Physics Homework 2

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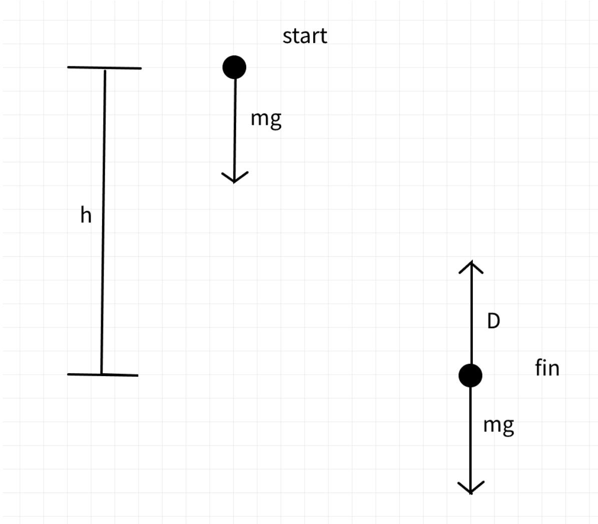
Problem 1 (25 pts)

In the movie "Fast and Furious 7", one particular scene features 5 parachute-equipped cars (Dom's 1968 Dodge Charger, Letty's 2015 Challenger SRT, Roman's 1968 Chevy Camaro Z/28, Brian's Subaru WRX STI, and Tej's Jeep Rubicon) being pushed out of a C-130 cargo airplane at the altitude of approximately 3500 meters. Some parameters of 3 of these cars are given in table below.

	Jeep Rubicon	Dodge Challenger SRT (2015)	Subaru WRX STi
Drag coefficient, C_d	0.5	0.38	0.33
Cross-sectional area, A (m^2)	2.58	2.41	2.225
Mass, m (kg)	2000	2450	1550

The air drag force is given by an equation $D = (1/2)Cd\varrho Av$^2 . Air density and the gravity constant are $\varrho = 1.007\ kg/m3$ and g = 9.8 m/s2 , respectfully. What would be the terminal velocities of each car (m/s, round to 1 decimal place), if they are performing a free-fall headfirst without tumbling in the air?



Solution:

Given:	According to lecture slides.
g = 9.8 m/s2 $\varrho = 1.007\ kg/m3$ h=3500 m	In some moment V will be constant and from this moment until falling down, because mg-D=0; a will be 0; So let us find;
Find: $-\ v$?	mg - $(1/2)Cd\varrho Av^2$=0 v^2 = 2mg/$Cd\varrho A$ v = $\sqrt{2mg/Cd\rho A}$ Take only positive number cause velocity; Answer: 1. Jeep Rubicon: v = 173.7 m/s 2. Dodge Challenger: v = 228.2 m/s 3. Subaru: v = 202.7 m/s == Pin my second solution. So in the initial step let us write the law of conservation of energy. For this

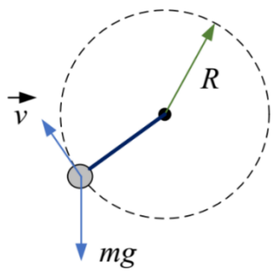
	system. First is potential energy+kinetic energy+Energy that is given by air drag force. $E_{gravity} + E_{kin} + E_{drag} = E_{full}$ So when the car is falling our $E_{gravity}$ goes for overtaking E_{drag} and for increasing E_{kin} We can overwrite in this form. $E_{gravity} = mgh$; $E_{kin} = mv^2/2$; $E_{drag} = D * h$ mgh = m$v^2/2 + D * h$ We know D from the condition 2hmg - $Cd\rho Av^2h = mv^2$ 2hmg = $v^2(m + Cd\rho Ah)$ $v = \sqrt{2hmg/(m + Cd\rho Ah)}$ Jeep Rubicon: v = 144.8 m/s Dodge Challenger: v = 172.1 m/s Subaru: v = 160.3 m/s

Problem 2 (25 pts)

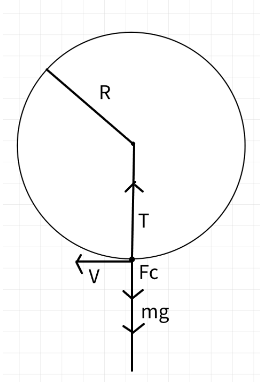
An object of mass m = 0.25 kg, rotating on a string along a circular path of radius R = 0.7 m in the vertical plane, subjects to gravitational force (see figure at the right). The maximum tension force that the string can sustain without breaking is 30 N. If the speed of the object is being slowly increased (it means that the tangential acceleration is negligibly small compared to centripetal one), and assuming g = 9.8 m/s2 , answer the following:

2.1. Find the position of the mass on the circular trajectory (exactly) where the string has maximum tension at a given constant speed of the mass. (10 pts)

2.2. What is the maximum speed (m/s, round to 1 decimal place), when the string does not break for any position of the object on the whole circle trajectory? (15 pts)



Solution:



<table>
<tr>
<td>Given:
m=0.25 kg
R=0.7 m
T = 30 N
g = 9,8 m/s^2</td>
<td rowspan="2">1st part.
We can write forces according to 2nd Newton law.
We have 3 forces 1. T - thread tension force; 2. mg; 3.Centripetal force
In vector form
As our string is not breaking.
T+mg+F_c>0
If we make projection
T+mg(projected somehow)-F_c>0
We can clearly see that T will have maximum value to correspond our equation if mg will be projected as -mg(opposite direction of T force)
T>mg+F_c
This equation fits to case when object is in the lowest point(As I draw)
2nd part
Now let's look on case when string break;
As we know it will be the first time in the lowest point.
It will be broken if
Vector form:
T+mg+F_c<=0
With projection:
T-mg-F_c<=0;
It will break if
T-mg-F_c=0;
T-mg-mv^2/R=0;
v^2=(T-mg)*R/m
$v = \sqrt{(T - mg) * R/m}$
Answer: v = 8.8 m/s</td>
</tr>
<tr>
<td>Find:
$- V$?</td>
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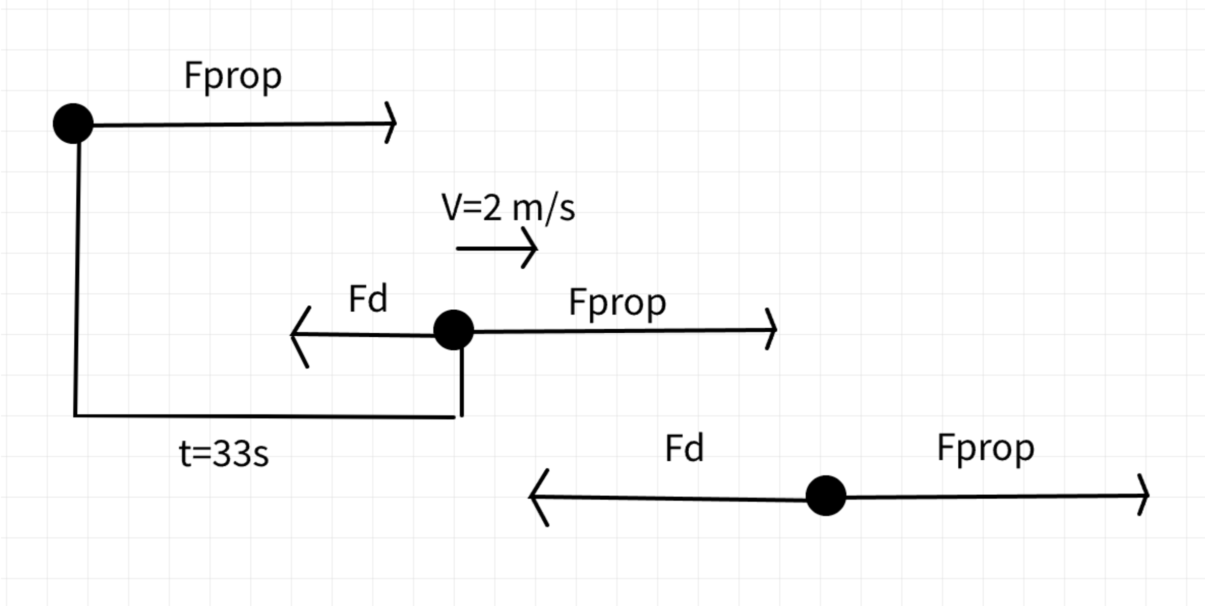
Problem 3 (25 pts)
A motorboat of mass m = 3 tons starts to move from rest. After 33 seconds, its velocity becomes 2 m/s. The engine force propelling the boat is constant throughout the whole period of the motion. Find the maximum velocity of the boat (m/s, round to 1 decimal place), if the drag force is given by the equation $F\ d = -k\vec{v}$. Where $\vec{v}$ denotes the boat velocity and $k = 100\ kg/s$.

Solution:

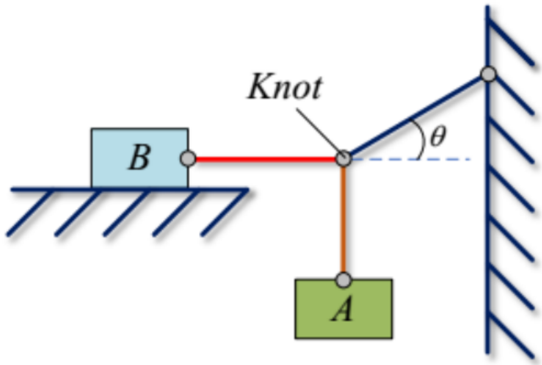


Given:	
Given: m = 3 tons = 3000kg $v_{fin} = 2\ m/s$ t = 33 s k = 100 kg/s Find: v_{max} −?	Start with 2nd Newton law: $F_{prop} + F_d = ma$ With projection on OX: $F_{prop} - kv = ma$ We know that a is dv/dt $m * dv/dt\ = F_{prop} - kv$ Divide both sides on $F_{prop} - kv$, m and mul on dt $dv/(F_{prop} - kv) = dt/m;$ Change $dv;\ According\ to\ rule\ f(u)'du = df(u)$ d($F_{prop} - kv$)/($F_{prop} - kv$) = -k/m*dt Integrate 2 parts first velocity from 0..2m/s second time from 0..33 s $\int_0^2 d(F_{prop} - kv)/(F_{prop} - kv) =- k/m * \int_0^{33} dt$ $ln\|F_{prop} - k2\| - ln\|F_{prop}\| =- k/m * 33$ $ln\|(F_{prop} - 2 * k)/F_{prop}\|$=-33k/m $(F_{prop} - 2 * k)/F_{prop} = e^{-33k/m}$ $1 - 2 * k/F_{prop} = e^{-33k/m}$ $F_{prop} = 2 * k/(1 - e^{-33k/m})$ Next like in the first task, at some moment we will have acceleration equals to 0 when the speed will be max. 2nd Newton law: $F_{prop} - kv = 0$

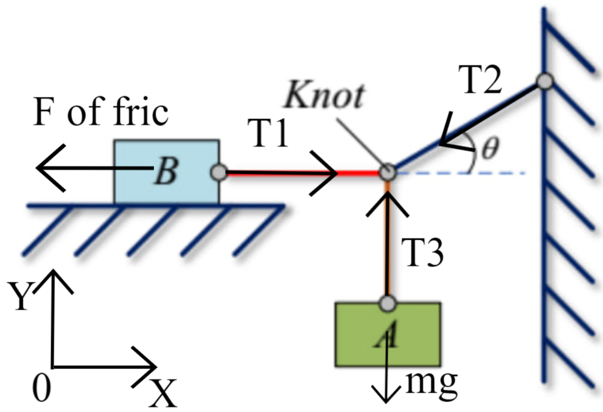
	$2 * k/(1 - e^{-33k/m})$-kv=0 $v = 2/(1 - e^{-33k/m})$ v=3.0 m/s Answer:v = 3.0 m/s

Problem 4 (25 pts)

Block B in figure (right) has the mass of 50 kg. The coefficient of static friction between the block and the table is 0.25; an angle θ is 30°; assume that the cord between B and the knot is horizontal. Find the maximum mass of block A (kg, round to 1 decimal place), for which the system will be stationary. Assume g = 9.8 m/s2 .



Solution:



Given: m_b = 50 kg μ = 0.25 θ = 30°	Write 2nd Newton law according to Knot. 3 Forces. T_1, T_2, mg $T_1 + T_2 + T_3 = ma;$ According to the problem. a=0 as system is stationary $T_1 + T_2 + T_3 = 0;$ Write 2nd Newton law according to B $T_1 + \mu N = m_b a;$

Find: m_a-?	The same with a(a=0) $T_1 + \mu N = 0$; Make projection on OX: $T_1 = \mu m_b g$; Make projection for the Knot on OX: $T_1 - T_2 cos\theta = 0$ Replace $\mu m_b g - T_2 cos\theta = 0$ $\mu m_b g/cos\theta = T_2$ Write 2nd Newton law according to A: $T_3 + m_a g = ma$; The same with a(a=0) $T_3 + m_a g=0$ Make projection for the A on OY $T_3 = m_a g$ Make projection for the Knot on OY: $- T_2 sin\theta + T_3 = 0$ Replace T3: $T_2 sin\theta/g = m_a$ Replace: $\mu m_b g * sin\theta/(cos\theta * g) = m_a$ $\mu m_b * sin\theta/cos\theta = m_a$ m_a = 7.2 kg Answer: m_a = 7.2 kg