PHY151H1F FALL 2022 HW3

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

QUESTION 2

2 Q1contin **0 / 0**

✓ **+ 0 pts marks found for this page are included with the first page of question 1**

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 clearly and correctly evaluating the data with the appropriate equations and/or concepts but missing a minor detail

+ **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 Q2contin **0 / 0**

✓ + **0 pts** **marks found for this page are included with the first page of question 2**

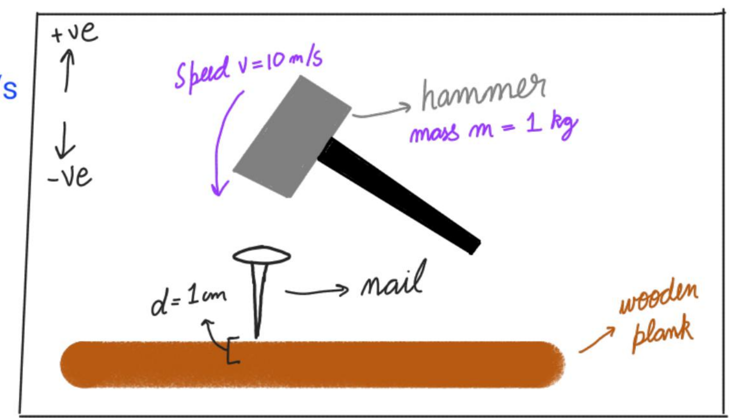
PHY151 Written Homework 3

Due Nov. 6, 2022
Two questions
Please check out the rubrics on Quercus before submitting this

1. Modelling Problem: You are using a hammer to drive a nail into some wood. What is the impulse you give to the nail each time you hit it with the hammer and what is the average force exerted by the hammer on the nail with each collision?

Assumptions:
1. Mass of the hammer is 1 kg, this is based on my general understanding and some Google searches. Also this value makes calculations easier.
2. I assume that the hammer and nail move together after their first interaction and then they both stop together after penetrating a certain distance. This assumption is made to maximize the distance penetrated by the nail.
3. I assume that the hammer hits the nail with a speed of 10 m/s. This is the speed with which an average person runs and I believe I can hit a running person with my hammer, so it is justified.
4. I assume that the wood applies a constant resistive force on the incoming hammer and nail. Thus the velocity of the hammer and nail while penetrating the wood is half of what the hammer came in with.
5. The distance penetrated by the nail in one strike of the hammer is assumed to be 1 cm. This is based on my general understanding and some Google searches. Also this value makes calculations easier.
6. We neglect any effect of the gravity of the Earth, this is because the force applied by the hammer is much greater than the force due to gravity, making it insignificant for our calculations.

Variables and Diagram:
m in kg, mass of the hammer= 1 kg
V in m/s, speed of hammer when it strikes the nail = 10 m/s
d in cm, distance penetrated by the nail in one strike
F in N, average normal force exerted by hammer on nail equivalent to normal force exerted by nail on hammer
V_a in m/s, average combined speed of hammer and nail while penetrating the wooden plank
t_1 in s, time taken for penetrating the distance d



Solution:
Since the resistive force applied by the wooden plank is assumed to be a constant, the average speed with which the hammer and nail penetrate the wood is ½ x 10 = 5 m/s
Now the distance penetrated is assumed to be 1 cm, the hammer and nail cover this distance with a speed of 5 m/s. Thus the time taken is t_1 = distance penetrated/ average velocity = 0.01 / 5 = 0.002 s
After this strike, the final velocity of hammer and nail is 0 m/s. Writing the impulse-momentum equation for the hammer → $\Delta p = \int F.\, dt \approx F.\, \Delta t \approx F.\, t_1$

→ $0 - M.v = F.\, t_1$

→ $-(1 \times 10) = F \times 0.002$

→ $F = -5000$ N (-ve sign indicates it is downwards)

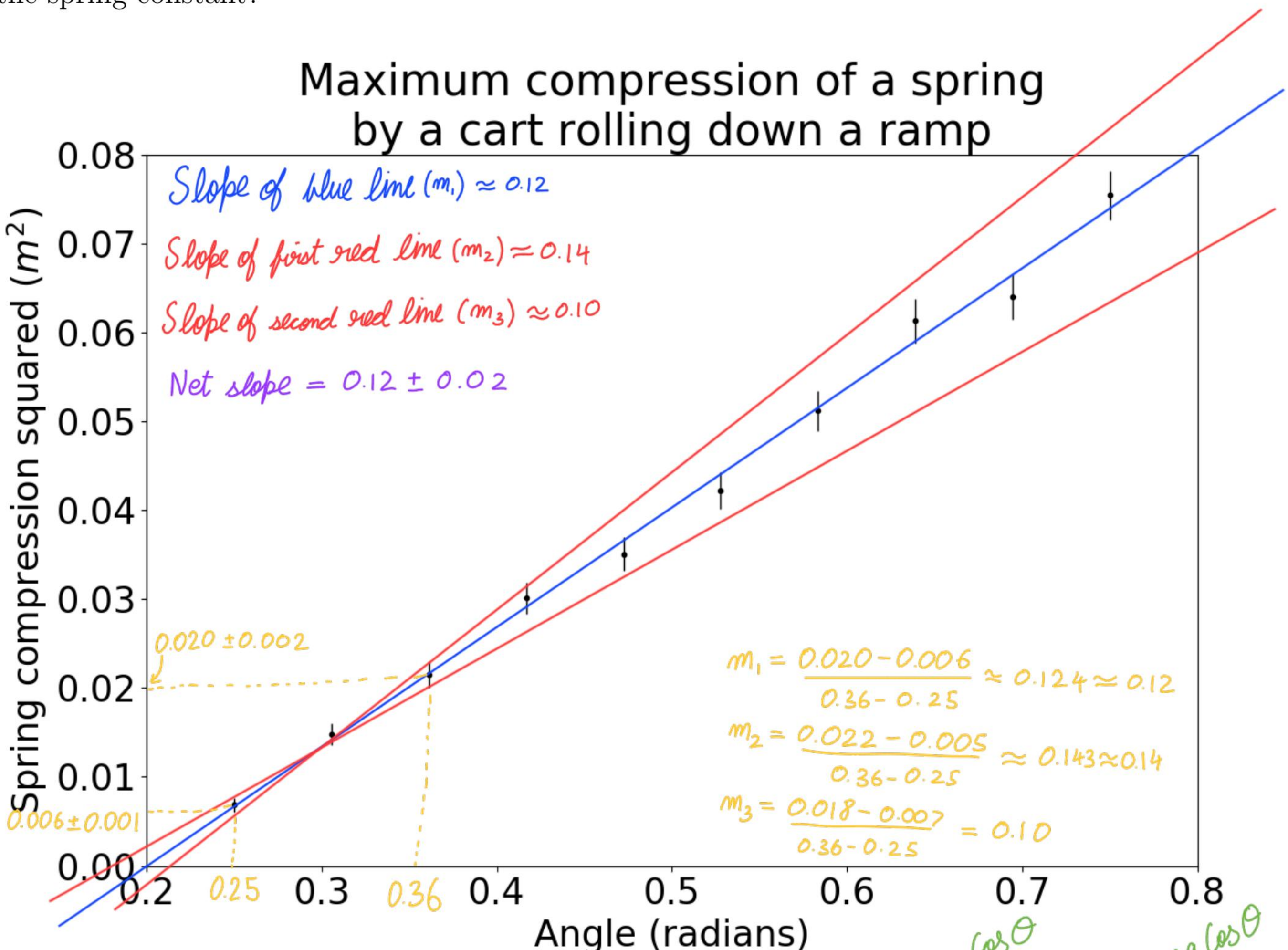
Question 1 continued (if needed)

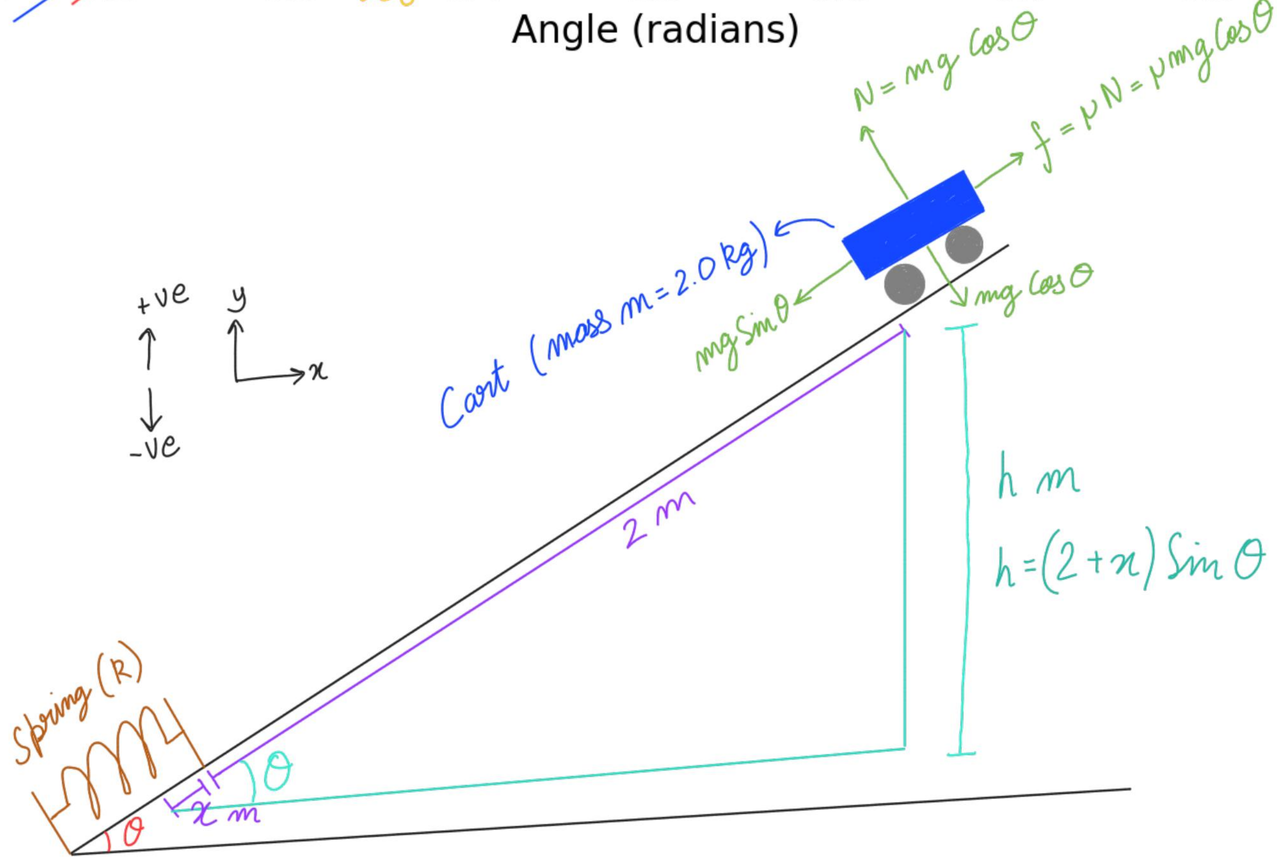
Thus the average force exerted but the hammer on the nail with each collision is 5000 N downwards.
The impulse given to the nail each time I hit it with the hammer is given by
$J = F.\ t_1 = -5000 \times 0.002 = -10$ Ns

In conclusion, the force exerted is 5000 N downwards and the impulse given is 10 Ns downwards.

Justification:
A force of 5000 N is approximately equivalent to the weight of a 500 kg mass. A car weighs around 2000 kg, which is 500 kg worth of weight on each tire. A car passing over my hand or a hammer hitting it are enough to severely injure my hand, I might break a few bones but I will survive in both the cases. I cannot assess which one of the two would be more fatal, thus I conclude that they are equal in effect. Therefore my answer of 5000 N or 500 kg mass worth of weight is in agreement with real life scenarios and is thus an accurate response to this question.

2. Data Analysis Problem: A cart (2.0 kg) is released from rest at the top of a 2.00-m-long plank. The cart rolls down the ramp and hits a spring. The angle of the ramp is varied and the maximum spring compression is recorded for each angle. The data is presented below. What is the spring constant?





Quest 2 continued (if needed)

Variables:

m in kg, mass of the cart = 2.0 kg

k in N/m, spring constant of the spring

θ in radians, inclination of the slope

g in m/s², acceleration due to gravity of Earth

f in N, frictional force on cart due to plane

ΔU_s in J, change in potential energy of spring

μ, coefficient of rolling friction between cart and plane

x in m, compression of the spring after cart strikes it

h in m, total vertical displacement of cart

N in N, normal force on cart due to plane

ΔU_g in J, change in gravitational potential energy of cart

W_f in J, work done by friction on cart

Solution:

Since there is no motion of the cart perpendicular to the plane, $N = mg.\cos\theta$

The static friction f acting on the cart is $f = \mu.N = \mu mg.\cos\theta$

The total vertical displacement of the cart $h = (2+x)\sin\theta$

The loss in gravitational potential energy of the cart $\Delta U_g = - mgh = - mg(2+x)\sin\theta$

The gain in potential energy of spring $\Delta U_s = \frac{1}{2} kx^2$

The work done by friction on cart $W_f = - f.(2+x) = - \mu mg.\cos\theta.(2+x)$

Applying conservation of energy (total change in energy = 0) $\rightarrow \Delta U_g + \Delta U_s + W_f = 0$

$\rightarrow - mg(2+x)\sin\theta + \frac{1}{2} kx^2 - \mu mg.\cos\theta.(2+x) = 0$

$\rightarrow mg(2+x)\sin\theta + \mu mg.\cos\theta.(2+x) = \frac{1}{2} kx^2$

Now x is much smaller than 2, so (2+x) is approximated to 2. Considering this equation for values of $\theta < 0.5$ radians, $\sin\theta \rightarrow \theta$ and $\cos\theta \rightarrow 1$. The equation becomes: $2mg\theta + 2\mu mg = \frac{1}{2} kx^2$

This is a linear plot in terms of x^2 vs θ, with slope $4mg/k = \frac{78.4 \pm 0.4}{k}$

Linking data to relevant physics and comments on uncertainties:

We formed our linear equation for values of $\theta < 0.5$, 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.

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 the slope of our best fit line is 0.12 ± 0.02

Thus using our previous value of slope, $\frac{78.4 \pm 0.4}{k} = 0.12 \pm 0.02 \rightarrow k = 653 \pm 110$ N/m

(Uncertainty in k is calculated using relative uncertainties)

Conclusion:

The value for spring constant 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 k satisfies most other points too, verified by plotting the exact graph equation on Desmos Virtual Graphing Calculator. In real life the spring constant is expected to be less than 2000 for most average roads, therefore our value for k is close enough to real data too.