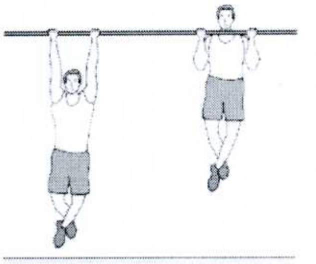
Multi-Step Calculations for Paper 1

Some of these questions are challenging and are designed to make you really think.

Gravitational field strength = 9.8 N/kg

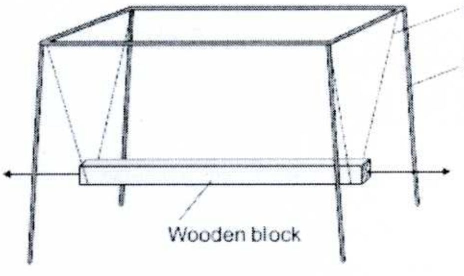


1 Each time the student does one chin-up he lifts his body 0.40 m vertically upwards. The mass of the student is 65 kg. The student is able to do 12 chin-ups in 60 seconds. Calculate the power developed by the student.

$E_p = mgh = 65 \times 9.8 \times 0.4 = 254.8\ J$

$P = E/t = 254.8 \times 12/60 = 51\ W$

2 The diagram shows a playground ride. A large wooden block rests on ropes. The ropes are attached to a metal frame. Children can sit on the wooden block.



When the wooden block is moved to the left and released it moves to and fro. The mass of the block is 40 kg.

A person pushes the wooden block with a force of 300N over a distance of 0.8 m

a) Calculate the maximum speed that the block reaches as it swings to and fro.

$W = Fs = 300 \times 0.8 = 240\ J = E_K$

$E_K = \frac{1}{2}mv^2 \therefore v = \sqrt{2E_K/m} = \sqrt{2 \times 240/40} = 3.46\ m/s$

b) Calculate the maximum height that the block reaches as it swings to and fro.

$E_K \rightarrow E_p = mgh \therefore h = E_p/mg = 240/40 \times 9.8$

$= 0.61\ m$

3 The speed of a toy rocket just after being launched is 12 m/s. The mass of the rocket is 0.05 kg. Calculate the maximum height the rocket will reach. Ignore the effect of air resistance.

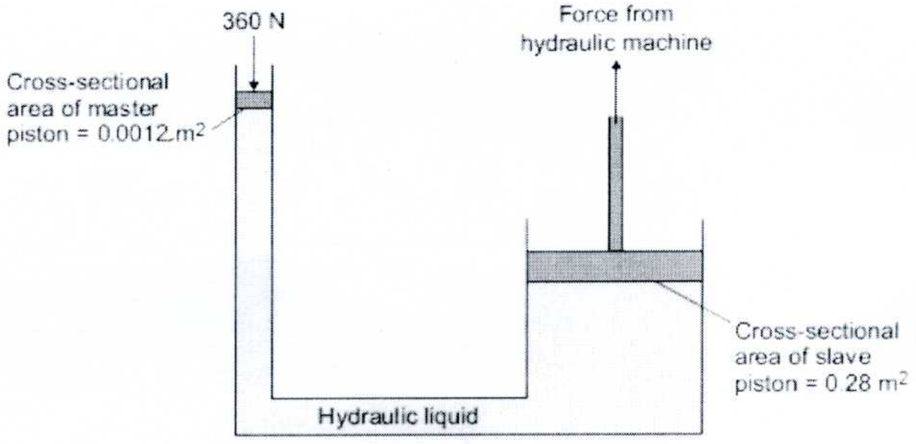
$E_K = \frac{1}{2}mv^2 = \frac{1}{2} \times 0.05 \times 12^2 = 3.6\ J$

$E_K \rightarrow E_p = mgh \therefore h = E_p/mg = 3.6/0.05 \times 9.8$

$= 7.35\ m$

4 The diagram shows a hydraulic jack. The pressure applied to the hydraulic liquid at the master piston is the same as the pressure applied by the hydraulic liquid to the slave piston.

A 360 N force acts on the master piston. Use information from the diagram to calculate the force applied by the hydraulic liquid to the slave piston.

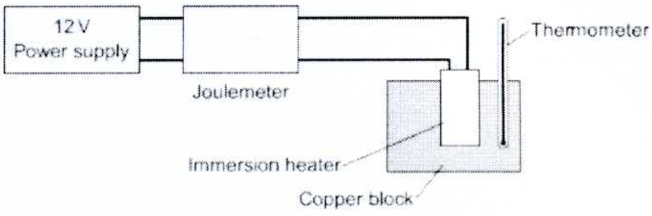


$P = F/A = 360/0.0012 = 300,000$ Pa

For slave $F = PA = 300,000 \times 0.28 = 84000$ N

5 A 2.0 kg copper block was heated up by 20°C in a time of 5 min when connected to the 12 V power supply.
300 s

The specific heat capacity of copper is 385 J/kg°C



a) Calculate the thermal energy transferred to the block.

$\Delta E = mc\Delta\theta = 2.0 \times 385 \times 20 = 15400$ J

b) Calculate the electrical energy suppled to the block assuming the efficiency is 0.7

Eff = OUT/IN ∴ IN = OUT/Eff = 15400/0.7

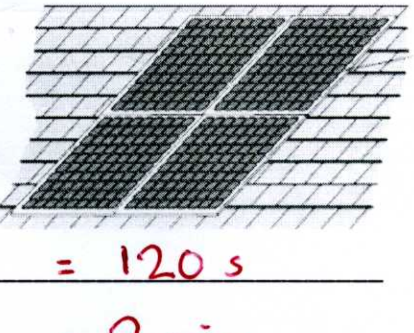
= 22000 J

c) Calculate the resistance of the immersion heater.

$P = E/t = 22000/300 = 73.33$ W

$I = P/V = 73.33/12 = 6.11$ A , $R = V/I = 12/6.11 = 1.96$ A

6 The maximum power available from the photovoltaic cells shown in the diagram is 1.4×10^3 W



a) How long, in minutes, does it take to transfer 168 kJ of energy?

$P = E/t$ ∴ $t = E/P = 168000/1.4 \times 10^3 = 120$ s

= 2 min

£0.4

b) The cost of installing the panels is £6000. The cost of electricity is 40p per kWh
On average the panels operate for 6.5 hours per day supplying 1.4 kW of electricity.
Calculate the time needed before the £6000 cost of the panels is recovered.

$6.5 \times 1.4 \times 0.4 = £3.64$ per day

$£6000 / £3.64 = 1648$ days

$\approx$ 4.5 years

7 A car of mass 1600 kg is travelling at a speed of 20 m/s when the driver applies the brakes. The car decelerates at a constant rate and stops. The braking force used to stop the car was 8000 N.
Calculate the braking distance of the car.

$E_K = \frac{1}{2} \times 1600 \times 20^2 = 3.2 \times 10^5$ J

$W = Fs \therefore s = W/F = 3.2 \times 10^5 / 8000$

$= 40$ m

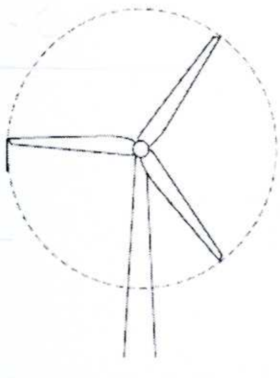
8 Calculate the maximum possible speed of the 90 kg person at the bottom of the slide.

$E_P \rightarrow E_K \therefore mgh = \frac{1}{2}mv^2$

$v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 15}$

$= 17.1$ m/s

9 When a wind turbine is operating, 15 000 kg of air, moving at a speed of 12 m/s pass through it in one second driving the turbine blades around.
This gives an electrical output from the turbine of 450 kW.
Calculate the efficiency of the turbine.

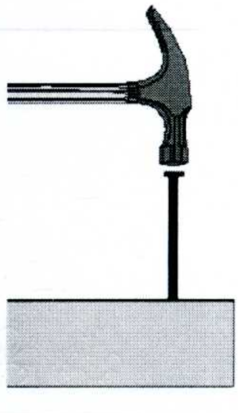


$P_{IN} = \frac{1}{2}mv^2 = \frac{1}{2} \times 15000 \times 12^2 = 1.08 \times 10^6$ W

$Eff = P_{OUT} / P_{IN} = 450{,}000 / 1.08 \times 10^6$

$= 0.42$

10 A hammer of mass 0.75 kg is used to hit a nail into a piece of wood.
The hammers velocity, just before it hits the nail, is 15 m/s
The hammer pushes the nail 2 cm into the wood before coming to a stop.
Calculate the average force that the hammer exerts on the nail.

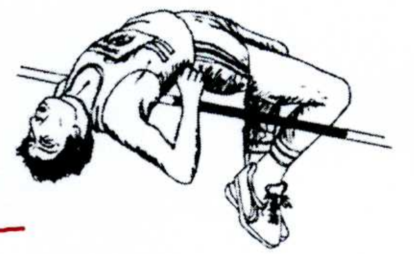


$E_K = \frac{1}{2}mv^2 = \frac{1}{2} \times 0.75 \times 15^2 = 84.4$ J

$W = Fs \therefore F = W/s = 84.4 / 0.02$

$= 4219$ N

11 In order to jump over the bar, the high jumper must raise his mass by 1.25 m. The high jumper has a mass of 65 kg.
Calculate the minimum speed the high jumper must reach for take-off in order to jump over the bar.



$E_K \rightarrow E_p = mgh = 65 \times 9.8 \times 1.25 = 796\text{ J}$

$E_K = \frac{1}{2}mv^2 \therefore v = \sqrt{2E_K/m} = \sqrt{2 \times 796/65}$

$= \underline{4.95\text{ m/s}}$

12 An electric motor was used to lift a mass.
The motor was supplied with a potential difference of 120 V and drew a current of 2.4 A
The motor lifted a mass of 100 kg through a height of 0.8 m in a time of 12 s.
Calculate the efficiency of the motor.

IN $P = IV = 2.4 \times 120 = 288\text{ W}$, $E = Pt = 288 \times 12 = 3456\text{ J}$

OUT $E_p = mgh = 100 \times 9.8 \times 0.8 = 784\text{ J}$, $Eff = 784/3456 = \underline{0.23}$

13 A bungee jumper of mass 75 kg leapt from a bridge attached to a bungee of unstretched length 25 m
At the lowest point the jumper was 92.2 m below the bridge.

a) Calculate the energy lost by the jumper and hence the energy gained by the bungee cord.

$E_p = mgh = 75 \times 9.8 \times 92.2 = 67767\text{ J}$

b) Calculate the spring constant of the bungee cord.

$E_e = \frac{1}{2}ke^2 \therefore k = 2E_e/e^2 \quad (e = 92.2 - 25 = 67.2\text{ m})$

$= 2 \times 67767/67.2^2 = \underline{30.0\text{ N/m}}$

14 A kettle connected to the 230 V mains supply draws a current of 10.5 A
The kettle contains 1.2 kg of water at 20 °C. Calculate how long it will take to heat the water to 100°C.
The specific heat capacity of water is 4200 J/kg °C

$\Delta E = mc\Delta\theta = 1.2 \times 4200 \times 80 = 403200\text{ J}$

$P = VI = 230 \times 10.5 = 2415\text{ W}$

$t = E/P = 403200/2415 = \underline{167\text{ s or } 2.78\text{ min}}$

15 Calculate the minimum time it would take a heater connected to a 24 V supply drawing a current of 5 A to boil away 0.25 kg of water assuming it starts at 100°C.
The latent heat of vaporisation of water is 2257 kJ/kg

$E = mL = 0.25 \times 2257 \times 10^3 = 5.64 \times 10^5\text{ J}$

$P = VI = 24 \times 5 = 120\text{ W}$

$t = E/P = 5.64 \times 10^5/120 = \underline{4700\text{ s} = 78\text{ min}}$