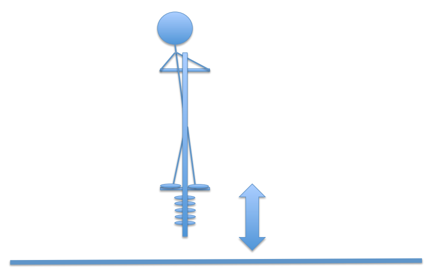
Høsten 2015

FYS100 Fysikk
Obligatorisk Indlevering III

To be handed in at the latest **Friday 16. September, at 23.59**. You must hand it in by scanning your handwritten solution into a single .pdf file, and uploading it to It's learning in "Indlevering 3". If you have written the solution as a electronic document (and not by hand), convert this to .pdf and upload.

Good luck!

Problem 1: Pogo-stick guy

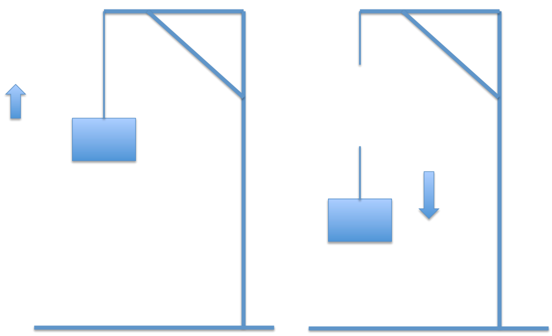


A man is jumping up and down on a pogo stick. For the purpose of this problem, we will think of such a stick as being a (massless) spring with a guy + stick on top. We will assume that no friction is involved, and so in principle the guy could keep jumping forever. At his highest point, the bottom of the (unstretched/unsqueezed) spring is at a height of 40.0 cm from the ground. The spring constant of the pogo stick is taken to be $k = 50000$ N/m. The mass of the guy is 70 kg and of the pogo stick 5 kg. Ignore details about him being able to go higher and higher by bending his knees and stuff; he just stands on the thing.

a) Explain, using a energy bar chart how the different types of energy increase and decrease at different stages of the jumping motion. What is the total energy of the system? (For the purpose for the gravitational potential energy, this is taken to be relative to the lowest point of the jumping motion, when the spring is on the ground, and the spring is squeezed; think carefully about this.)

b) Compute the value of the different energy components at the following points: At the highest point of the jumping motion (A); At the lowest point of the jumping motion (B); at the point where the spring of the pogo stick is at its equilibrium point (C).

Problem 2: Parachute box



A crane is slowly lifting a large box of mass 2 kg by means of a thick (but massless) rope, from the ground to a height of 10.0 m.

a) How much work does the crane do on the box? How much work does gravity do on the box?

b) The rope suddenly breaks and the box falls to the ground. What is its speed as it reaches the ground?

c) Sofar, we have assumed that there is no friction of any kind. Now consider the case when there is a resistive (air drag) force on the box as it drops down from an initial height of 10.0 m. The resistive force is modelled by

$$\vec{\mathbf{R}} = -av^2\hat{\mathbf{v}}. \tag{1}$$

with $a = 0.2\text{kg/m}$. What is the terminal speed v_T of the box? Using Newton's second law, write down the differential equation for $v(t)$.

d) The solution to this differential equation is of the form:

$$v(t) = v_T \tanh\left[\frac{gt}{v_T} + C\right], \tag{2}$$

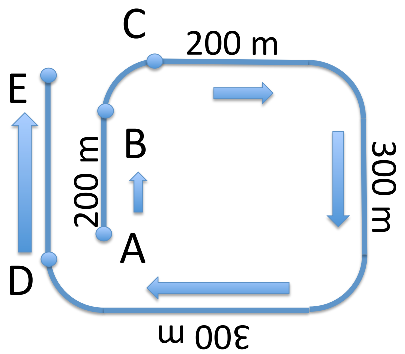
where tanh is the hyperbolic tangent function (look it up), and C is some integration constant. If $t = 0$ is the time when the rope breaks, what should

C be? By direct integration, find $x(t)$; the distance fallen as a function of time. You will need that

$$\int \tanh(y)dy = \ln[\cosh(y)], \tag{3}$$

where cosh is the hyperbolic cosine function (look it up). Find by insertion, whether 1.67 s, 6.71 s or 7.16 s is (approximately) the time it takes do drop to the ground.

Problem 3: Bob-sleigh



At the Olympic bob-sleigh competition, a new (I admit, fairly boring...) track has been built, as drawn in the figure. It is composed of straight lines with lengths as indicated in the figure and 90.0 degree turns, each with the same radius of curvature $r_1 = r_2 = r_3 = r_4 = 40.0$ m. The track slopes evenly downwards all the way down (including through the corners), a total altitude drop of 100 m over a distance of 1.50 km, so between the starting point (A) and the end point (E). You may assume that the ice is frictionless. There is gravity, $g = 9.80$ m/s^2.

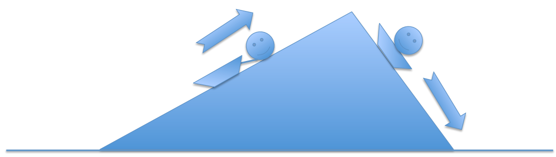
a) Assuming that the sleigh starts from rest at (A), what is its speed when it reaches (B)? How long does the whole run take (from A to E)? (To keep it simple, we will ignore that bobsleighs are usually pushed to begin with by the crew. Here, it is just sliding under the effect of gravity).

b) Consider the point when the sleigh enters the first corner (B). What is the required centripetal acceleration, that the track has to provide immediately after (B)? What is the tangential acceleration during the turn? What is the required centripetal acceleration immediately before reaching (C)?

(c) At what angle ϕ with the horizontal does the sleigh need to slide up the side of the track in order to have the required centripetal force at (B) and (C)?

d) What is the total acceleration of the sleigh as it comes out of the fourth corner (immediately before (D))? In units of g?

Problem 4: More sleighs



A child wants to go ride on her sleigh, and she decides to walk up the Big Hill, of height 100 m relative to where she starts. There are two ways up; the steep way, where the slope is 30.0°, and the not-so steep way, where the slope is 15.0°. The coefficient of kinetic friction between snow and sleigh is $\mu_k = 0.100$. The mass of the sleigh is 8.00 kg, the mass of the child is 30.0 kg.

a) How much work does the child have to do on the sleigh to get it to the top of the hill: the steep way? The not-so-steep way? How much potential energy does the sleigh now have relative to the starting point?

b) The child now sits down on the sleigh and slides down the steep side. What is her speed as she gets to the bottom of the hill? What if she would have gone down the not-so-steep side?

c) Assuming that after reaching the bottom, she can continue on a horizontal surface of snow, how far does she slide before coming to a halt (steep and not-so-steep)?