Fall 2019 Physics 7A Lec 002 (Yildiz) Final Exam

Instructions:

Please do all your work in this exam, in the blank spaces provided.

You must attempt all seven problems. If you become stuck on one, go on to another and return to the first one later. Be sure to show all your reasoning, since partial credit will be allotted. No credit will be given for unjustified answers.

Remember to circle your final answer.

Please complete the following. On each subsequent page, please write your SID in the upper right corner, where indicated.

Please write your answers in the space below each problem statement. Write only on the front of each page. If you need more paper for scratch work, it is available, but do not put your final answer on your scratch paper. **Only the front side of each page, including scratch paper, will be scanned.**

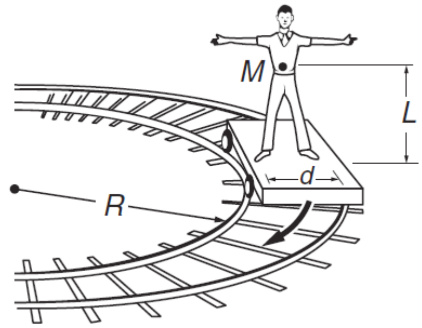
Full name:

SID:

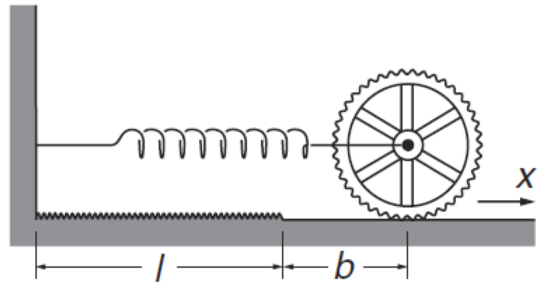
Signature:

1. *(10 points) Man on a railroad car*

A man of mass M stands on a railroad car that is rounding an unbanked turn of radius R at speed v. His center of mass is height L above the car, and his feet are distance d apart. The man is facing the direction of motion. How much weight is on each of his feet?



2. (20 points) Toothed wheel and spring



A wheel with fine teeth is attached to the end of a spring with constant k and unstretched length l, as shown. For $x > l$, the wheel slips freely on the frictionless surface, but for $x < l$ there is a gear track with the teeth on the ground so that the wheel immediately starts rolling without slipping. The wheel has mass M and radius R. Assume that all the mass of the wheel is in its rim. The wheel is pulled to $x = l+b$ and released.

a) What is the velocity of the wheel right before it engages with the gear track at $x = l$?

b) As the wheel engages with the track, it immediately starts rolling without slipping. Is linear momentum, mechanical energy and/or angular momentum conserved at this point? Explain

c) What is the velocity of the wheel right after it starts rolling without slipping at $x = l$?

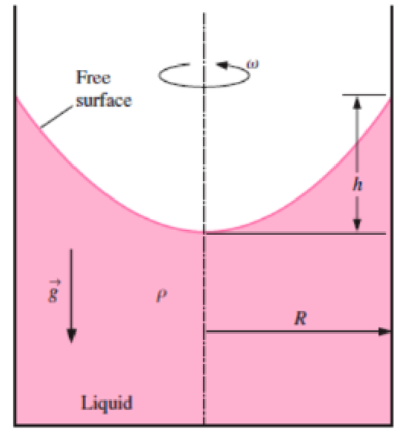
d) How close will the wheel come to the wall on its first trip?

e) When the wheel oscillates back from the wall, how far out will it go after it leaves the gear track?

f) What happens when the wheel hits the gear track again?

3) (15 points) Rotating water

Consider a bucket of a liquid with density ρ in a rigid body rotation with constant angular velocity ω (Both the bucket and the liquid inside rotate together). Show that the surface of the liquid has parabolic shape ($h(R) = AR^2$), where *h(R)* is the height of the liquid surface at a radius *R* from the center of the bucket and *A* is constant. Assume that the height of the liquid surface at the center is 0. Find *A* in terms of ρ, *g*, and ω.

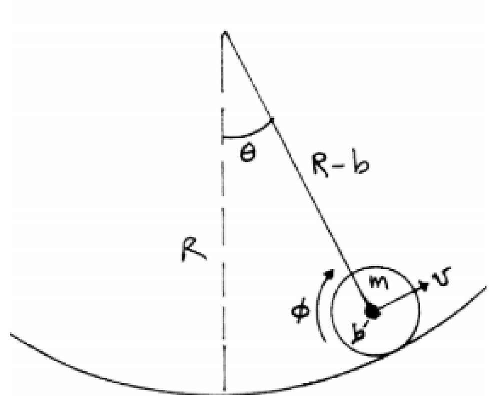


4) (7 points) Bullet train

Conceptual problem: Children are told to avoid standing too close to a rapidly moving (bullet) train because they might get sucked under it. Is this possible? Explain.

5) *(20 points) Marble in dish*

A marble of radius b rolls back and forth in a shallow dish of radius R, where $R >> b$. Find the frequency of small oscillations of the marble.



6) (8 points) Ear Canal

The ear canal is about 3cm long and can be viewed as a tube open at one end and closed at the other. Using the concept of a standing wave, relate this to the fact that we seem to hear best at around 3,000Hz. (Hint: the speed of sound is 330 m/s in air)

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7) (20 points) Doppler Effect

The Doppler equation presented in class is valid when the motion between the observer and the source occurs on a straight line so that the source and observer are moving either directly toward or directly away from each other. If this restriction is relaxed, one must use the more general Doppler equation

$$f' = \left(\frac{v_{snd} + v_0 cos\theta_0}{v_{snd} - v_s cos\theta_s}\right)$$

where v_{snd} is the speed of sound (340 m/s in air), v_s is the velocity of the source, v_0 is the velocity of the observer, and θ_0 and θ_s are defined in the figure below. Use the preceding equation to solve the following problem. A train moves at a constant speed of 25 m/s toward the intersection. A car is stopped near the crossing, 30 m from the tracks. The train's horn emits a frequency of 500 Hz when the train is 40 m from the intersection.

(a) What is the frequency heard by the passengers in the car?

(b) If the train emits this sound continuously and the car is stationary at this position long before the train arrives until long after it leaves, what range of frequencies do passengers in the car hear?

(c) Suppose the car is foolishly trying to beat the train to the intersection and is traveling at 40 m/s toward the tracks. When the car is 30 m from the tracks and the train is 40 m from the intersection, what is the frequency heard by the passengers in the car now?