Physics 235, Midterm Exam # 3

December 3, 2019: 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**

A projectile is fired due east from a point on the surface of the Earth at a northern latitude λ with a velocity of magnitude V_0 and at an angle of inclination to the horizontal α. The Earth rotates eastward with an angular velocity ω.

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

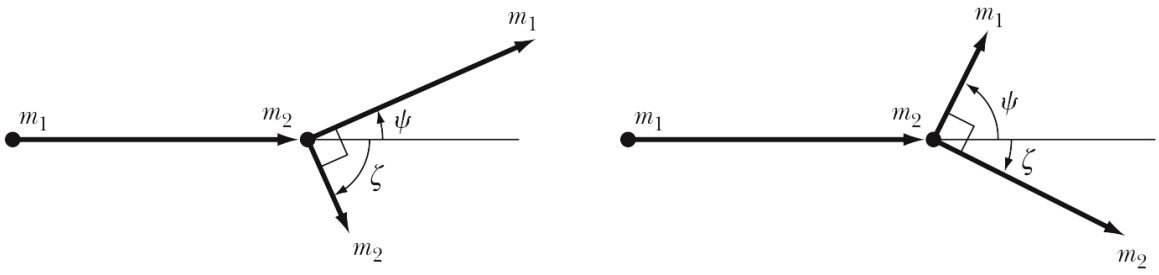
b. What is the lateral deflection when the projectile strikes Earth?

c. Specify the direction of the deflection (N, E, S, or W)?

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 mass m_1 and m_2. Mass m_2 is initially at rest in the laboratory system. Two possibilities are shown in the Figure below.



Assume particle 1 is moving with a velocity v_1 before the collision and has the same mass as particle 2 ($m_1 = m_2 = m$).

a. What are the velocities of particles 1 and 2 before the collision in the center-of-mass frame?

b. The center-of-mass scattering angle of particle 1 after the collision, measured with respect to the direction of particle 1 before the collision, is θ. What are the velocities of particles 1 and 2 after the collision in the center-of-mass frame?

c. What are the laboratory scattering angles ψ and ζ of particles 1 and 2, respectively, after the collision?

d. Show that after the collision, the two masses travel at right angles with respect to each other in the laboratory frame.

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

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

a. A particle is observed to move in a logarithmic spiral orbit, given by the following equation:

$$r = ke^{\alpha\theta}$$

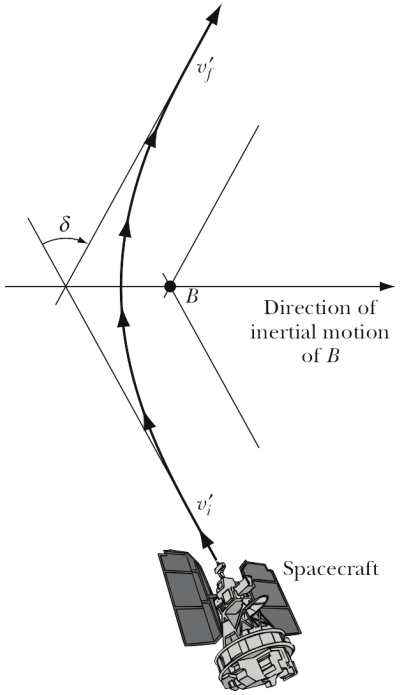
where k and α are constants. Determine the force law $F(r)$ that produces this orbit.

b. Consider a particle of mass μ moving in a central force field described by a potential function $U(r)$. Use the Lagrangian, expressed in plane polar coordinates, to show that the areal velocity of the motion of this particle is constant in time.

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

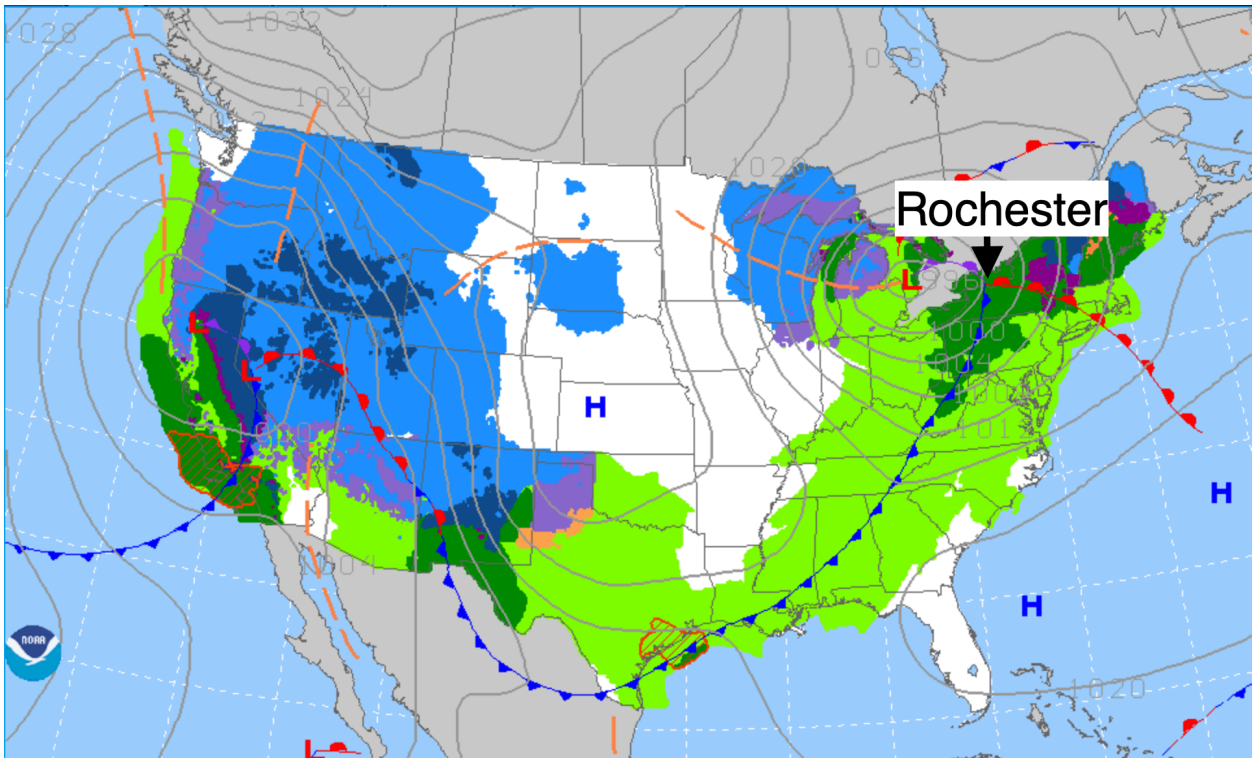
PROBLEM 4 (25 POINTS) **ANSWER IN BOOK 2**

a. 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.



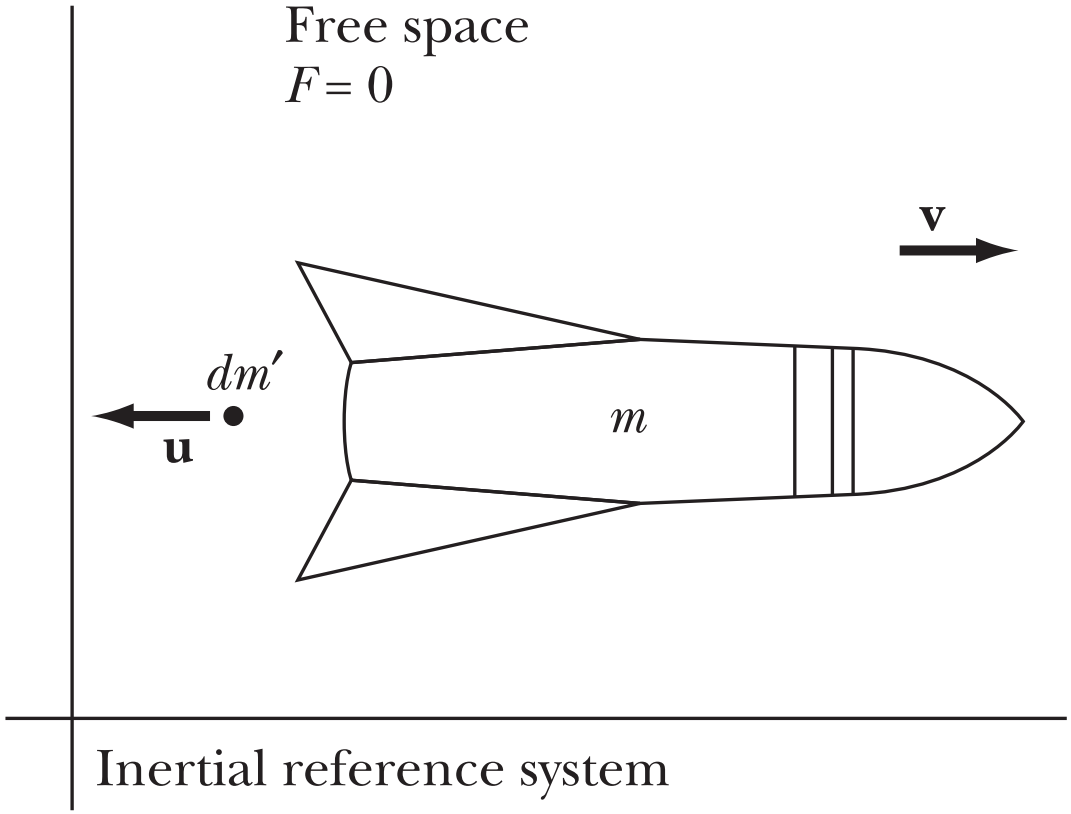
What happens to the speed of the spacecraft?

b. Consider the location of the low pressure system (L) with respect to the location of Rochester.



From what direction do you expect the wind to blow in Rochester?

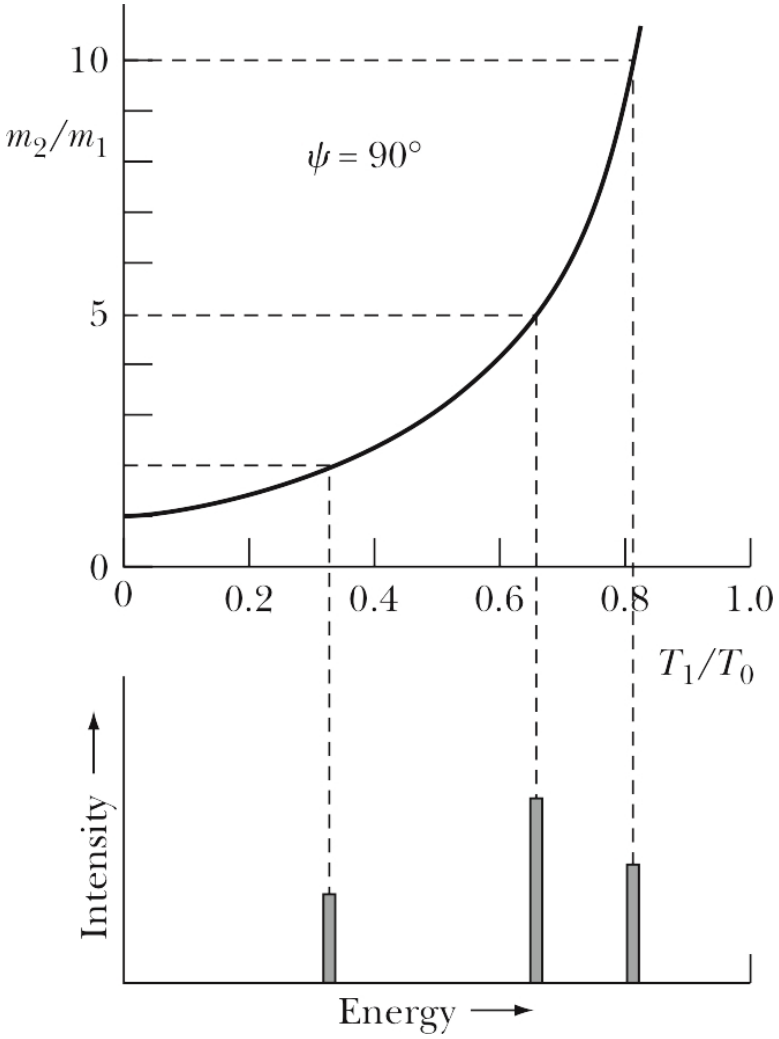
c. A rocket of mass m moves in free space with a velocity v, as shown in the Figure. Your engine ejects exhaust with a velocity u with respect to the engine.



What fraction of the initial mass m must you burn if you want to double your velocity?

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

d. 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. Dutch-American Heritage Day

Dutch-American Heritage Day marks the longstanding history and shared bonds between the Netherlands and the United States.

In 1776, the Netherlands became the first country to formally recognize the United States of America. On that day, the governor of Sint Eustasius ordered the island's cannons fired in response to the 13-gun salute from the Andrew Doria as it sailed into the harbor of the Dutch island. Only four months before, the United States declared its independence from Great Britain. This simple act is recorded as the first salute to the American flag by a foreign nation.

The ties between the Netherlands and New York extend further back to 1609 when Henry Hudson sailed the Dutch ship, the Half Moon, into what is now known as New York Harbor. Hudson's voyage led to the founding of New Netherlands and the trading post New Amsterdam.

From: http://nlintheusa.com/nlus/.

On what date is Dutch-American Heritage Day celebrated?

1. January 16
2. February 16
3. March 16
4. April 16
5. May 16
6. June 16
7. July 16
8. August 16
9. September 16
10. October 16
11. November 16
12. December 16

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