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ENGS121 Mechanics Section C - Homework 5

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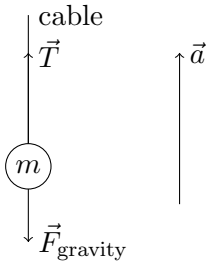
Problem 1 (40 points).

A $250kg$ load is lifted $15m$ vertically with an acceleration $a = 0.15g$ by a single cable. Determine (a) the tension in the cable; (b) the net work done on the load; (c) the work done by the cable on the load; (d) the work done by gravity on the load; (e) the final speed of the load assuming it started from rest.



$$T - mg = ma \implies T = m(a+g) = 250 \cdot (0.15 \cdot 9.8 + 9.8) = 2820N$$

$$A_{\text{net}} = \vec{F}_{\text{net}} \cdot \vec{S} = maS = 250 \cdot 0.15 \cdot 9.8 \cdot 15 = 5510J$$

$$A_{\text{cable}} = \vec{T} \cdot \vec{S} = m(a+g)S = 250 \cdot (0.15 \cdot 9.8 + 9.8) \cdot 15 = 42260J$$

$$A_{\text{gravity}} = \vec{F}_{\text{gravity}} \cdot \vec{S} = -mgS = -250 \cdot 9.8 \cdot 15 = -36750J$$

$$S = v_0 t + \frac{at^2}{2} \overset{v_0=0}{\implies} t = \sqrt{\frac{2S}{a}},\ a = \frac{\Delta v}{t} \overset{v_0=0}{\implies} v = at = \sqrt{2Sa} = \sqrt{2 \cdot 15 \cdot 0.15 \cdot 9.8} = 6.64m/s$$

Problem 2 (25 points).

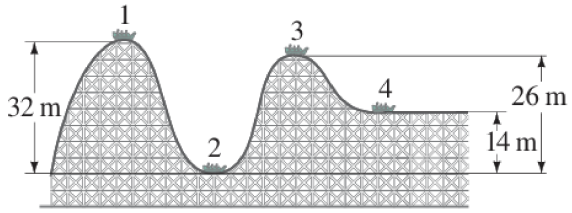
A $1.72m$ tall person lifts a $1.5kg$ book off the ground so it is $2.5m$ above the ground. What is the potential energy of the book relative to (a) the ground, and (b) the top of the person's head? (c) How is the work done by the person related to the answers in parts (a) and (b)?

$$PE_1 = mgh_1 = 1.5 \cdot 9.8 \cdot 2.5 = 36.8J$$

$$PE_2 = mg(h_1 - h_2) = 1.5 \cdot 9.8 \cdot (2.5 - 1.72) = 11.5J$$

Assuming the person has no mass, the only work done by the person is the work lifting the book from ground to height $h = 2.5m$, which is the same as answer at (a), $A = 36.8J$. Without this assumption, the provided information is insufficient to calculate the work done by the person, because there is no way a person can reach a book on the ground without bending their body and doing work against gravity to straighten their own body.

Problem 3 (15 points).



A roller coaster car is pulled up to point 1 where it is released from rest. Assuming no friction, calculate the speed at points 2, 3, 4.

Due to the incompleteness of the conditions described in this problem, it was assumed that air resistance is negligible.

$$E_{\text{total}} = PE_1 + KE_1 \overset{v_0=0}{=} PE_1 = mgh_1$$

$$E_{\text{total}} = PE_i + KE_i \implies KE_i = E_{\text{total}} - PE_i = mgh_1 - mgh_i = \frac{mv_i^2}{2},\ i \in 2,3,4$$

$$\therefore v_i = \sqrt{2g(h_1 - h_i)},\ i \in 2,3,4 \implies \begin{cases} v_2 = \sqrt{2g(h_1 - h_2)} \\ v_3 = \sqrt{2g(h_1 - h_3)} \\ v_4 = \sqrt{2g(h_1 - h_4)} \end{cases} \implies \begin{cases} v_2 = \sqrt{2 \cdot 9.8(32 - 0)} = 25.0m/s \\ v_3 = \sqrt{2 \cdot 9.8(32 - 26)} = 10.8m/s \\ v_4 = \sqrt{2 \cdot 9.8(32 - 14)} = 18.8m/s \end{cases}$$

Problem 4 (10 points).

Suppose the roller coaster car passes point 1 with a speed of $2m/s$. If the average force of friction is equal to 0.5 of its weight, with what speed will it reach point 2? The distance traveled is $50m$.

$$W = mg \implies F_{\text{friction}} = 0.5W = 0.5mg \implies A_{\text{friction}} = -0.5mgS$$

$$E_{\text{total}} = PE_1 + KE_1 = PE_1 + KE_1 - A_{\text{friction}} \implies \frac{mv_1^2}{2} + mgh_1 = \frac{mv_2^2}{2} + mgh_2 + 0.5mgS$$

$$v_2 = \sqrt{v_1^2 + 2gh_1 - 2gh_2 - gS} = \sqrt{2^2 + 2 \cdot 9.8 \cdot 32 - 2 \cdot 9.8 \cdot 0 - 9.8 \cdot 50} = 11.9m/s$$

Problem 5 (10 points).

What minimum horsepower (hp) must a motor have to be able to drag a $350kg$ box along a level floor at a speed of $1m/s$ if the coefficient of friction is 0.25?
It was assumed that static and kinetic frictions are the same and their coefficients equal to 0.25, because otherwise more data would be needed for the calculations, that is not provided.

$$P = \frac{A}{t} = \frac{\vec{F}\vec{S}}{t} = \vec{F}\vec{v} = \mu mg \cdot v = 858W = 1.15hp$$