

Mixed Turkish Tubitak olimpiad's problems and solutions

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Problems

1 Problem 1

There is a plane with slope angle θ . Length of the first part's plane is l_1 . Friction ratio of l_1 is μ_1 . The length of the second part's plane is l_2 and its friction ratio is μ_2 . We know that $\mu_1 > \mu_2$. Object released on the top of the plane. If an object falls down and stops bottom of the plane what's ratio between l_1 and l_2 ?

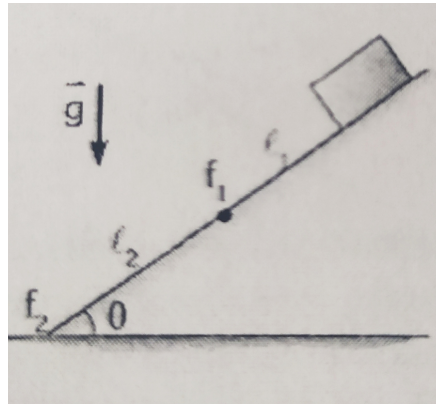


Figure 1: Problem 1

2 Problem 2

Electron with mass m collides with nuclear with mass M . Because of the collision combined nuclear gets energy with magnitude E . What was the velocity of electron? (Ignore relativistic effects)

3 Problem 3

The rocket sent to space from planet with velocity v_0 . What is the maximum altitude rocket can rise? (Radius of the planet is R and ignore air resistance)

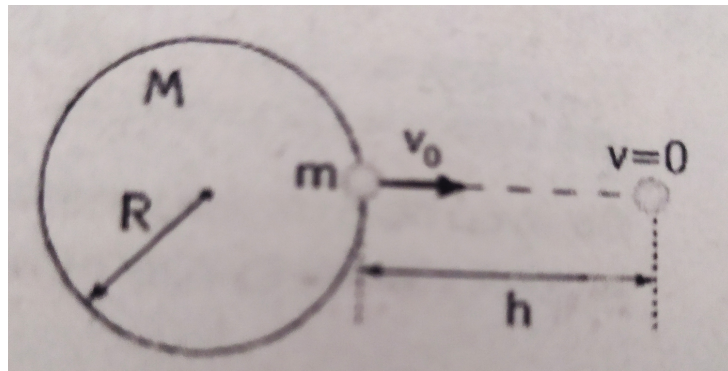


Figure 2: Problem 3;

4 Problem 4

There is a huge container with 2 bases. Area of above base is A_1 , below base's is A_2 . These bases closed by active pistons. Masses of pistons are very small so we can ignore them. Also pistons connected with each other with the help of string in length l . Find the tension force appears in string. (Ignore friction. There is also atmosphere pressure effects to bases. g is gravity acceleration)

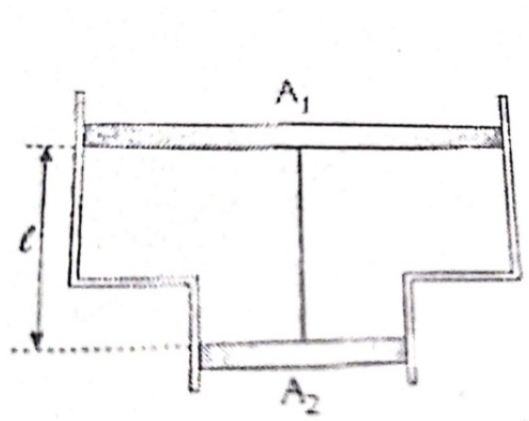


Figure 3: Problem 4

5 Problem 5

1 mol monoatomic ideal gas do some prosses. $A - B$ is adiabatic prosses. Find the efficiency of cycle. ($\gamma = 5/3$)

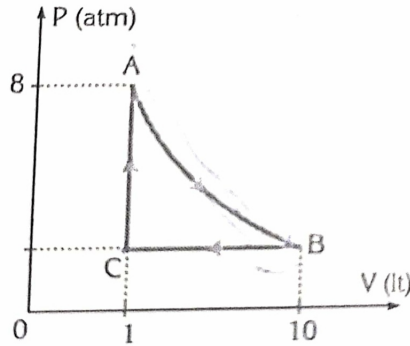


Figure 4: Problem 5

Solutions

6 Problem 1

The road which object went is

$$l_1 = \frac{v^2}{2a_1}$$

$$l_2 = \frac{v^2}{2a_2}$$

Thus:

$$l_1 a_1 = l_2 a_2$$

$$a_1 = g(\sin\theta - \mu_1 \cos\theta)$$

$$a_2 = g(\mu_2 \cos\theta - \sin\theta)$$

Dividing these yields give us:

$$\frac{l_1}{l_2} = \frac{\mu_2 \tan\theta}{\tan\theta - \mu_1}$$

7 Problem 2

Initially momentum of electron is $P = mv$, momentum of combined nuclear and electron is $P_{combined} = (m + M)v_{middle}$ From balance of energy we can write:

$$\frac{1}{2}mv^2 = \frac{1}{2}(m + M)v_{middle}^2 + E$$

These 2 equations give us:

$$v = \sqrt{\frac{2E(m+M)}{mM}}$$

8 Problem 3

We know that total initially energy of system is:

$$E_0 = \frac{1}{2}mv_0^2 - \frac{GMm}{R}$$

$$E_{final} = \frac{-GMm}{R+h}$$

For energy balance we can write:

$$\frac{1}{2}mv_0^2 - \frac{GMm}{R} = \frac{-GMm}{R+h}$$

We know that $GM = gR^2$ So:

$$\frac{1}{2}v_0^2 - \frac{gR^2}{R} = \frac{-gR^2}{R+h}$$

This gives us:

$$h = \frac{v_0^2 R}{2gR - v_0^2}$$

9 Problem 4

Let's say pressure which effects above piston P ,so below piston's pressure must be $P = P_0 + \rho gl$ We know that pistons are balanced.And we can write:

$$P_0 A_1 + T = P A_1$$

$$(P + \rho gl) A_2 = P_0 A_2 + T$$

These give us:

$$T = \frac{\rho gl A_1 A_2}{A_1 - A_2}$$

10 Problem 5

We know that $A - B$ is adiabatic prosses.First of all we can find magnitude of P_C otherwise P_B .We can write :

$$P_{AV}^\gamma = P_{BV}^\gamma$$

solving this yields for P_B we get

$$P_B = P_A \frac{V_A^\gamma}{V_B^\gamma}$$

Now we gotta find efficiency of cycle. $\eta = 1 - \frac{Q_{giv}}{Q_{got}}$. Q_{got} is $A - B$ and $C - B$ processes so: For the 1st rule of thermodynamics $Q = W + U$

$$Q_{BC} = P\delta V + \frac{3}{2}nR\delta T$$

$$Q_{BC} = \frac{5}{2}nR\delta T$$

So we can write:

$$Q_{BC} = \frac{5}{2}\delta PV$$

But law for $A - B$ is a little different. We know that it's isotherm and only temperature const. So $\delta * U = 0$ but work is $W = \int_1^{10} PdV$. It gives us $P\delta V$ For processes $A - C$ we can write only $Q = \frac{3}{2}nR\delta T$ also we can write $Q = \frac{3}{2}\delta PV$ At the end:

$$\eta = 1 - \frac{1.5(8 - 0.17)}{(8 - 0.17)9 + 2.5 * 0.17 * 9}$$

The answer is $\eta = 0.84$