Theory Question Set 1

Team Decoherence

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NOTE State clearly any assumptions made and try to justify any statement you write.. If any statement or conclusion is not properly justified, marks will be deducted.

Lets have a small Doraemon Episode !

As usual, Nobita woke up late in the morning and started to panic that he would be late at school. Crying he went to Doraemon for help. Unfortunately Doraemon had sent all his advanced gadgets for service to the 22nd Century Factory. He is left with the basic ones.

To help Nobita, he took out a gadget. If someone writes the name of a place and fires the gadget, a rope will get fixed between the two location (a tightrope). Nobita fires it with his school's name on it. But he has no idea how to walk on a tight rope. Help him understand the very basic of it -

Q1) Model Nobita as two point masses (same mass m) attached to the tightrope with two mass less ideal rods. One mass is for the lower portion of the body (toe to waist) and the other for the upper portion. The length of the rods are H and $2H$ respectively. These are assumes to rotate independently around the rope (bending from the waist). Assume the rope is fixed.α_1 and α_2 are the angle made by the two rods (of length $2H$ and H respectively) with respect to the vertical and β is $\alpha_1 - \alpha_2$.
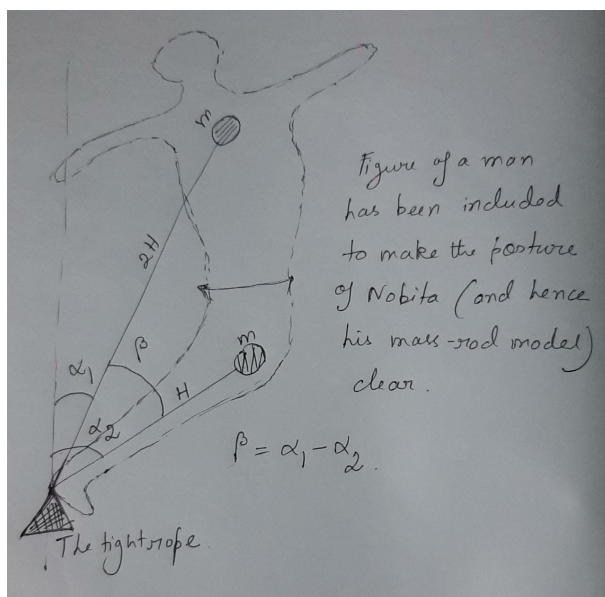
Figure 1:

(a) Suppose Nobita starts falling very very slowly. He realises it instantly and when $\alpha_1 = \alpha_2 = \alpha_0$, he instantly bends such that β value changes from 0 to β_0 instantly. At this position, find the new values of α_1 and α_2 in terms of α_0 and β_0. Assume angular velocity at time of fall is very small and no external torque is applied. [2.5]

(b) His aim is to stand upright on the rope again. In that case, what should have been the direction of bending ? (i.e. β_0 should have been < 0 or > 0 ?). Give Reason. [2.5]

Getting an idea on how to bend and trying his best to keep his balance, Nobita reached school, entered the classroom through the window. Unfortunately, he was anyway late and adding to it the teacher was giving away the test papers. As usual, Nobita got a 0. Suddenly he saw one question which he though was wrongly corrected. His answer was 'No' but the teacher said that it was 'Yes'. The teacher was right (obviously). Help Nobita understand his mistake.

Q2) Consider a square current loop with side L, carrying a current I. An electric field E exists in the region as shown in the figure. The current carrying loop is neutral and the velocity of all the charge carriers passing through a given cross section are equal. The loop is heavy and its motion can be neglected (due to collisions by carriers etc). When the current is switched off, will the loop get an impulse and start moving ? - This was the question.
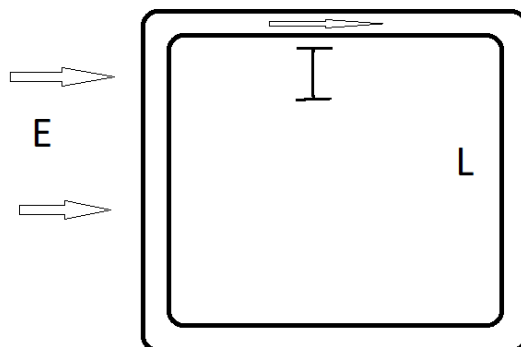
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Figure 2:

(a) Consider a current carrying wire, carrying current I, mass of charge carriers as m and number density is n and charge e and assume same velocity of all carriers. Find the total momentum p of the charged particle per unit length of the wire taking special relativity into account. [1.5]

(b) Account for the the correct 'YES' answer and calculate the momentum imparted. Assume some uniform cross section area of the loop. [4]

After the school hours got over, Nobita started returning home when he noticed Gian and Suneo doing something. Nobita runs to see what they are doing. Gian has taken a rod and supported the rod by his two fingers at the two ends of the rod. Now slowly he is bringing his fingers together to meet under the centre of the rod. Either one or the other finger slides.

Q3) Suppose the rod is of mass m, length L, coefficient of static friction is μ_s and kinetic friction is μ_k. Calculate the work done in the process (obviously, $\mu_k < \mu_s$). [4]

While Gian was trying it, Nobita slipped and pushed Gian. Gian became red angry and ran after Nobita. Nobita somehow managed to escape from Gian but stepped on the tail of a dog. The dog starts chasing him and he entered a field which has only one entrance. Across the field there is a wall (see the figure).

Q4) Nobita started running towards the wall, straight. The dog started chasing Nobita in a way that the velocity vector of the dog at all times is aimed directly towards Nobita. The speed of Nobita is u and that of the dog is v. Find the condition for which Nobita can escape the dog. (the starting positions of the dog and Nobita are shown in the figure itself). [2]
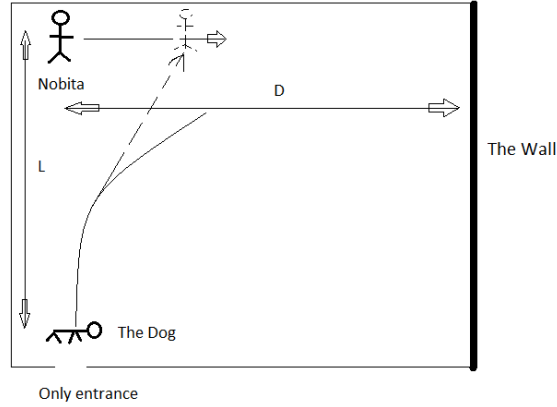
Figure 3:

Nobita came back home (yeah he was successful in escaping) and cried a lot and asked Doraemon to help him take revenge on Gian. Now, Doraemon gave him a potato gun. The gun is shown in the figure.

Q4) Initially, the potato is at rest, volume between the closed end of the cylinder and the potato is V_0 and pressure of gas in the volume is P_0. Atmospheric pressure is P_{atm} and $P_0 > P_{atm}$. The gas in the cylinder is diatomic (ideal). The potato moves down the cylinder quickly enough that no heat transfer takes place. Neglect friction between potato and barrel. You may assume the polytropic index is very close to that of the reversible process. Cross section area of the gun cylinder is A. Parameters P_0, P_{atm}, V_0, and A are fixed, only L can be varied.
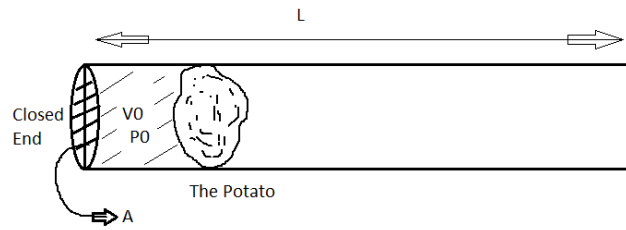

Figure 4:

(a) What is the maximum kinetic energy E_{max} with which the potato can exit the barrel ? Express in terms of P_0, P_{atm}, V_0 ? [2]

(b) What is the length L in this case ? [0.5]

Nobita shot Gian with the gun and then he was happy. In joy, Nobita fired the gun towards some random direction with the maximum energy (E_{max}) found in previous problem. But unfortunately, it hit one of the flower pots in the garden of Sizuka.

Q6) Suppose Nobita was on the roof of one of the houses at a height H above the ground. In terms of E_{max}, find the range in which Sizuka's house was situated from where Nobita was standing. [1]

Sizuka became angry. Nobita became extremely sad and started crying again. Nobita's luck is really bad !