Physics Homework 4

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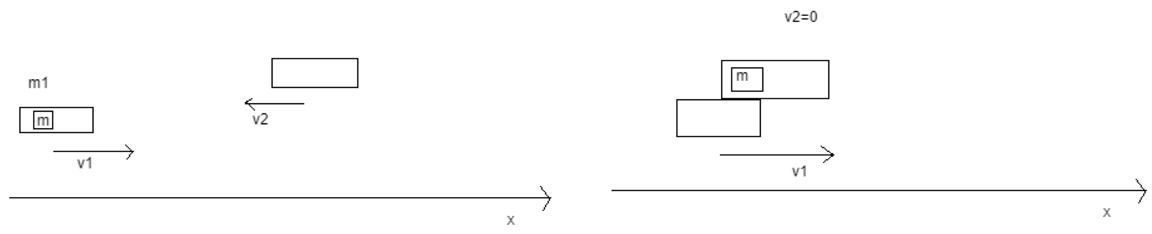
Problem 1 (25 pts)

Two boats were slowly moving by inertia (drag forces exerted by water are negligibly small) along parallel courses towards each other. When the boats reached each other, the load of 25 kg was carefully reloaded from first boat to second one. After that, the second loaded boat stopped, first boat continued moving with velocity of 8 m/s. What were the initial velocities of the boats (m/s, round to 1 decimal place), if the mass of second boat before reloading was 1 ton?

Solution:

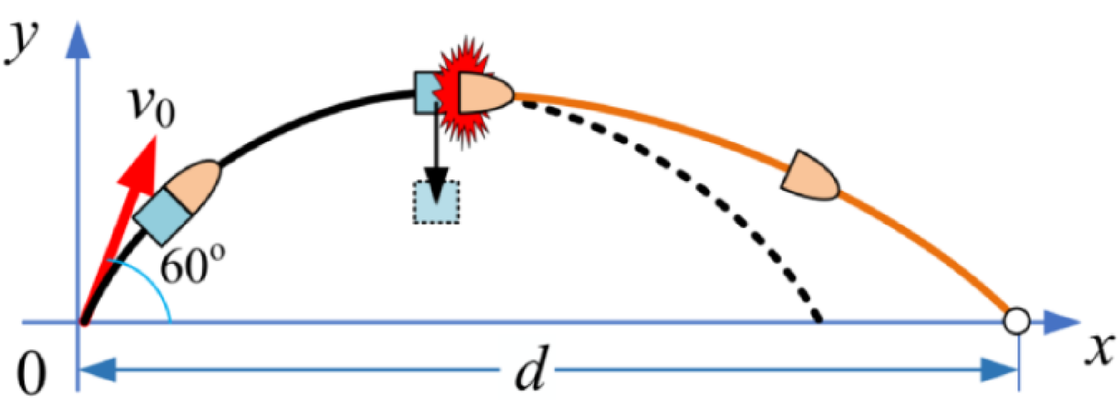


We are searching for v2 after meet and reload it becomes zero

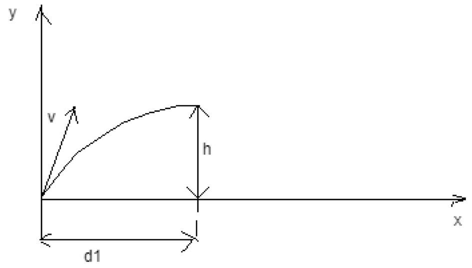
Given: $m = 25\ kg$ $m_1 = 1000\, kg$ $v = 8\, m/s$ g = 9,8 m/s^2	1. Due to careful transportation, regarding the direction of bouts shipping of load does not affect the velocity of the first bout does not change. $v_{first} = v = 8\, m/s$ 2. Then we need to write the impulse conservation law for second boat: $mv + (m_1 - m)v_{second} = 0$ $v_{second} = - \frac{mv}{m_1 - m}$ $v_{second} = - 0.2\, m/s$ **Answer**: $v_{first} = 8\, m/s;\ v_{second} = - 0.2\, m/s$
Find: v_{first} −? v_{second} −?	

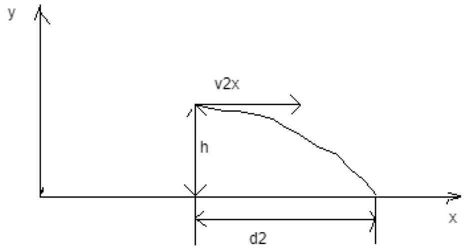
Problem 2 (25 pts)

A projectile is shot from a gun at angle θ = 60° to the flat ground with an initial velocity of v0 = 20 m/s. Once the projectile reaches its maximum height, it explodes into 2 pieces of equal mass, with the rear piece having zero horizontal velocity after the explosion (and thus vertically dropping to the ground, as shown in figure below). What will be the total travel distance d (m, round to 1 decimal place) of the other piece of projectile from the gun, assuming zero air drag?



Solution:
left before division right after





<table>
<tr>
<td>Given:
$v\ =\ 20\ m/s$
$\alpha\ =\ 60°$
g = 9,8 m/s^2</td>
<td rowspan="2">Find the max height: Use formula
$h_{max}\ =\ \frac{v^2 sin^2\alpha}{2g}$
Next step in the highest point it divides, write impulse conservation law and find velocity of the second part which flies horizontally:
$vm\ =\ \frac{m}{2}v_1\ +\ \frac{m}{2}v_2$, make projections on x axis:
$vcos\alpha\ *\ m\ =\ \frac{m}{2}v_2$
$2\ *\ v\ *\ cos\alpha\ =\ v_{2x}$
Find distance before division:
$S\ \ =\frac{v^2 sin2\alpha}{g}$ We know that the distance before division is S/2 because division is in the highest point so $d_1\ =\ S/2\ =\frac{v^2 sin2\alpha}{2g}$
find d_2 using formula $d_2\ =\ v_{2x}\ *\sqrt{\frac{2*h_{max}}{g}}$
$d\ \ =d_1\ +\ d_2\ =$
$\frac{v^2 sin2\alpha}{2g}\ +v_{2x}\ *\sqrt{\frac{2*h}{g}}=\frac{v^2 sin2\alpha}{2g}\ +2\ *\ v\ *\ cos\alpha\ *\sqrt{\frac{2}{g}\ *\ \frac{v^2 sin^2\alpha}{2g}}$
d =53.0 m
Answer: $d\ =$ 53.0 m</td>
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<tr>
<td>Find:
$d\ -?$</td>
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</table>

Problem 3 (25 pts)
Three blocks are placed on a frictionless surface, with blocks of masses m2 and m3 being initially at rest. Block 1 is moving with a velocity of v1i = 10 m/s. It then collides with a block 2 (left figure), which then collides with block 3 (right figure). The third block has mass m3 = 6 kg. After the second collision, block 2 becomes stationary again, while block 3 has the velocity of v3f = 5 m/s. Assuming all collisions to be elastic, find the final velocity v1f of block 1 (m/s, round to 1 decimal place).

Collision between blocks 1-2 (left) and 2-3 (right)

Solution:

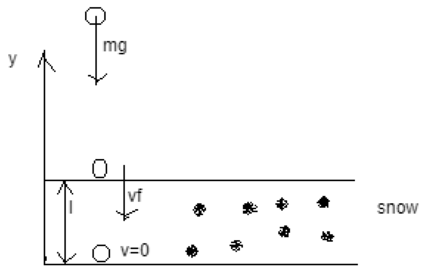
Given:	The law of conservation of impulse for left picture:
$v_{1i} = 10\,m/s$ $m_3 = 6\,kg$ $v_{3f} = 5\,m/s$	$v_{1i}m_1 + m_2v_{2i} = m_1v_{1f} + m_2v_{2f}$; v_{2i}=0; $v_{1i}m_1 = m_1v_{1f} + m_2v_{2f}$ $v_{1f} = \frac{m_1v_{1i} - m_2v_{2f}}{m_1}$;
Find: v_{1f} –?	The second block continue moving so it's v_{2f} becomes $v_{2i\,sec}$ The law of conservation of impulse for right picture: $v_{2i\,sec}m_2 + m_3v_{3i} = m_2v_{2f\,sec} + m_3v_{3f}$; v_{3i}=0; also second block becomes stationary after collision so $v_{2f\,sec} = 0$ $v_{2i\,sec}m_2 = m_3v_{3f}$ Substitute $v_{1f} = \frac{m_1v_{1i} - m_3v_{3f}}{m_1}$ Then write law of conservation of energy: Left: $v_{1i}^2m_1/2 = m_1v_{1f}^2/2 + m_2v_{2f}^2/2$ Right: $v_{2i\,sec}^2m_2/2 = m_3v_{3f}^2/2$ Substitute: $v_{1i}^2m_1/2 = m_1v_{1f}^2/2 + m_3v_{3f}^2/2$ $v_{1f}^2 = \frac{m_1v_{1i}^2 - m_3v_{3f}^2}{m_1}$ Obtain a system: $v_{1f} = \frac{m_1v_{1i} - m_3v_{3f}}{m_1}$ and $v_{1f}^2 = \frac{m_1v_{1i}^2 - m_3v_{3f}^2}{m_1}$ to system to unknowns solve: $v_{1f} = \frac{m_1*10-30}{m_1}$ and $v_{1f}^2 = \frac{m_1*100-6*25}{m_1}$ Substitute: $\frac{100m_1^2-600m_1+900}{m_1^2} = \frac{m_1*100-150}{m_1}$ $100m_1^2 - 600m_1 + 900 = 100m_1^2 - 150m_1$ $450m_1 = 900$ $m_1 = 2$ $v_{1f} = \frac{2*10-30}{2} =- 5\,m/s$ **Answer:** $v_{1f} =- 5\,m/s$

Problem 4 (25 pts)

In February 1955, a paratrooper fell 370 m from an airplane without being able to open his chute but happened to land in snow, suffering only minor injuries. Assume that his speed at impact was vf = 56 m/s (terminal speed), that his mass (including gear) was 85 kg, and that the magnitude of the constant force on him from the snow was at the survivable limit of 1.2 × 10^5 N.

Find: (a) the minimum depth of snow (cm, round to the nearest integer) that would have stopped him safely (15 pts);

(b) time (s, round to 2 decimal places) required for the trooper to pass through this layer of snow before coming to a full stop (5 pts);
(c) the magnitude of the impulse p (N·s, round to 2 decimal places) on him from the snow
Solution:



<table>
<tr>
<td>Given:
h = 370 m
$v_f = 56\ m/s$
m = 85 kg
F = 1.2*10^5 N</td>
<td rowspan="2">a. First write second Newton law in snow:
$mg - F = ma$
Find acceleration: $g - F/m = a$
We know that final speed before snow find l:
$l_{of\ snow} = \frac{v_f^2}{2a} = \frac{v_f^2}{2*g-2*F/m} =- 1,12m =- 112\ cm$
(Final speed in snow 0)
$v_f + at_{in\ snow} = 0$ (Final speed in snow 0)
$t_{in\ snow} =- \frac{v_f}{g-F/m} = 0.04s$
To find magnitude
$p = p_i - p_f; p_f = 0\ as\ v_{final\ in\ snow} = 0$
So $p = p_i = m * v_f = 4760\ N * s$
Answer: $l_{of\ snow} =- 112\ cm$; $t_{in\ snow}$=$0.04s$; $p = 4760\ N * s$</td>
</tr>
<tr>
<td>Find:
$l_{of\ snow}$ −?
$t_{in\ snow}$ −?
p −?</td>
</tr>
</table>