EPFL

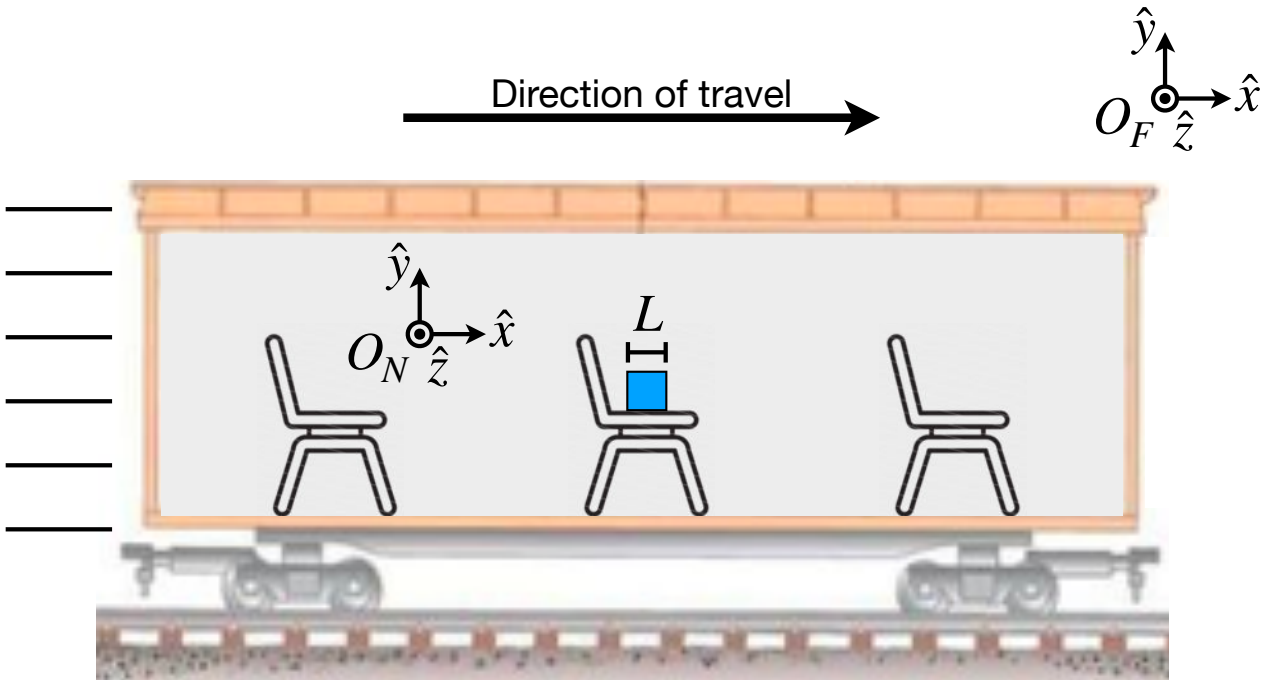
Mock exam 2
PHYS-101(en)
5 December 2023

Problem booklet

Problems

EPFL

1. Box on the Metro (5 points)



You are traveling to EPFL by metro and are carrying a box. The box has mass M and a square cross-section with sides of length L. You sit the box down on an empty forward-facing seat. As you approach the station, the train decelerates at a constant value of $-a_T$. In this problem, we will analyze the range of possibilities for what happens to the box.

You may assume that

- the box has a uniform mass distribution,
- the seat is flat and horizontal,
- the coefficient of static friction between the box and seat is μ_s,
- the coefficient of kinetic friction between the box and seat is μ_k (which is less than μ_s),
- the constant a_T represents the *magnitude* of the deceleration,
- the deceleration is constant and sustained for a very long time,
- air drag is negligible, and
- the acceleration due to gravity is $-g\hat{y}$.

Two Cartesian coordinates system are shown above (which you may use if you wish): one system O_F is in the laboratory frame watching the train move by and one system O_N is in the frame moving with the train. Note that in both $\hat{x}$ points in the direction of travel and $\hat{y}$ points up. Note that "deceleration" means a negative acceleration (i.e. slowing down).

All answers below should be expressed in terms of M, L, g, $\hat{x}$, $\hat{y}$, $\hat{z}$, and/or any quantities specified in the individual question.

First, we will assume that the coefficient of static friction μ_s is sufficiently *small* such that we are concerned the box may start to slide.

a. Calculate the smallest magnitude of the deceleration a_T for which the box will slide. Note that you may include the variables μ_s and μ_k in your answer.

b. If the box begins to slide, what will be the magnitude of the box's acceleration a_b as viewed in the *frame of reference of the train* O_N? Note that you may include the variables μ_s, μ_k, and a_T in your answer.

c. What is the smallest possible value of a_b? Note that you may include the variables μ_s, μ_k, and a_T in your answer.

Next, we will assume that the coefficient of static friction μ_s is sufficiently *large* that it will not slide, but instead potentially tip over.

d. Calculate the smallest magnitude of the acceleration a_T for which the box will *start* to tip over. Note that you may include the variables μ_s and μ_k in your answer.

e. What is the critical value of the coefficient of static friction μ_s that separates when the box tips versus slides? Note that you may include the variables a_T and μ_k in your answer.

f. Calculate the smallest magnitude of the acceleration a_T for which the box will tip all the way over (i.e. rotate from flat on the seat to past 45°). Note that you may include the variables μ_s and μ_k in your answer.

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