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 10 must be answered on the scantron form. Problems 11 and 12 must be answered in exam booklet 1. Problem 13 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 must hand in your exam, the scantron form, 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."

Name: _____

Signature: _____

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

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

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

Problem 1 (2.5 points) **Answer on Scantron form**

A ball is dropped from the edge of a cliff. Soon after, a second ball is dropped. As a function of time, the separation between the two balls ...

1. stays the same.
2. increases.
3. decreases.
4. it depends on the time specified.

Problem 2 (2.5 points) **Answer on Scantron form**

Two cars, car A and car B, start from rest and travel a distance d with constant acceleration. The acceleration of car B is four times that of car A. After each car has traveled a distance d

1. car B is moving 16 times as fast as car A.
2. car B is moving 8 times as fast as car A.
3. car B is moving 4 times as fast as car A.
4. car B is moving 2 times as fast as car A.

Problem 3 (2.5 points) **Answer on Scantron form**

Two balls are projected off a cliff. One is thrown horizontally while the other is released from rest and falls vertically. Which of the following statements is true?

1. The ball that falls vertically hits the ground first.
2. The ball that is projected horizontally hits the ground first.
3. Both balls hit the ground at the same time.
4. We can not determine which ball hits the ground first unless we know the speed at which the first ball was projected horizontally.

Problem 4 (2.5 points) **Answer on Scantron form**

An elevator has a frayed cable which will break if the tension exceeds a certain value. The tension is more likely to exceed this value if the elevator is

1. moving at constant velocity.
2. accelerating upward.
3. accelerating downward.
4. the motion is irrelevant.

Problem 5 (2.5 points) **Answer on Scantron form**

A skier accelerates from rest on a slope inclined at an angle θ. From this information, we conclude that

1. $\mu_k > \tan\theta$
2. $\mu_k < \tan\theta$
3. $\mu_k = \tan\theta$
4. $\mu_k = \mu_s$

Problem 6 (2.5 points) **Answer on Scantron form**

The time it takes for a falling object to attain its terminal velocity

1. increases with increasing mass.
2. decreases with increasing mass.
3. is independent of mass.

Problem 7 (2.5 points) **Answer on Scantron form**

Two blocks of the same size but different masses, m_1 and m_2, are placed on a frictionless table side-by-side in contact with each other, as shown in Fig. 1. Assume that $m_1 > m_2$.

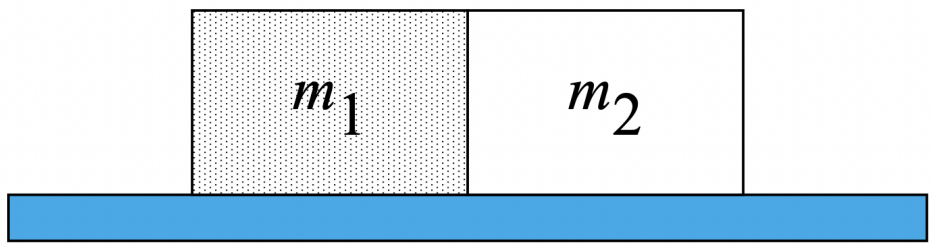

Figure 1: Masses m_1 and m_2 on a table.

Let N_1 be the magnitude of the normal force between the two blocks when you push horizontally with a force $\vec{F}$ on the free side of m_1 (towards m_2). Let N_2 be the magnitude of the normal force between the two blocks when you push horizontally with a force $-\vec{F}$ on the free side of m_2 (towards m_1). Which of the following statements is true?

1. $|N_1| = |N_2|$
2. $|N_1| < |N_2|$
3. $|N_1| > |N_2|$

Problem 8 (2.5 points) **Answer on Scantron form**

A car travels along the x axis with increasing speed. We are not sure if it is moving to the left or to the right. Which of the graphs shown in Fig. 2 could possibly represent the motion of the car?

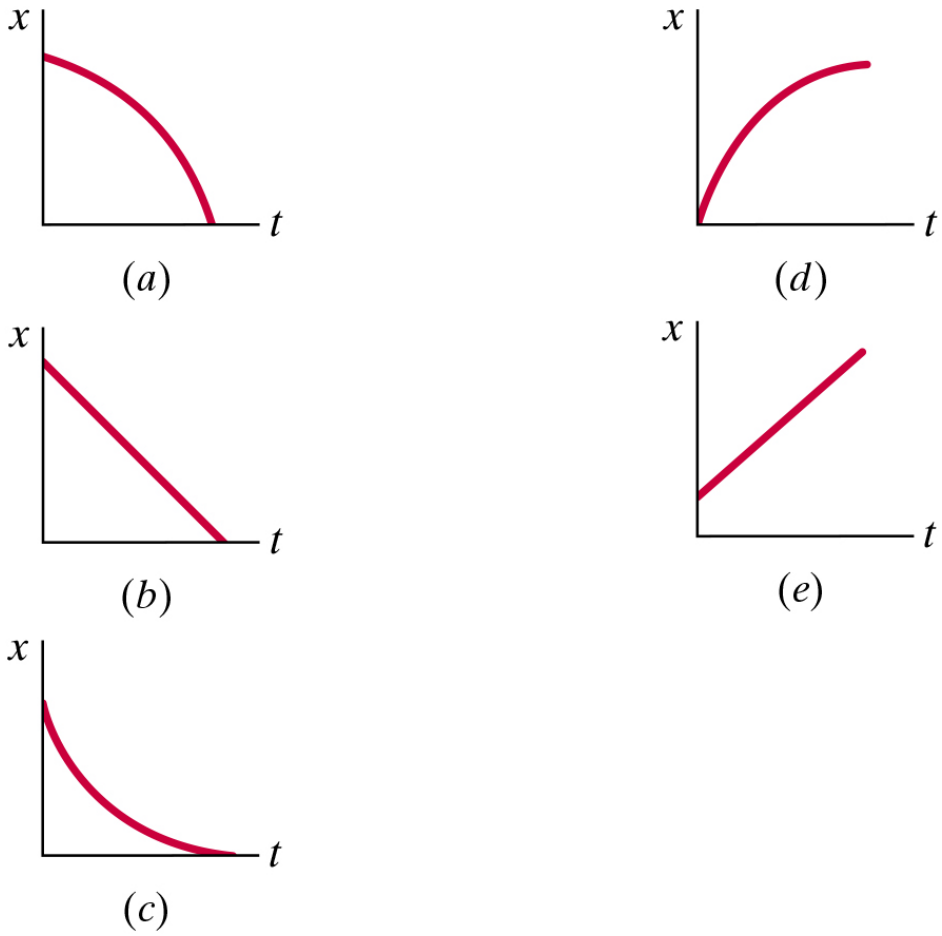

Figure 2: The position x of the car as function of time.

1. Graph (a).
2. Graph (b).
3. Graph (c).
4. Graph (d).
5. Graph (e).

Problem 9 (2.5 points) **Answer on Scantron form**

You measure the length of a plate using a ruler, as shown in Fig. 3.

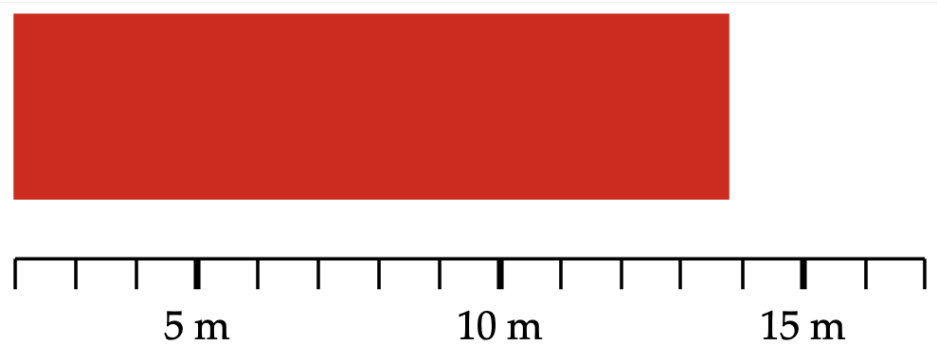

Figure 3: The measurement of the length of a plate.

What is your best estimate of the length of the plate (in units of meters)?

1. 10.0 - 10.5 m.
2. 10.5 - 11.0 m.
3. 11.0 - 11.5 m.
4. 11.5 - 12.0 m.
5. 12.0 - 12.5 m.
6. 12.5 - 13.0 m.
7. 13.0 - 13.5 m.
8. 13.5 - 14.0 m.
9. 14.0 - 14.5 m.
10. 14.5 - 15.0 m.

Problem 10 (2.5 points) **Answer on Scantron form**

What must be the weather condition for the Dutch to hold the tegenwindfietsen race? Hint: see Fig. 4.

Figure 4: https://www.youtube.com/watch?v=VMinwf-kRlA

1. Snowy.
2. Rainy.
3. Foggy.
4. Windy.
5. Very windy.
6. Sunny.
7. No special weather conditions are required.

Problem 11 (25 points) **Answer in booklet 1**

A ball of mass m is attached to a rigid vertical rod by means of two massless strings with length L. The strings are attached to the rod at points a distance L apart, as shown in Fig. 5. The system is rotating about the axis of the rod, both strings being taut and forming an equilateral triangle. The tension in the upper string is T_1.

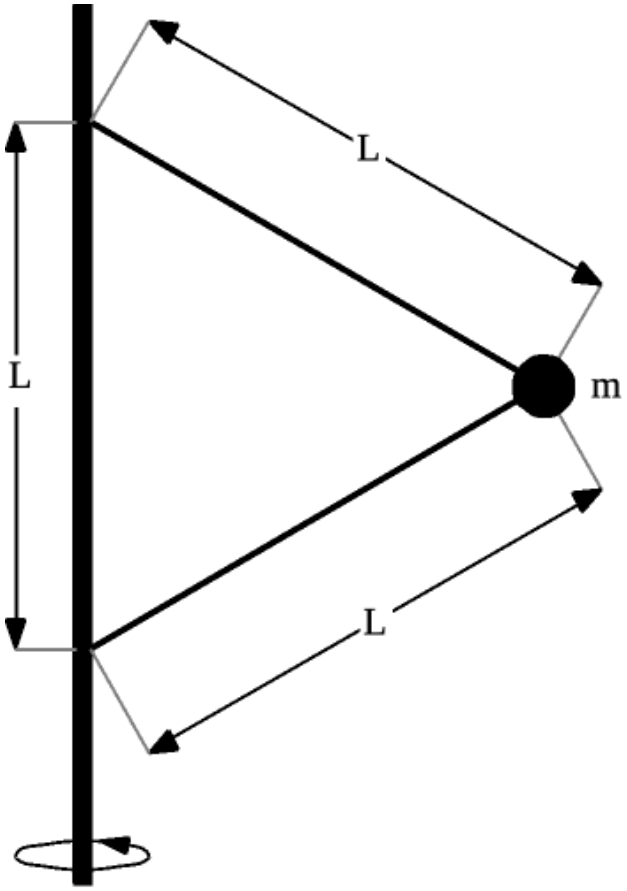

Figure 5: Configuration studied in Problem 11.

a) **(5 points)** Draw a diagram showing all forces acting on the ball.

b) **(5 points)** What is the tension in the lower string?

c) **(5 points)** What is the net force on the ball at the instant shown in Fig. 5?

d) **(10 points)** What is the speed of the ball?

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

Problem 12 (25 points) **Answer in booklet 1**

Two blocks with mass m_A and mass m_B are connected by a massless string over a frictionless and massless pulley as shown in Fig. 6. The angle of the incline is equal to θ. The inclined plane is **not** frictionless!

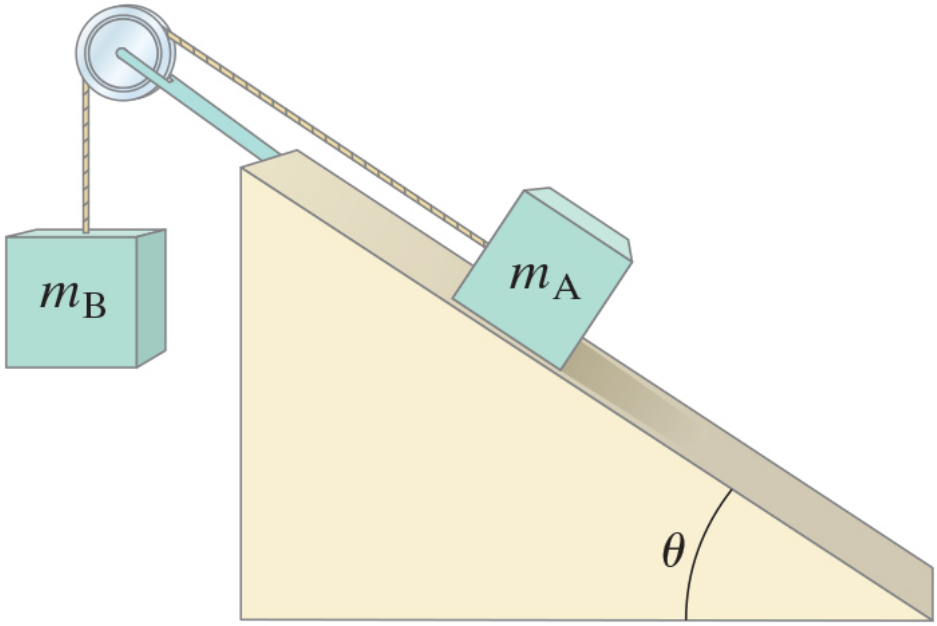

Figure 6: Two masses, a pulley, and an inclined plane.

a) **(5 points)** Draw free-body diagrams showing all forces acting on each mass. On these diagrams, indicate the coordinate systems you will use to solve this problem.

b) **(10 points)** What is the minimum value of the static friction coefficient that will prevent mass m_A from starting to move if it is at rest?

c) **(10 points)** If the initial condition of the system is such that mass m_B is moving down, what must the coefficient of kinetic friction be to ensure that both masses are moving with constant velocity?

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

Problem 13 (25 points) **Answer in booklet 2**

A projectile of mass m is fired at time $t = 0$ s from ground level at an angle θ above the horizontal plane, as shown in Fig. 7. The projectile has an initial speed v_0.

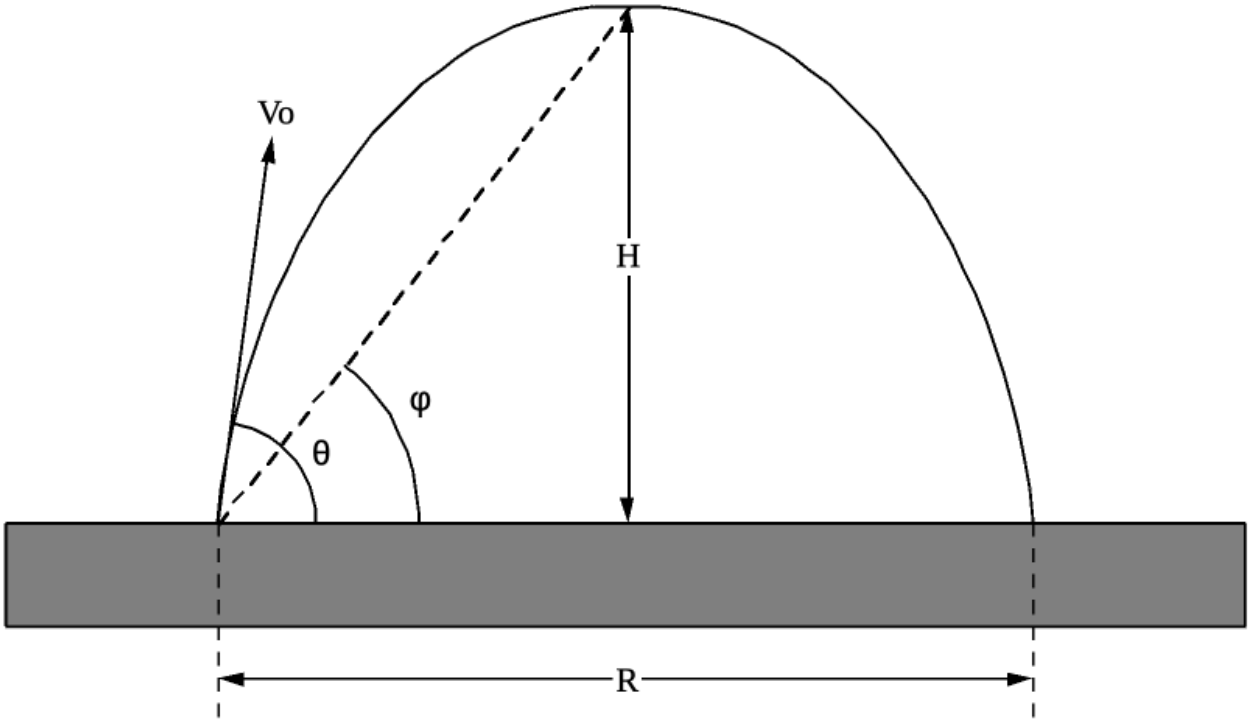

Figure 7: Projectile motion.

a) **(5 points)** Calculate the time at which the projectile hits the ground again.

b) **(5 points)** Calculate the range R of the projectile.

c) **(10 points)** Find an expression for the ratio of maximum height H and the range R in terms of θ.

d) **(5 points)** Find a relation between the elevation angle ϕ of the highest point as seen from the launch point (see Fig. 7) and the firing angle θ.

Your answers need to be well motivated and expressed in terms of the variables provided. You may assume that $v \ll c$.

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Figure 8: The favorite Boeing 777 of Prof. Wolfs. Photo made by Jeanie Wolfs.