PHY151H1F FALL 2022 HW2

Prakash Shivesh

TOTAL POINTS

24 / 24

QUESTION 1

1 q1 12 / 12

✓ **+ 4 pts marks for making reasonable assumptions and clearly communicating these assumptions**

+ **3 pts** marks for making reasonable assumptions and clearly communicating these assumptions, but also making some assumptions which were not explicitly used or needed.

+ **2 pts** marks for making any questionable or unreasonable assumptions, or for not clearly communicating an implicit assumption that was needed when solving the problem

+ **1 pts** marks for making and communicating at least one useful assumption

✓ **+ 4 pts marks for solving the physics problem to get an answer**

+ **3 pts** marks for minor mistakes when solving the physics problem to get an answer

+ **2 pts** marks for a major mistake when solving the physics problem to get an answer.
A well done sketch of the situation and any other relevant representation (force
diagram, velocity-time graph if not already provided, energy bar chart), gets 2 marks

+ **1 pts** marks for any reasonable progress in solving the physics problem. A well done
sketch of the situation, or any other relevant representation (force diagram, velocity-time graph, energy bar chart), gets 1 mark

✓ **+ 4 pts marks for evaluating whether the answer was reasonable by comparing it with a
simple solution using the given numerical values and dimensional analysis or similar
arguments**

+ **3 pts** marks for evaluating whether the answer was reasonable by comparing it with
an intuited estimate which was vaguely explained and based on the given numerical
values

+ **2 pts** marks for evaluating whether the answer was reasonable by comparing it with a
reasonable, intuited value without any justification for the intuited value

+ **1 pts** marks for evaluating whether the answer was reasonable by comparing it with
an unreasonable value

+ **0 pts** marks for not evaluating whether the answer was reasonable

All numerical calculations should include units.

QUESTION 2

2 q1continued 0 / 0

✓ **+ 0 pts Correct**

QUESTION 3

3 q2 12 / 12

✓ **+ 6 pts marks for clearly and correctly evaluating the data with the appropriate equations and/or concepts**

+ **5 pts** marks for correctly evaluating the data with the appropriate equations and/or
concepts, but missing a few minor details

+ **4 pts** marks for correctly evaluating the data with the appropriate equations and/or
concepts, but missing a major detail

+ **3 pts** marks for using appropriate equations and/or concepts but incorrectly evaluating
the data

+ **2 pts** marks for an attempt at analyzing the data using inappropriate equations and/or

concepts which nonetheless demonstrates some understanding of relevant physics.
A well done sketch of the situation and any other relevant representation (force diagram, velocity-time graph if not already provided, energy bar chart), gets 2 marks

+ **1 pts** marks for any correct statement. A well done sketch of the situation, or any other relevant representation (force diagram, velocity-time graph if not already provided, energy bar chart), gets 1 mark

✓ + **3 pts** **marks for clearly and quantitatively answering the question based on the data**

+ **2 pts** marks for having a concluding sentence that is relevant to the question

+ **1 pts** marks for at least underlining or otherwise drawing attention to the final answer

✓ + **3 pts** **marks for correctly addressing the effect of the uncertainties on the analysis**

+ **2 pts** marks for making reasonable statements about the magnitude of the uncertainties.

+ **1 pts** marks for mentioning the uncertainties in some nontrivial fashion

+ **0 pts** Nothing submitted.

QUESTION 4

4 q2continued 0 / 0

✓ + **0 pts** **Correct**

PHY151 Written Homework 2

Due Oct. 16, 2022

Two questions

Please check out the rubrics on Quercus before submitting this

1. Modelling Problem: A typical car engine can provide a force of around

$$F(v) = \left(\frac{100\,\mathrm{m/s}}{v}\right)\,\mathrm{kN}$$

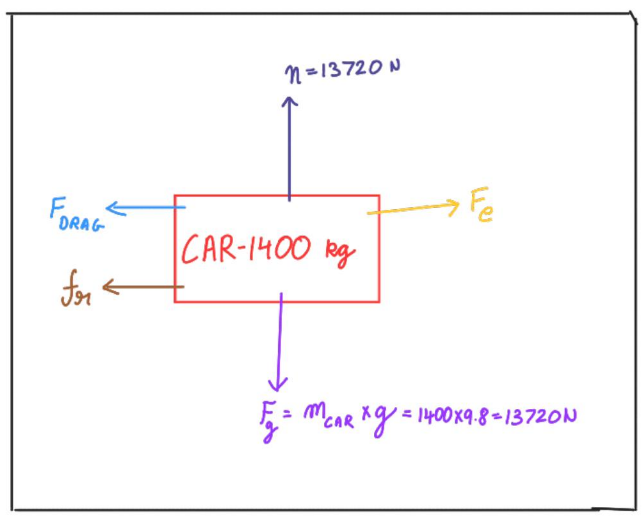
where v is the car's speed. Estimate the car's top speed, taking air resistance into account.

Assumptions:

1. I am assuming the drag coefficient Cd for a car to be 0.24, source: Table 6.3 of Physics for Scientists and Engineers by Randall D Knight.
2. I am assuming the density of air ρ to be 1.2 kg/m^3, source: Table 6.2 of Physics for Scientists and Engineers by Randall D Knight.
3. I am assuming the car to be 1.7 m wide and 1.5 m tall from the front, source: Example 6.7 of Physics for Scientists and Engineers by Randall D Knight.
4. I am assuming the coefficient of rolling friction to be 0.02 and the mass of the car to be 1400 kg, source: Example 6.7 of Physics for Scientists and Engineers by Randall D Knight.
5. I am assuming that the car strictly moves in one direction, this is to obtain the car's top speed with maximum precision.

Free Body Diagram and Forces:

1. F_g (in N), force on car due to the Earth's gravitation
2. n (in N), normal contact force on car from the road
3. F_e (in N), car engine's mechanical force
4. F_{DRAG} (in N), drag force due to air resistance
5. f_r (in N), rolling friction acting on the car's wheels



Solution:

Let's say the car is travelling with its top speed v.

The gravitational force, normal force and rolling friction are independent of the car's speed (if the car is in motion). The gravitational force and normal force is calculated as 13720 N. Since the car is moving, the rolling friction can be calculated as $f_r = \mu_r \times N = 0.02 \times 13720 \approx 274.4\ \mathrm{N}$

Question 1 continued (if needed)

The engine's force can be represented as $F_e = \frac{100}{V} kN = \frac{100000}{V} N$

The drag force can be represented as $F_{DRAG} = \frac{1}{2} C_d \rho A V^2 = \frac{1}{2} \times 0.24 \times 1.2 \times (1.7 \times 1.5) V^2 \approx 0.4 V^2$

For the car to maintain its top speed, the net horizontal force must be zero -->

$$F_e - F_{DRAG} - f_r = 0$$

$$\Rightarrow \frac{100000}{V} - 0.4V^2 - 274.4 = 0$$

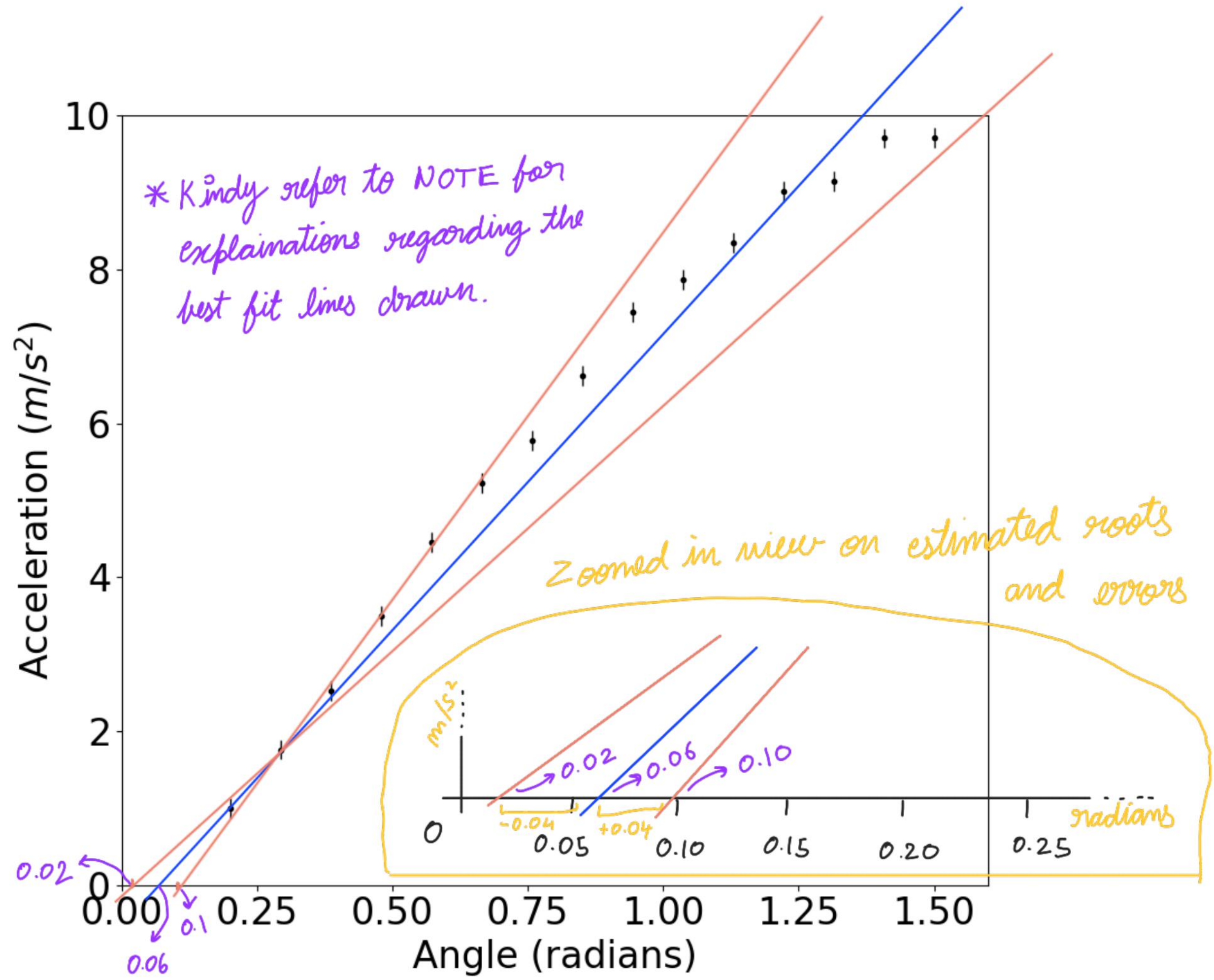
$$\Rightarrow 0.4V^3 + 274.4V - 100000 = 0$$

$$\Rightarrow V \approx 59.4 \text{ m/s (only real solution)}$$

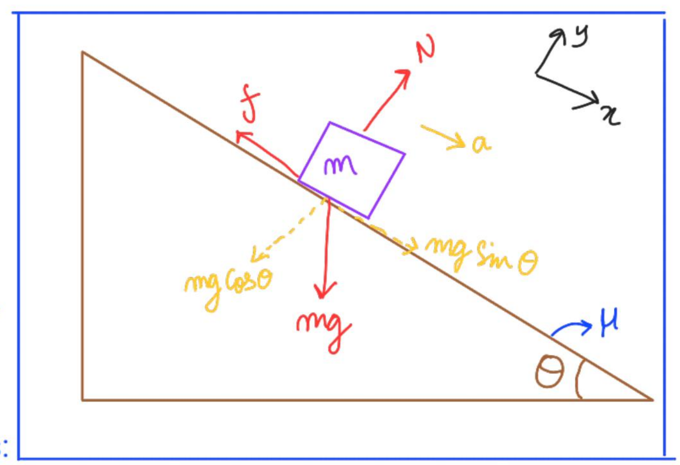
If we neglect rolling friction we get the top speed to be 62.9 m/s, but we can see that rolling is not small enough to be neglected completely. Therefore 59.4 m/s is a more precise and realistic answer for this modelling question. If we round it off to one significant figure, we get the top speed to be 60 m/s in both the cases.

Justification:
This is approximately equivalent to 216 m/s, this is coherent with the top speed of most cars. Speedometer's in most cars go up to 180 or 200 kmph, thus our answer is reasonable and in accordance with various real life examples. I have seen cars on highway easily cross 120 kmph, so 216 kmph or 60 mps is a very reasonable estimate.

2. Data Analysis Problem: A cart's acceleration is measured as it rolls down a ramp of varying angles. The data is presented in the graph below. What's the coefficient of friction of the cart?



Let the coefficient of rolling friction of the ramp be μ
Let the angle of the ramp be θ °.
Let the mass of the cart be m kg.
Let the acceleration of the cart be a m/s^2.
Let acceleration due to gravity be g m/s^2.
Let the normal force on cart be N Newtons
Let the force of rolling friction on the cart be f N
Since there is no acceleration in y direction, $N = mg\cos\theta$



The force acceleration in the x direction can be written as:

$$F_{NET_x} = ma = mg\sin\theta - f = mg\sin\theta - \mu N = mg\sin\theta - \mu mg\cos\theta$$

$$\Rightarrow a = g\sin\theta - \mu g\cos\theta$$

Quest 2 continued (if needed)

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NOTE (Linking data to relevant physics and comments on uncertainties) --->:

The exact equation of the graph given is $a = g \sin\theta - \mu g \cos\theta$, which is not linear. When θ is small, $\sin\theta \to \theta$ and $\cos\theta \to 1$. Thus for small angles the graph equation becomes $a = g\theta - \mu g$, this equation represents a line. Thus for our interpretation of the best fit line we are considering only the first 3-4 data points of the graph. The blue line represents our version of the best fit line, the red lines represent alternative best fit lines considering the error in the given data. Since we are only interested with the roots of the lines, the red lines also show possible deviations from the root of the blue line.

The root cause of uncertainties in our answer is due to the error in the given data, represented by the error bars in the graph. We have accommodated uncertainties in our answer by drawing alternative (red) best fit lines passing throught error bars of important data points (first three points). By using slight approximations, a ruler and multiple best fit lines drawn to estimate uncertainties, we reached the conclusion that acceleration is zero when θ is 0.06 ± 0.04 radians.

Now the equation for acceleration of the cart is $a = g\theta - \mu g$ for small values of θ, the root of this equation is $\theta = 0.06 \pm 0.04$ radians. Therefore ->

$$a = g\theta - \mu g \Rightarrow 0 = g\theta - \mu g \Rightarrow \mu g = g\theta \Rightarrow \mu = \theta$$

$$\Rightarrow \mu = 0.06 \pm 0.04$$

Thus the value of μ is 0.06 ± 0.04

Conclusion:

The value for coefficient of rolling friction calculated by us is completely in agreement with the data presented to us in the graph. The uncertainty which we have estimated is in accordance with the error bars shown in the graphical data. Even though we considered only the first three points to draw best fit lines, our value for θ satisfies most other points too, verified by plotting the exact graph equation on Desmos Virtual Graphing Calculator.

In real life the coefficient of rolling friction is expected to be less than 0.1 for most decent roads, therefore our value for θ is close enough to real data too.