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: ______________________________

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$$\cos(30^\circ) = \frac{1}{2}\sqrt{3} \quad \sin(30^\circ) = \frac{1}{2} \quad \tan(30^\circ) = \frac{1}{3}\sqrt{3}$$

$$\cos(45^\circ) = \frac{1}{2}\sqrt{2} \quad \sin(45^\circ) = \frac{1}{2}\sqrt{2} \quad \tan(45^\circ) = 1$$

$$\cos(60^\circ) = \frac{1}{2} \quad \sin(60^\circ) = \frac{1}{2}\sqrt{3} \quad \tan(60^\circ) = \sqrt{3}$$

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

$$\cos(2\theta) = 1 - 2\sin^2(\theta) \quad \sin(2\theta) = 2\sin(\theta)\cos(\theta)$$

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

What must be the weather condition in order for the Dutch to hold the tegenwindfietsen race? Hint: see Fig. 1.

Figure 1: https://www.youtube.com/watch?v=VMinwf-kRlA

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

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

List the four basic forces in order of strength (start with the strongest force and end with the weakest force)

1. Strong > Electromagnetic > Gravitational > Weak.
2. Electromagnetic > Strong > Weak > Gravitational.
3. Strong > Electromagnetic > Weak > Gravitational.
4. Strong > Electromagnetic > Gravitational > Weak.

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

Consider the distribution of 11 equal-mass spheres, located on the circumference of a circle, as shown in Fig. 2.

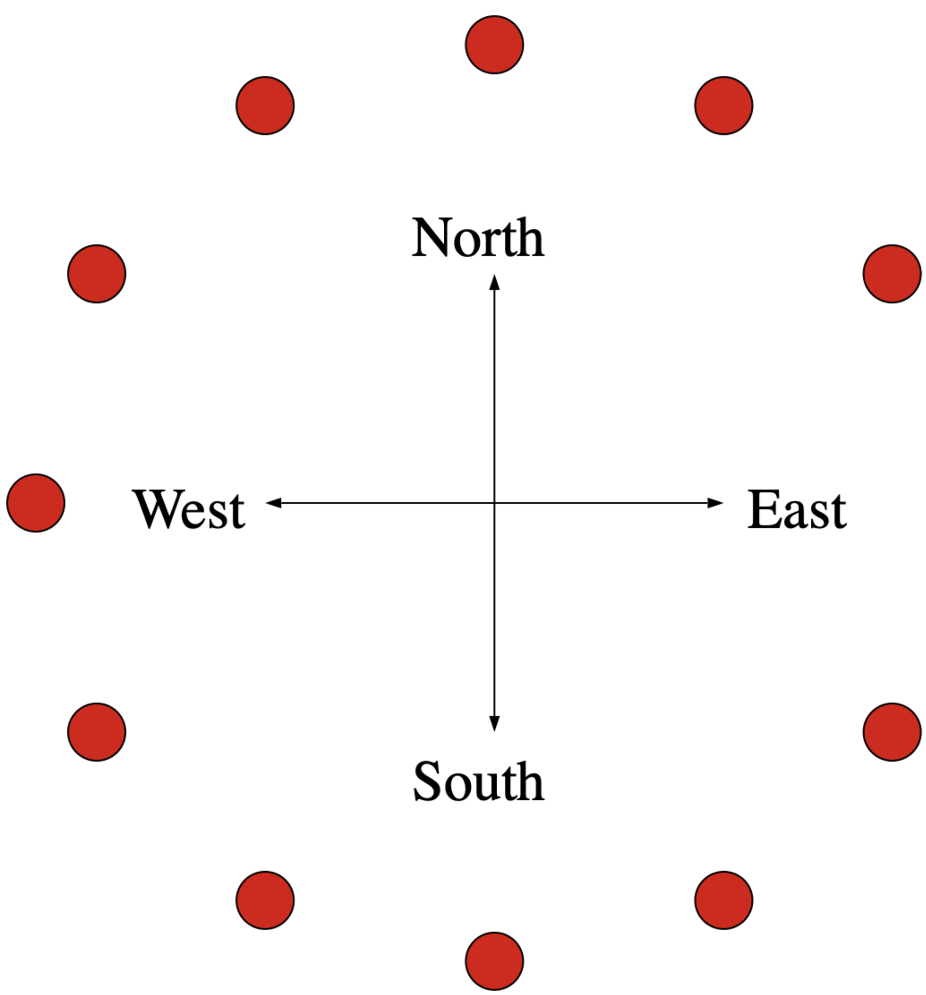

Figure 2: Mass distribution for Problem 3.

If we place another mass at the center of the circle, in what direction will the net gravitational force acting on this mass point?

1. Towards the East.
2. Towards the South.
3. Towards the West.
4. Towards the North.

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

The time dependence of a force, acting on a object of mass m, is shown in Fig. 3. The force is acting along the x axis of the coordinate system.

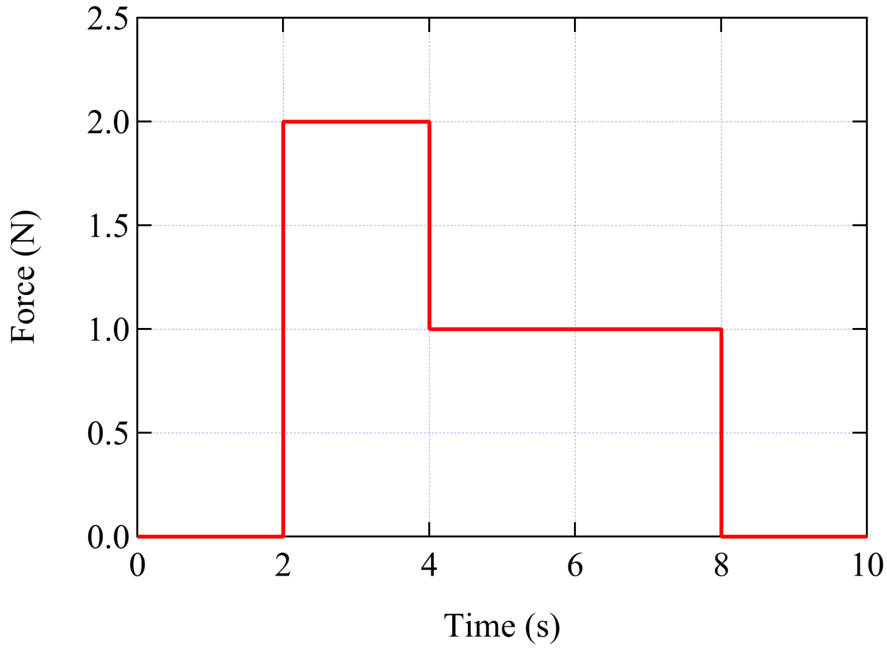

Figure 3: Force acting on mass m as function of time.

What is the change in the x component of the linear momentum of this object between t = 0 s and t = 10 s?

1. 2 kg m/s.
2. 4 kg m/s.
3. 5 kg m/s.
4. 6 kg m/s.
5. 7 kg m/s.
6. 8 kg m/s.
7. 9 kg m/s.
8. 10 kg m/s.
9. 11 kg m/s.
10. 12 kg m/s.

Problem 5 (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 6 (2.5 points) **Answer on Scantron form**

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

1. stay the same.
2. increase.
3. decrease.
4. depend on the time specified.

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

The measured velocity of a car, moving with a constant acceleration a, is shown in Fig. 4. Note: the indicated error bars are $\pm 1\sigma$. Assuming that the measured velocity v is proportional to the measured time t (that is $v = at$), which data point constrains the possible values of a the most?

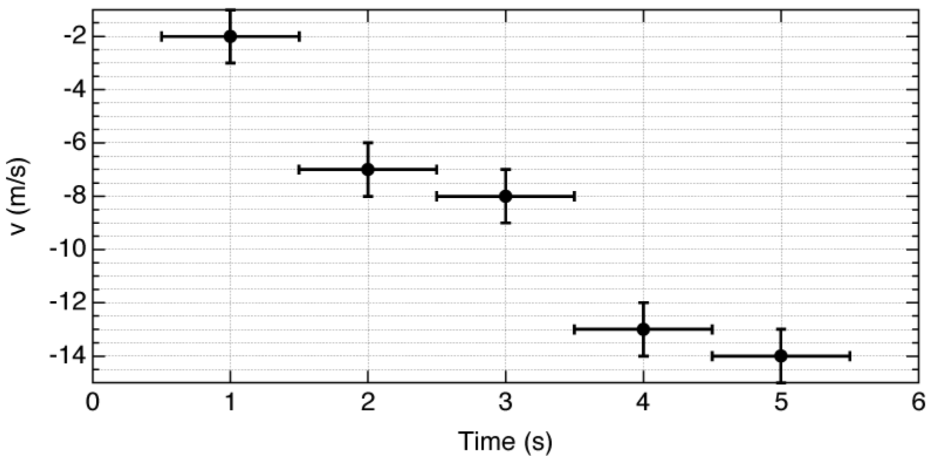

Figure 4: Measured velocity of a car as function of time.

1. The data point at $t = 1$ s.
2. The data point at $t = 2$ s.
3. The data point at $t = 3$ s.
4. The data point at $t = 4$ s.
5. The data point at $t = 5$ s.

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

A mass attached to a spring oscillates back and forth as indicated in the position vs. time plot shown in Fig. 5.

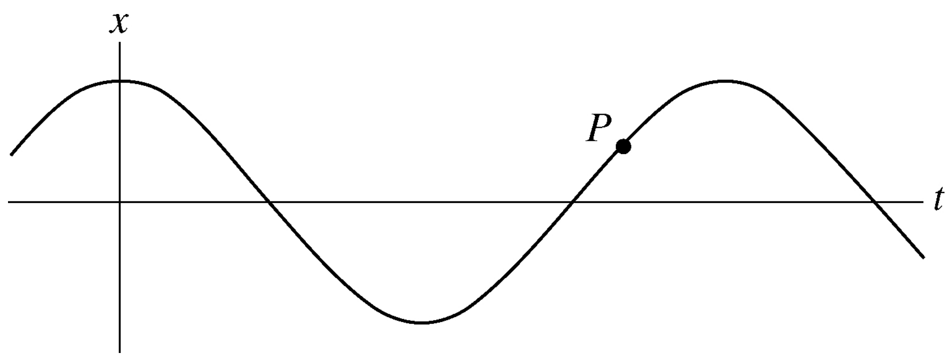

Figure 5: Position versus time distribution for a mass on a spring.

What is the velocity and the acceleration of the mass at point P?

1. Positive velocity and positive acceleration.
2. Positive velocity and negative acceleration.
3. Negative velocity and positive acceleration.
4. Negative velocity and negative acceleration.
5. Zero velocity and non-zero acceleration (positive or negative).
6. Zero velocity and zero acceleration.

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

You measure the length of a plate using a ruler, as shown in Fig. 6.

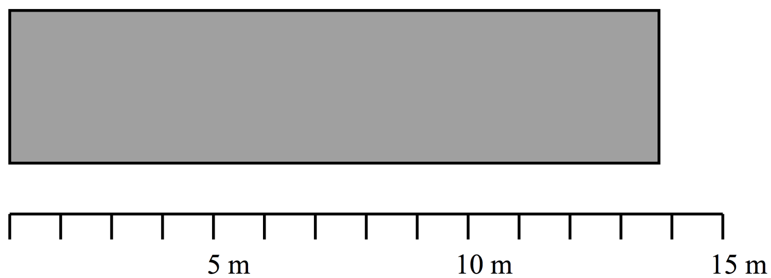

Figure 6: The measurement of the length of a plate.

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**

Two satellites A and B of the same mass are going around Earth in concentric orbits. The distance of satellite B from Earth's center is twice that of satellite A. What is the ratio of the centripetal force acting on B to that acting on A?

1. 1/8
2. 1/4
3. 1/2
4. $1/\sqrt{2}$
5. 1

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

A spherical hollow is made in two spheres of radius R such that its surface touches the outside surface of each sphere and passes through its center as shown in Fig. 7. The mass of each of the spheres before hollowing was M. What is the magnitude of the gravitational force between the two hollowed-out spheres when their centers are located a distance d apart?

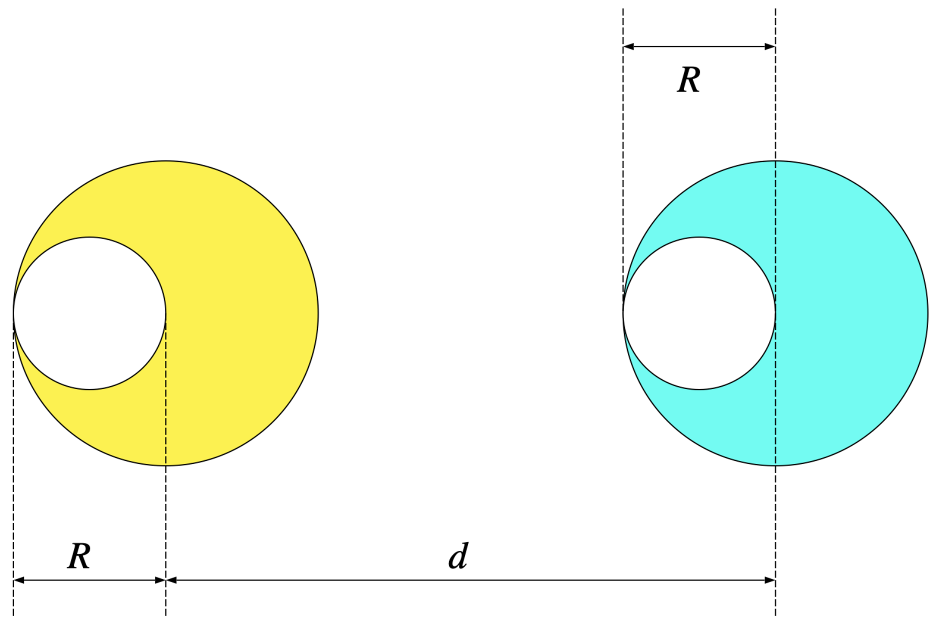

Figure 7: Mass distribution for Problem 11.

Your answer needs to be well motivated and expressed in terms of M, R, d, and G.

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

Moving objects left traces labelled $A - F$, shown in Fig. 8. The dots were deposited at equal time intervals (one dot each second). In each case, the object starts from the square.

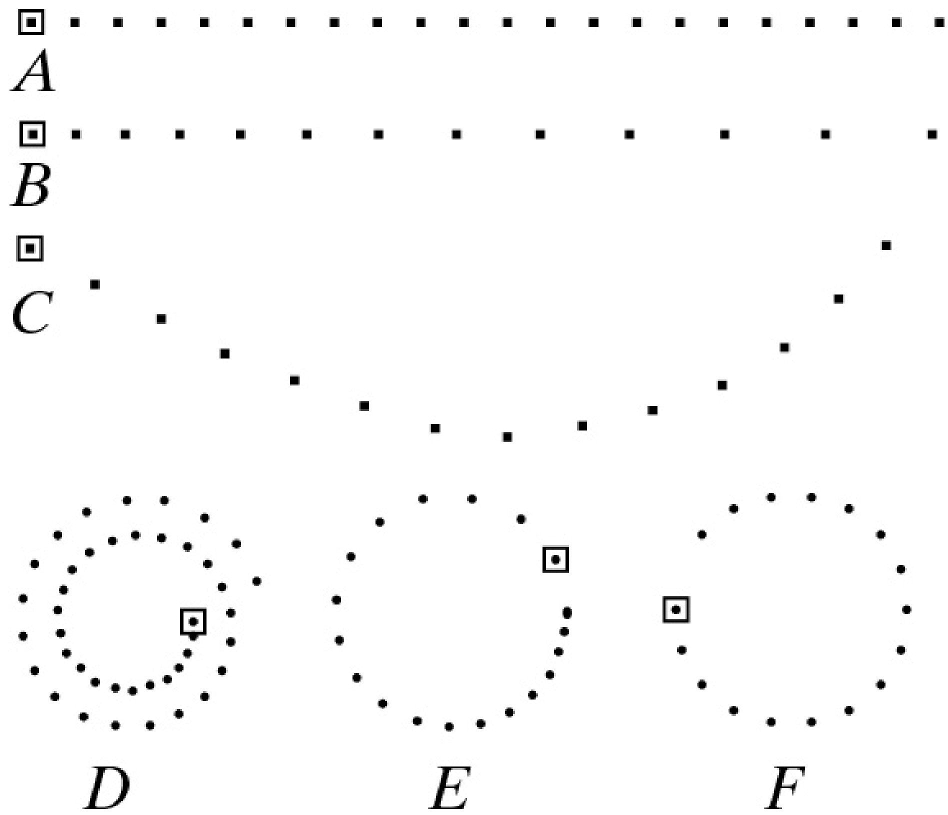

Figure 8: Traces left by moving objects.

(a) For trace A, determine if a force is acting on the object. If a force is acting on the object, describe its direction and its magnitude as function of time.

(b) For trace B, determine if a force is acting on the object. If a force is acting on the object, describe its direction and its magnitude as function of time.

(c) For trace C, determine if a force is acting on the object. If a force is acting on the object, describe its direction and its magnitude as function of time.

(d) For trace D, determine if a force is acting on the object. If a force is acting on the object, describe its direction and its magnitude as function of time.

(e) For trace E, determine if a force is acting on the object. If a force is acting on the object, describe its direction and its magnitude as function of time.

(f) For trace F, determine if a force is acting on the object. If a force is acting on the object, describe its direction and its magnitude as function of time.

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

Two blocks with masses M_1 and M_3, connected by a rod of mass M_2, are sitting on a frictionless surface, as shown in Fig. 9. A constant external force F, directed towards the left, is applied to the right-hand side of the right block. The motion of the system is such that you can treat the system non-relativistically.

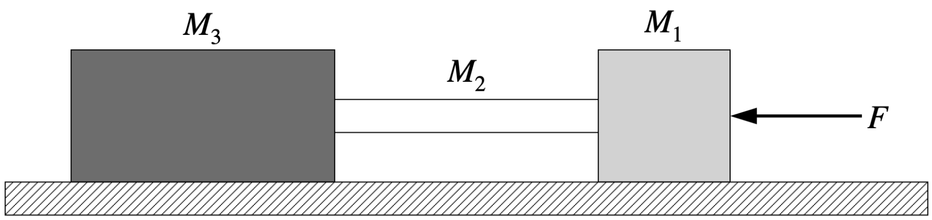

Figure 9: Mass distribution for Problem 12.

(a) What is the acceleration of the system of masses?

(b) What is the compression force in the rod at its right end?

(c) What is the compression force in the rod at its left end?

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

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