0.05 kg arrow is shot vertically upward at 40 m/s. Find its KE at launch and the maximum height.

Given: $m = 0.05 \text{ kg}$, $u = 40 \text{ m/s}$

Solution:

$$KE = \frac{1}{2} \times 0.05 \times 1600 = 40 \text{ J}$$

$$h = u^2 / 2g = 1600 / 19.6 = 81.6 \text{ m}$$

Answer: $KE = 40 \text{ J}$; $h = 81.6 \text{ m}$

E6. A 500 kg pile driver hammer is dropped from 2 m onto a pile. Find its KE and speed just before impact.

Given: $m = 500 \text{ kg}$, $h = 2 \text{ m}$

Solution:

$$KE = mgh = 500 \times 9.8 \times 2 = 9800 \text{ J}$$

$$v = \sqrt{2gh} = \sqrt{39.2} = 6.26 \text{ m/s}$$

Answer: $KE = 9800 \text{ J}$; $v = 6.26 \text{ m/s}$

E7. 2000 kg of water is lifted from a basement 5 m below the ground to a tank 20 m above the ground. Find the increase in PE.

Given: $m = 2000 \text{ kg}$

Solution:

$$\text{Height difference} = 5 + 20 = 25 \text{ m}$$

$$\Delta PE = mg \Delta h = 2000 \times 9.8 \times 25 = 490000 \text{ J}$$

Answer: $4.9 \times 10^5 \text{ J}$

E8. Two bodies of masses 2 kg and 8 kg have the same KE of 64 J. Find their speeds and the ratio.

Given: $m_1 = 2 \text{ kg}$, $m_2 = 8 \text{ kg}$, $KE = 64 \text{ J}$

Solution:

$$v_1 = \sqrt{2 KE / m_1} = \sqrt{(128 / 2)} = 8 \text{ m/s}$$

$$v_2 = \sqrt{(128 / 8)} = 4 \text{ m/s}$$

$$v_1 : v_2 = 2 : 1 = \sqrt{(m_2 / m_1)}$$

Answer: 8 m/s and 4 m/s

E9. A 0.4 kg ball is thrown upward at 12 m/s from a balcony 1.5 m above the ground. Find the maximum height above the ground.

Given: $u = 12 \text{ m/s}$, $h_0 = 1.5 \text{ m}$

Solution:

$$\text{Rise above the balcony} = u^2 / 2g = 144 / 19.6 = 7.35 \text{ m}$$

$$\text{Height above ground} = 1.5 + 7.35 = 8.85 \text{ m}$$

Answer: 8.85 m

B5. Power

P1. A 15 kW motor lifts a 1000 kg lift at constant speed. Ignoring losses, find the speed.

Given: $P = 15000 \text{ W}$, $m = 1000 \text{ kg}$

Solution:

$$P = F v = mgv$$

$$v = P / mg = 15000 / 9800 = 1.53 \text{ m/s}$$

Answer: 1.53 m/s

P2. A 120 kW engine drives a train at a maximum speed of 20 m/s. Find the resistance.

Given: $P = 120000 \text{ W}$, $v = 20 \text{ m/s}$

Solution:

At maximum speed, tractive force = resistance

$$R = P / v = 120000 / 20 = 6000 \text{ N}$$

Answer: 6000 N

P3. A turbine receives 600 kg of water per second from a height of 30 m. Find the available power and the output at 85 % efficiency.

Given: $m/t = 600 \text{ kg/s}$, $h = 30 \text{ m}$, $\eta = 0.85$

Solution:

$$P = (m/t) g h = 600 \times 9.8 \times 30 = 176400 \text{ W}$$

$$\text{Output} = 0.85 \times 176400 = 149940 \text{ W}$$

Answer: Available = **176.4 kW**; output = **149.9 kW**

P4. A pump lifts water at $0.02 \text{ m}^3/\text{s}$ through 15 m. Find the output power and the input power at 75 % efficiency.

Given: $Q = 0.02 \text{ m}^3/\text{s}$, $h = 15 \text{ m}$, $\eta = 0.75$

Solution:

$$P = \rho g Q h = 1000 \times 9.8 \times 0.02 \times 15 = 2940 \text{ W}$$

$$\text{Input} = 2940 / 0.75 = 3920 \text{ W}$$

Answer: Output = **2940 W**; input = **3920 W**

P5. Three 75 W fans run 8 h/day and two 40 W tube lights run 6 h/day. Find the energy used in 30 days and the bill at ₹6.5 per unit.

Given: Fans: $3 \times 75 \text{ W} \times 8 \text{ h}$; Tubes: $2 \times 40 \text{ W} \times 6 \text{ h}$

Solution:

$$\text{Fans: } 225 \text{ W} \times 8 \text{ h} = 1800 \text{ Wh} = 1.8 \text{ kWh}$$

$$\text{Tubes: } 80 \text{ W} \times 6 \text{ h} = 480 \text{ Wh} = 0.48 \text{ kWh}$$

$$\text{Per day} = 2.28 \text{ kWh; } 30 \text{ days} = 68.4 \text{ kWh}$$

$$\text{Bill} = 68.4 \times 6.5 = ₹444.6$$

Answer: 68.4 kWh; ₹444.60

P6. A 60 W bulb is replaced by a 9 W LED lamp, used 5 h/day for 30 days. Find the energy saved and the money saved at ₹6.5 per unit.

Given: $P_1 = 60 \text{ W}$, $P_2 = 9 \text{ W}$, 5 h/day, 30 days

Solution:

$$\text{Power saved} = 60 - 9 = 51 \text{ W} = 0.051 \text{ kW}$$

$$\text{Energy saved} = 0.051 \times 5 \times 30 = 7.65 \text{ kWh}$$

$$\text{Money saved} = 7.65 \times 6.5 = ₹49.73$$

Answer: 7.65 kWh; ₹49.73

P7. A 3 HP motor pumps water from a depth of 25 m. Find the mass of water lifted per minute.

Given: $P = 3 \text{ HP}$, $h = 25 \text{ m}$, $t = 60 \text{ s}$

Solution:

$$P = 3 \times 746 = 2238 \text{ W}$$

$$\text{Work per minute} = 2238 \times 60 = 134280 \text{ J}$$

$$m = W / gh = 134280 / (9.8 \times 25) = 548 \text{ kg}$$

Answer: $\approx 548 \text{ kg per minute}$

P8. A 70 kg athlete runs up stairs 5 m high in 4 s. Find the power developed.

Given: $m = 70 \text{ kg}$, $h = 5 \text{ m}$, $t = 4 \text{ s}$

Solution:

$$W = mgh = 70 \times 9.8 \times 5 = 3430 \text{ J}$$

$$P = 3430 / 4 = 857.5 \text{ W}$$

Answer: 857.5 W (about 1.15 HP)

P9. A motor (90 % efficient) drives a pump (70 % efficient) that lifts 360 kg of water per minute through 10 m. Find the electrical input power.

Given: $m/t = 360 \text{ kg/min} = 6 \text{ kg/s}$, $h = 10 \text{ m}$, $\eta_1 = 0.9$, $\eta_2 = 0.7$

Solution:

$$\text{Useful output power} = 6 \times 9.8 \times 10 = 588 \text{ W}$$

$$\text{Overall efficiency} = 0.9 \times 0.7 = 0.63$$

$$\text{Input power} = 588 / 0.63 = 933 \text{ W}$$

Answer: $\approx 933 \text{ W}$

Exam tip: In multi-step problems, list the given data, write each formula separately, and keep units with every line.