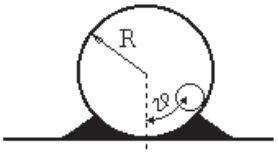
Physics UN2801 Professor Christ
Final Examination (Practice) 12/15/2022

Answer **three (3)** of the following **five (5)** questions.

Please give a complete description of your method of solution since *partial credit* will be given. (On the actual final there will most likely be only three problems and no choice.)

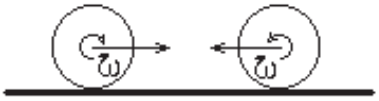
1. A small cylinder of radius r rolls without slipping inside a larger, fixed cylinder of radius R.



   (a) Find the acceleration of the smaller cylinder (*e.g.* $d^2\vartheta/dt^2$) as a function of ϑ. [8 points]

   (b) If the small cylinder is released from rest at an angle $\vartheta_0 \ll 1$, how long does it take to reach the bottom? [12 points]

2. Two identical billiard balls of radius R and mass M rolling with velocities $\pm\vec{v}$ collide elastically, head-on. Assume that after the collision they have both reversed motion and are still rolling.

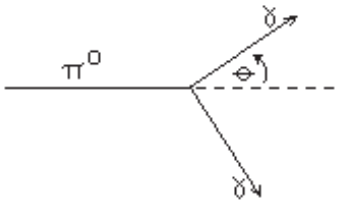


   (a) Find the impulse which the surface of the table must exert on each ball during its reversal of motion. [10 points]

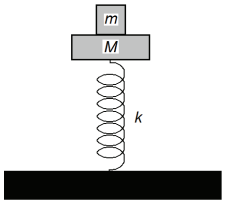
   (b) What impulse is exerted by one ball on the other? [10 points]

   Recall that a time varying force $F(t)$ exerts an impulse $\mathbf{I} = \int F(t)dt$.

3. A π^0 particle of mass $m_\pi = 140MeV/c^2$ is moving with velocity v. It decays into two massless photons. Find the energy of one of the photons as a function of the angle θ between the original direction of the π and the momentum of that decay photon. [20 points]



4. A platform of mass M is supported by a massless spring with spring constant k and equilibrium length l. The spring and platform are constrained to move in the vertical direction. A block of mass m rests on this platform.



   (a) Find the equilibrium height of the block-platform combination. [2 points]

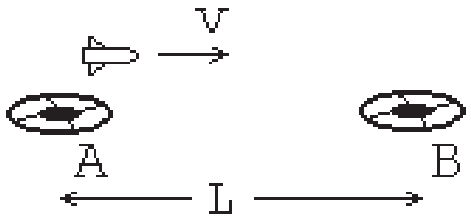
   (b) Find the frequency of small oscillation about that equilibrium. [8 points]

   The block-platform combination is pushed downward below this equilibrium position an additional distance D and then released from rest at $t = 0$.

   (c) What is the largest value, $D_{\max}$, of D for which the block will never lose contact with the platform? [5 points]

   (d) If the mass-platform combination is released from rest after being pushed downward by an amount $3D_{\max}$ what is the maximum height reached by the block? [5 points]

5. Two space stations, A and B, are separated by a distance L and are at rest with respect to each other. The two stations have accurately synchronized clocks. A rocket moving at a constant speed v travels from station A to station B. When the rocket pilot passes the first station A, she sets the ship's clock to agree with that of station A. For simplicity assume that they both read zero when the rocket passes station A.



(a) What is the time t_B shown on the clock of station B when the rocket goes by B? [5 points]

(b) What time is displayed on the ship's clock, t'_B when the rocket passes station B? Explain your result from the perspective of an observer in station B. [4 points]

(c) Explain the result found in (b) from the perspective of the rocket pilot. [3 points]

(d) Explain the result found in (a) from the perspective of the rocket pilot. [8 points]