Physics 235, Midterm Exam # 3

December 7, 2021: 8.00 am - 9.30 am

Do not turn the pages of the exam until you are instructed to do so.

Exam rules: You may use *only* a writing instrument while taking this test. You may *not* consult any calculators, computers, books, nor each other.

Problems 1 and 2 must be answered in exam booklet 1. Problems 3 and 4 must be answered in exam booklet 2. The answers need to be well motivated and expressed in terms of the variables used in the problem. You will receive partial credit where appropriate, but only when we can read your solution. Answers that are not motivated will not receive any credit, even if correct.

At the end of the exam, you need to hand in your exam, the blue exam booklets, and the equation sheet. All items must be clearly labeled with your name, your student ID number, and the day/time of your recitation. **If any of these items are missing, we will not grade your exam, and you will receive a score of 0 points.**

You are required to complete the following *Honor Pledge for Exams*. Copy and sign the pledge before starting your exam.

"I affirm that I will not give or receive any unauthorized help on this exam, and that all work will be my own."

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Name: _____

Signature: _____

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Useful Relations:

$$\cos(30°)=\frac{1}{2}\sqrt{3} \quad \sin(30°)=\frac{1}{2} \quad \tan(30°)=\frac{1}{3}\sqrt{3}$$
$$\cos(45°)=\frac{1}{2}\sqrt{2} \quad \sin(45°)=\frac{1}{2}\sqrt{2} \quad \tan(45°)=1$$
$$\cos(60°)=\frac{1}{2} \quad \sin(60°)=\frac{1}{2}\sqrt{3} \quad \tan(60°)=\sqrt{3}$$

$$\cos\left(\frac{1}{2}\pi-\theta\right)=\sin(\theta) \quad \sin\left(\frac{1}{2}\pi-\theta\right)=\cos(\theta)$$
$$\cos(2\theta)=1-2\sin^2(\theta) \quad \sin(2\theta)=2\sin(\theta)\cos(\theta)$$

	Circle	Sphere
circumference	$2\pi r$	
(surface) area	πr^2	$4\pi r^2$
volume		$\frac{4}{3}\pi r^3$

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Good Luck !

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PROBLEM 1 (25 POINTS) **ANSWER IN BOOK 1**

At time $t = 0$ s, a projectile is fired vertically upward at the equator with an initial velocity of magnitude v_0. The Earth rotates eastward with an angular velocity ω and is assumed to be constant. The radius of the Earth is R and the gravitational acceleration at the equator, measured in an inertial reference frame, is g. In this problem, you **cannot** ignore the centrifugal and Coriolis terms unless you are instructed to do so.

a. **(5 points)** Define the coordinate system (x, y, z) in which you will view the motion of this projectile.

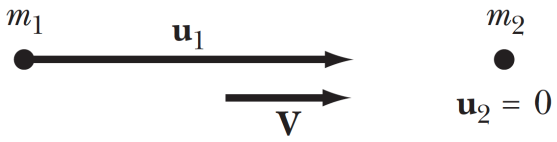
b. **(10 points)** What is the time of impact of the projectile? You **can** ignore the Coriolis effect in this calculation.

c. **(10 points)** How far from its launch position does the projectile hit the ground? Specify the magnitude of the displacement and the direction (N, NE, E, SE, S, SW, W, or NW)?

Your answers must be well motivated and expressed in terms of the variables provided.

PROBLEM 2 (25 POINTS) **ANSWER IN BOOK 1**

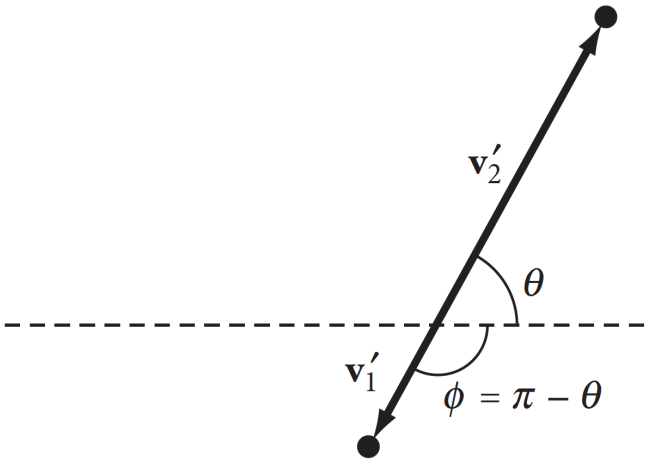
Consider an elastic collision of two particles with masses m_1 and m_2. Mass m_2 is initially at rest in the laboratory system. The initial configuration is shown in the following figure.



a. **(5 points)** What is the velocity V of the center of mass of the system?

b. **(5 points)** What are the linear momenta of particles 1 and 2 before the collision in the center-of-mass frame?

After the collision, particle 2 scatters with an angle θ, measured in the center-of-mass frame with respect to the direction of particle 1 before the collision, as shown in the following figure.



c. **(5 points)** What is the linear momentum of particle 2 after the collision in the center-of-mass frame?

d. **(10 points)** What are the laboratory scattering angle and the velocity of particle 2 after the collision?

Your answers must be well motivated and expressed in terms of the variables provided.

PROBLEM 3 (25 POINTS) **ANSWER IN BOOK 2**

A communication satellite of mass m is in a circular orbit of radius R around the earth. Its velocity is v. Its engine accidentally fires, giving the satellite an outward radial velocity v in addition to its original velocity.

a. **(5 points)** Calculate the ratio of the angular momentum after the engine has fired to its initial angular momentum.

b. **(10 points)** Calculate the ratio of the total energy of the satellite after the engine has fired to its initial total energy.

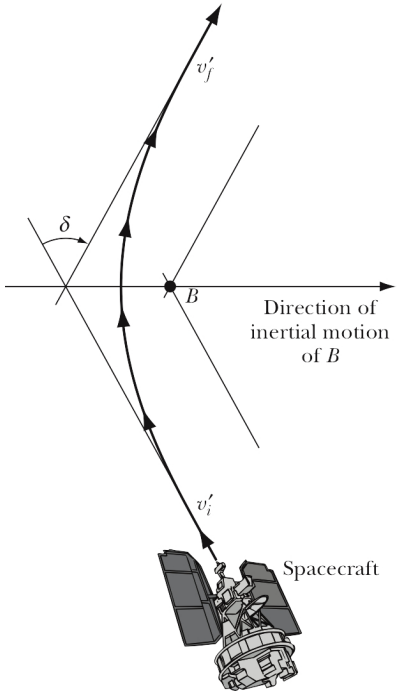
c. **(5 points)** Describe the orbital motion the satellite carries out after the engine fires.

d. **(5 points)** Make a sketch of the radial kinetic energy, the gravitational potential energy, and the centrifugal potential energy as function of the radial distance after the engine has fired. Use the convention that the gravitational potential energy is 0 at infinity.

Your answers must be well motivated and expressed in terms of the variables provided.

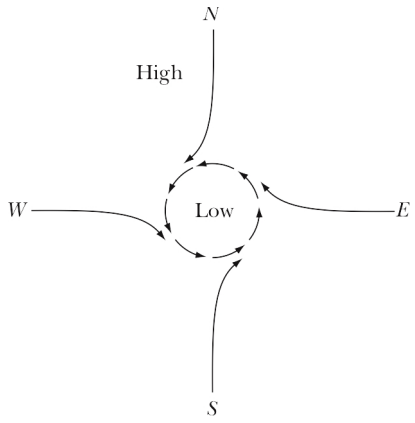
PROBLEM 4 (25 POINTS) **ANSWER IN BOOK 2**

a. **(5 points)** Consider a spaceraft that flies by a large body B. The force exerted by B on the spacecraft causes the spacecraft to change its direction, as shown in the Figure below.



What happens to the speed of the spacecraft in the inertial reference frame?

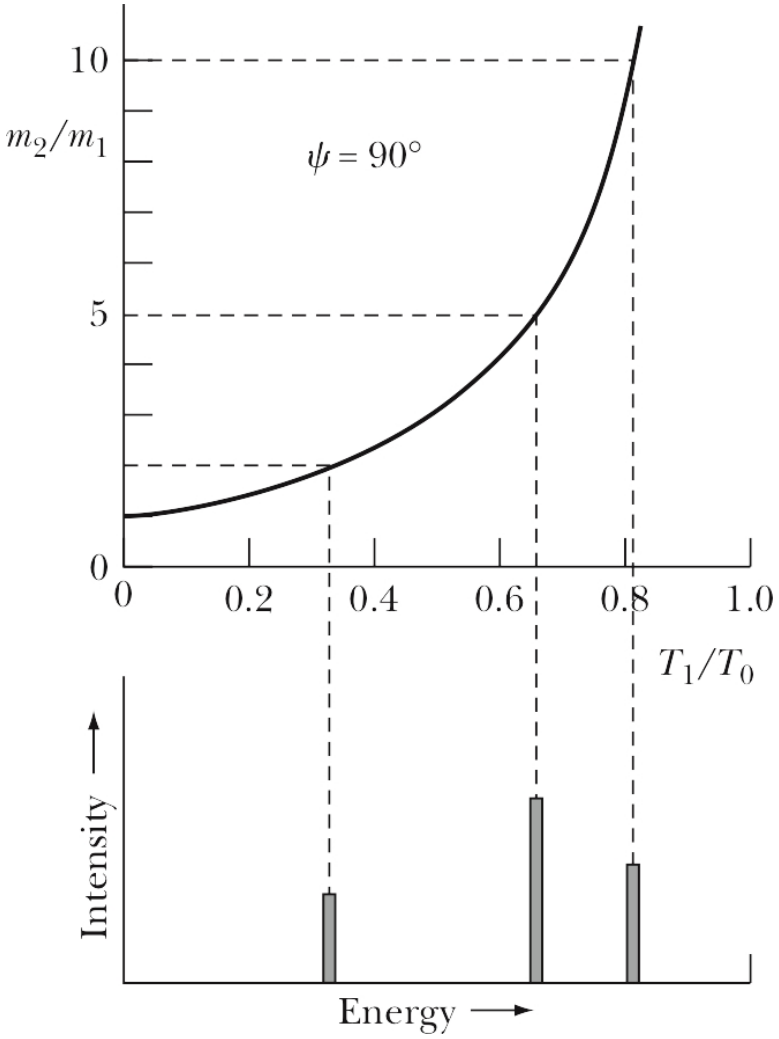
b. **(5 points)** You observe the following deflection of air that approaches a low-pressure system. On which hemisphere is this low-pressure system located? The Northern or the Southern hemisphere?



c. **(5 points)** Consider a large pendulum in its equilibrium position on the Northern hemisphere.

Due to the rotation of the Earth, the equilibrium position of the pendulum in your laboratory does not coincide with the vertical direction in your laboratory reference frame. What is the direction of the deflection you observe? Specify: North, East, South, or West.

d. **(5 points)** You use a beam of alpha particles (atomic mass = 4 amu, kinetic energy = T_0) to determine the composition of your target material. You measue the kinetic energy T_1 of the alpha particles that are scattered at 90° and determine that the energy spectrum of these scattered alpha particles is dominated by three specific energies, as shown in the Figure below.



What are the atomic masses (in units of amu) of the three types of atoms found in your target?

e. **(5 points)** What happens on pakjes avond?

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