



Angl. 1

Final exam
General Physics I, PHYS-101 (English)
January 21, 2022
Prof. Suliana Manley

Sciper :

Name :

Signature :

Instructions

1. Write clearly in ink (pen), explain your reasoning, and indicate clearly your result.
2. Only responses written inside of the boxes on the A4 sheets of the exam (front and back) will be taken into account.
3. Justify your calculations and responses with diagrams and by identifying the laws of physics you have used.
4. This exam should be taken in 3 hours.

Allowed:

- one page A4 (front and back) *handwritten by you*
- language dictionary

Not allowed:

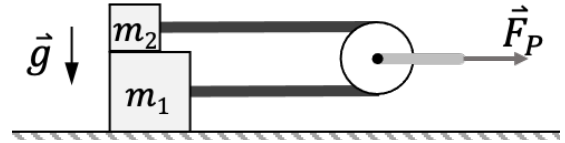
- Any form of electronic device including a calculator
- Leaving the room without authorization

(Do not mark on this page below this line)

NO CONTENT ON THIS PAGE

1. Accelerated Atwood machine.

Two blocks of masses m_1 and m_2 ($m_1 < m_2$) are stacked on top of each other on the surface of a frictionless table (see diagram). The blocks' centers of mass are connected by a string, which is wrapped around a pulley. The mass of the pulley and string are negligible.



The system starts at rest, then a force $\vec{F}_P$ is applied horizontally to the pulley.

- Assume there is no friction between the blocks or in the pulley. Determine the forces acting on the system and each object (Block 1, Block 2, pulley) separately. Draw free body diagrams.

Answer inside the box

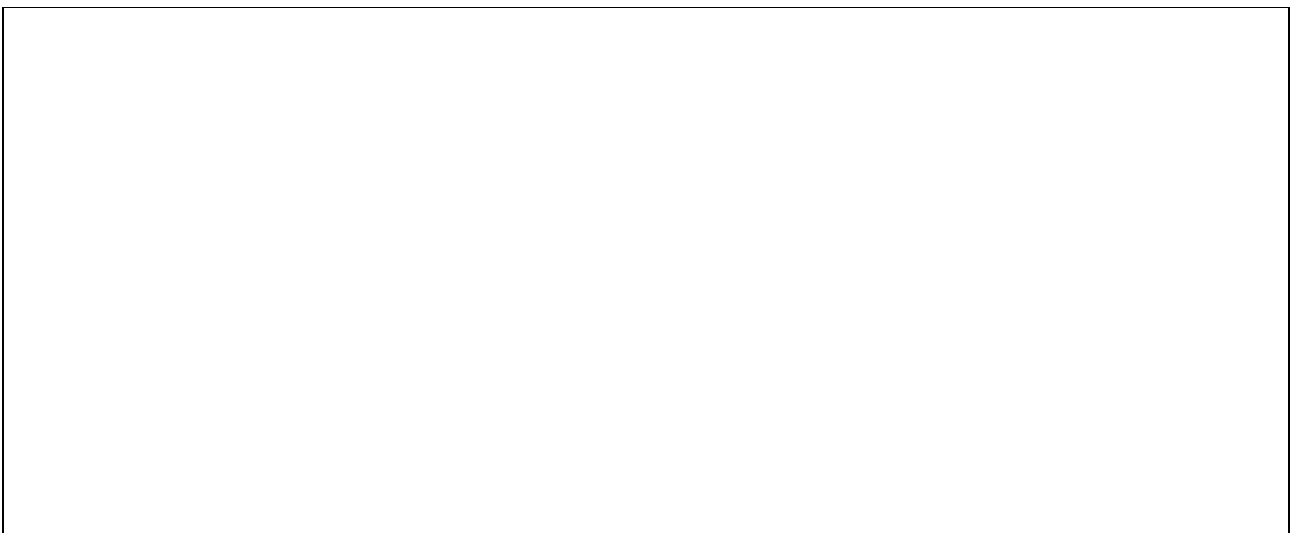
- What are the accelerations, $\vec{a}_1$ and $\vec{a}_2$, of the blocks?

1. Accelerated Atwood machine.

- c) Now, assume there is a coefficient of friction between the blocks, μ (same for static and kinetic cases). Re-draw the free body diagrams for each block. What are the accelerations of each block, for "low" ($\vec{a}_{1L}, \vec{a}_{2L}$) and "high" ($\vec{a}_{1H}, \vec{a}_{2H}$) values of F_P ?



- d) Sketch the configuration of the system (blocks and pulley) in the limit of long times, in each case described in (c) ("low" and "high").

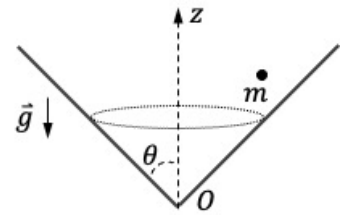


1. Accelerated Atwood machine.

- e) What is the critical value of the force, F_P^* , which separates the two kinds of motion described in parts (c) and (d)?

2. Funnel fun.

A point-like object of mass m slides on the inside of a frictionless, symmetrical cone, whose symmetry axis is vertical (parallel to gravity). The vertex half-angle is θ , as shown. Take the point of the cone as the origin of the coordinate system, O .



- a) Determine the forces acting on the object. Draw a free body diagram.

Answer inside the box

- b) Write the differential equations of motion of the object in spherical coordinates, without solving them. Take into account all constraints.

2. Funnel fun.

- c) Suppose the object is placed at height H , and given an initial angular velocity of magnitude ω_0 , that is in a horizontal plane and tangent to the surface of the cone. Find an expression for ω_0 such that the object will move in a horizontal, circular orbit.

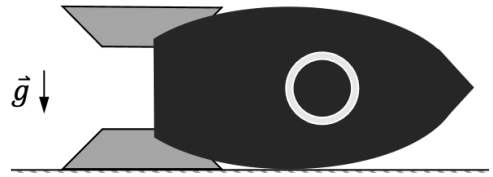
- d) What is the relationship between the kinetic energy K and the potential energy U in the scenario described in (c)?

- e) Sketch the potential energy function $U(\rho)$ where ρ is the horizontal distance from the z-axis, and indicating the kinetic and potential energies for the scenario described in (c). Note any stable or unstable equilibria and turning points.



3. Tabletop rocket.

A rocket has mass m_0 , including fuel of mass $m_0/2$. It starts at rest on a horizontal surface, whose coefficient of friction is μ (same for static and kinetic cases). At time $t = 0$, the fuel is ignited. Assume combusted fuel is ejected horizontally toward the left at a constant rate $\gamma = |dm/dt|$ with a constant velocity u relative to the rocket. Thus, the thrust force from the fuel burning is $\vec{F}_p = \gamma \vec{u}$. (You will not need to derive the "rocket equation.")



- a) Draw momentum diagrams representing time t and time $t + \Delta t$ in the ground reference frame.

Answer inside the box

- b) Draw a free body diagram. What is the condition on γ for the rocket to start moving? In the case that it does not start moving at time $t = 0$, at what time will it start?

3. Tabletop rocket.

In the following parts (c-e), assume the condition in (b) is met at $t = 0$.

- c) Determine the velocity as a function of time, $v(t)$ as a function of the given variables. What will be the maximum speed v_{max} reached by the rocket?

3. Tabletop rocket.

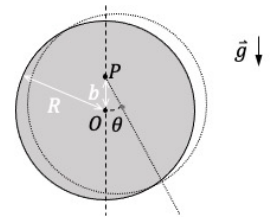
- d) What is the distance d traveled by the rocket after all of the fuel is burned? Express your answer in terms of the given variables and v_{max} .

- e) Sketch the position as a function of time of the rocket from time $t = 0$ until it is at rest. Be sure to note any important features.



4. Swinging saucer.

A solid, uniform thin disk of mass m and radius R hangs vertically. The disk is attached to pivot about the point P , which is a distance b from the disk's center, O . All motion takes place in the plane of the disk. Neglect friction.



- a) Determine the forces acting on the disk (draw a free body diagram).

- b) The disk is rotated so that a line through P and O makes an angle θ_0 relative to gravity, and then released. Write an expression for the initial torque, τ , relative to point P .

- c) Calculate from general principles the moment of inertia, I_P , of the disk about the pivot point.

4. Swinging saucer.

- d) Write the differential equation of motion of the disk in terms of the given variables.

- e) Assuming the initial angle θ_0 is small, what is the period ω_0 of the disk's oscillation? Show that your answer makes sense in the appropriate limit, when compared with a pendulum composed of a point mass suspended from a string.