

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. Windy.
5. Very windy.
6. Sunny.
7. No special weather conditions are required.

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

You measure the length of a plate using a ruler, as shown in Fig. 2.

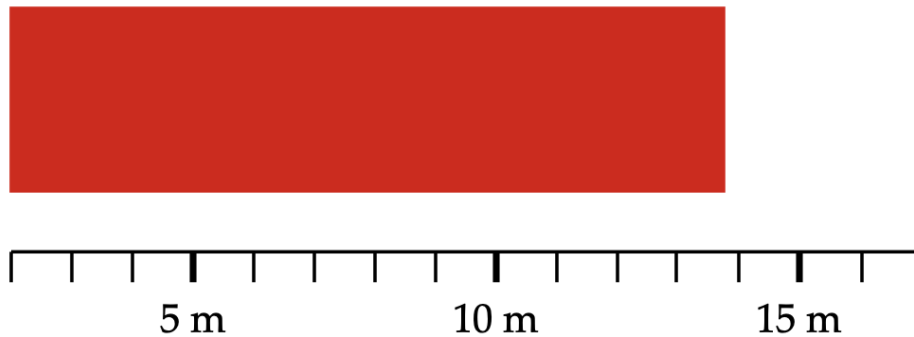


Figure 2: The measurement of the length of a plate.

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

Moving objects left the traces shown at in Fig. 3 The dots were laid down at equal time intervals. In each case, the object starts from the square.

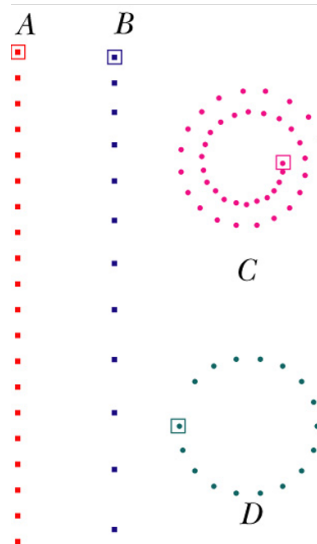


Figure 3: Trajectories of moving objects.

Which object(s) did NOT interact with another object somewhere?

1. A.
2. B.
3. C.
4. D.
5. A and D.
6. A and B.
7. A, B, and D.

Problem 4 (2.5 points)

Answer on Scantron form

A ball travels through the air. Part of its trajectory is shown. Fig. 4.

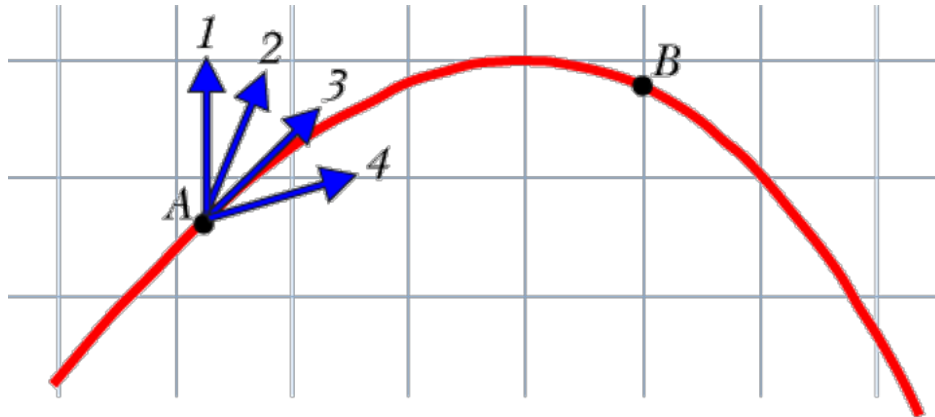


Figure 4: Trajectory of a ball.

Question A: Which arrow best represents the direction of the **average velocity** of the ball as it travels from location A to location B?

Question B: Which arrow best represents the direction of the **instantaneous velocity** of the ball when it passes through location A?

What are the correct answers to Questions A and B?

1. Question A: Arrow 1. Question B: Arrow 3.
2. Question A: Arrow 2. Question B: Arrow 1.
3. Question A: Arrow 2. Question B: Arrow 3.
4. Question A: Arrow 2. Question B: Arrow 4.
5. Question A: Arrow 3. Question B: Arrow 1.
6. Question A: Arrow 3. Question B: Arrow 2.
7. Question A: Arrow 3. Question B: Arrow 4.
8. Question A: Arrow 4. Question B: Arrow 1.
9. Question A: Arrow 4. Question B: Arrow 2.
10. Question A: Arrow 4. Question B: Arrow 3.

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

The time dependence of a force, acting on an object of mass m , is shown in Fig. 5. The force is acting along the x axis of the coordinate system.

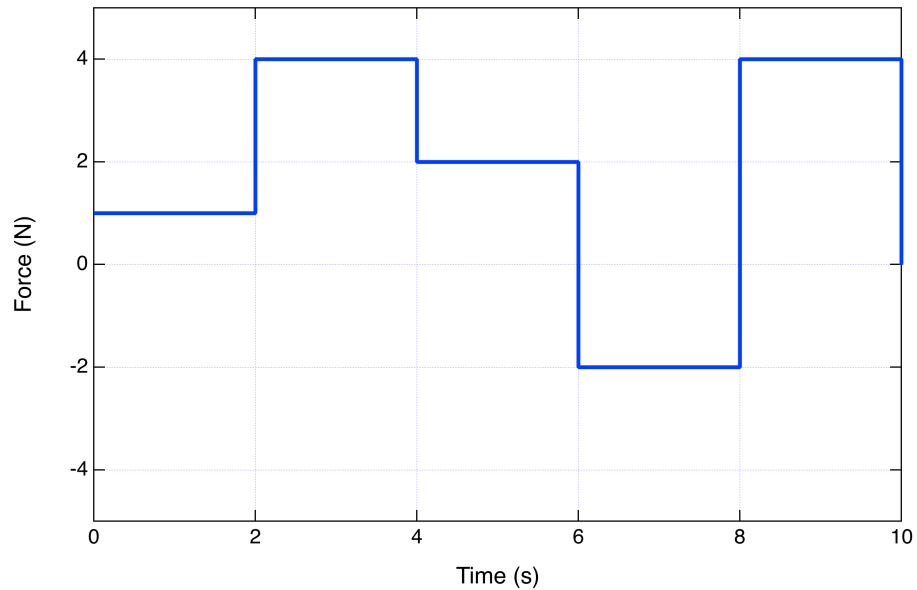


Figure 5: Force acting on mass m as function of time.

What is the change in the x component of the linear momentum of this object between $t = 3$ s and $t = 9$ s?

1. -4 kg m/s.
2. -2 kg m/s.
3. 0 kg m/s.
4. 2 kg m/s.
5. 4 kg m/s.
6. 6 kg m/s.
7. 8 kg m/s.
8. 10 kg m/s.
9. 12 kg m/s.
10. 14 kg m/s.

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

An object is moving in the $+x$ direction. Which of the following statements about the net force acting on the object could be true?

- A. The net force is in the $+x$ direction
- B. The net force is in the $-x$ direction
- C. The net force is zero

- 1. A only.
- 2. B only.
- 3. C only.
- 4. A and B.
- 5. B and C.
- 6. A and C.
- 7. A, B, and C.

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

Fig. 6 shows two positively charged particles (with the same charge) on the left and one negatively charged particle on the right.

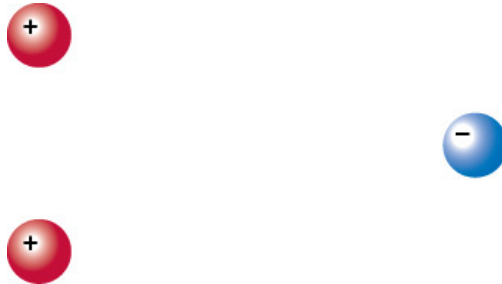


Figure 6: Three charged particles.

Which of the arrows shown in Fig. 7 best indicates the direction of the net electric force on the negatively charged object?

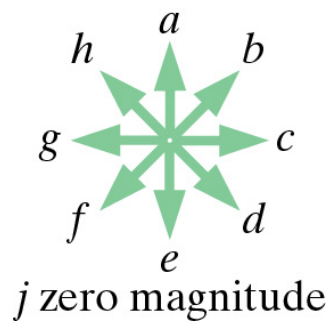


Figure 7: The direction of the net force.

1. Arrow a.
2. Arrow b.
3. Arrow c.
4. Arrow d.
5. Arrow e.
6. Arrow f.
7. Arrow g.
8. Arrow h.
9. The force has a magnitude of 0 N.

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

The measured velocity of a car, moving with a constant acceleration a , is shown in Fig. 8. The error bars for v are $\pm 1\sigma$. Time t is measured with great accuracy, and its error bars are not visible.

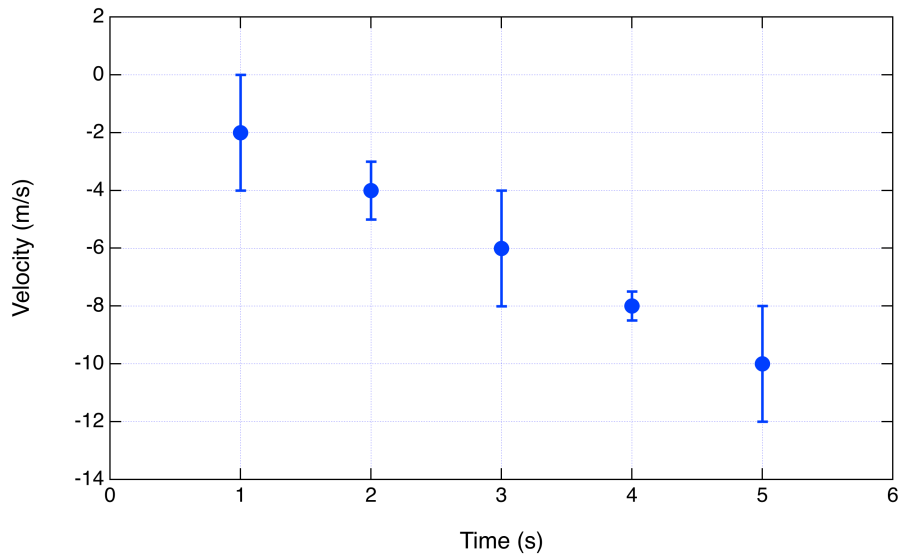


Figure 8: Measured velocity of a car as function of time.

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?

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

You measure the length of a plate using a ruler multiple times. The results of two sets of measurements are shown in Fig. 9.

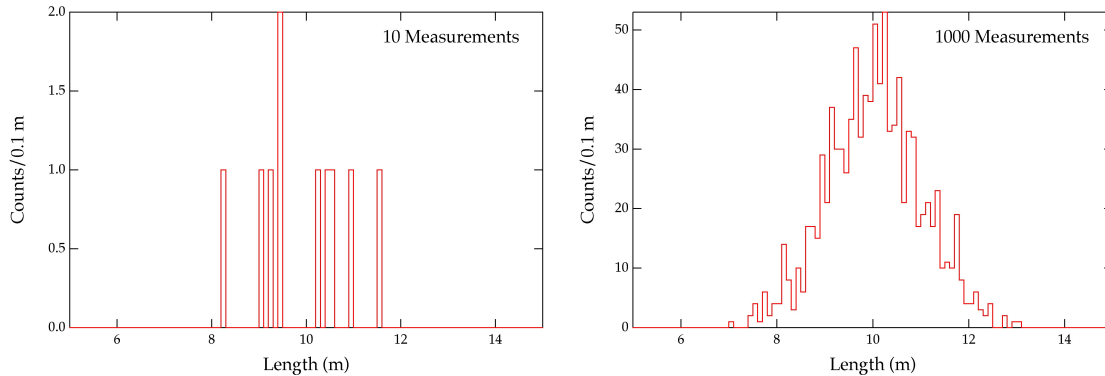


Figure 9: Multiple measurements of the length of a plate.

As you increase the number of measurements, what can you say about the change in the standard deviation of your measurements, and what can you say about the change in the error of the mean of your measurements?

1. The standard deviation of your measurements will decrease. The error in the mean will decrease.
2. The standard deviation of your measurements will not change. The error in the mean will decrease.
3. The standard deviation of your measurements will increase. The error in the mean will decrease.
4. The standard deviation of your measurements will decrease. The error in the mean will not change.
5. The standard deviation of your measurements will not change. The error in the mean will not change.
6. The standard deviation of your measurements will increase. The error in the mean will not change.
7. The standard deviation of your measurements will decrease. The error in the mean will increase.
8. The standard deviation of your measurements will not change. The error in the mean will increase.
9. The standard deviation of your measurements will increase. The error in the mean will increase.

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.
6. Insufficient information is provided to be able to answer the question.

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

A block of ice of mass m is sliding by you on a very slippery floor with a velocity $v_0\hat{x}$. As it goes by, you give it a kick perpendicular to its path. Your foot is in contact with the ice block for a very short period Δt . The block eventually slides at an angle of 30° from its original direction. An overhead view is shown in Fig. 10 and it is approximately to scale. The arrow represents the average force your toe applies briefly to the block of ice. The x direction is defined by the original direction the block of ice. The z direction is defined by the direction of the applied force.

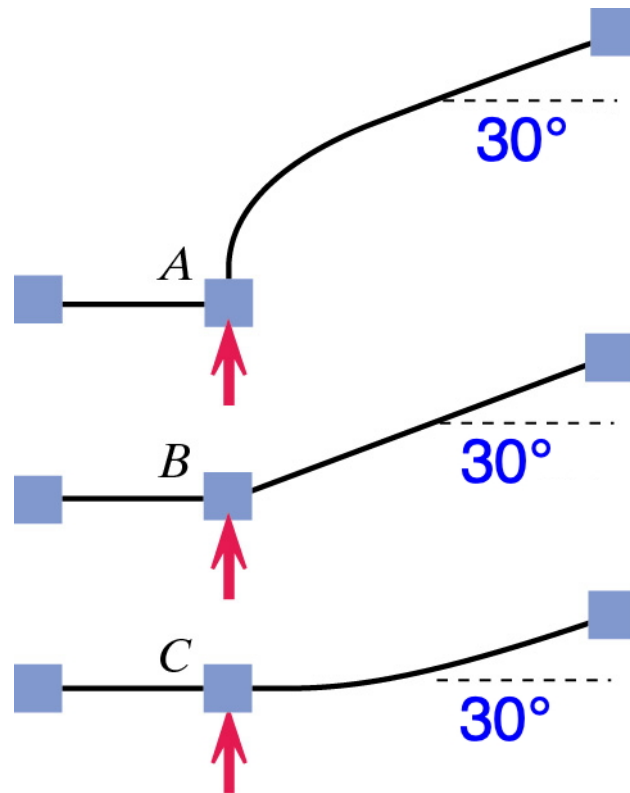


Figure 10: Kicking a block of ice.

- (5 points) Which of the possible paths shown in Fig. 10 corresponds to the correct overhead view of the block's path.
- (5 points) What is the x component of the block's linear momentum after the kick?
- (10 points) What is the z component of the block's linear momentum after the kick?
- (5 points) What is the magnitude of the average force you applied to the block?

Your answer needs to be well motivated and expressed in terms of the variables provided.

Problem 12 (25 points)

Answer in booklet 1

Moving objects left traces labelled $A - F$, shown in Fig. 11. The dots were deposited at equal time intervals (one dot each second). In each case, the object starts from the square.

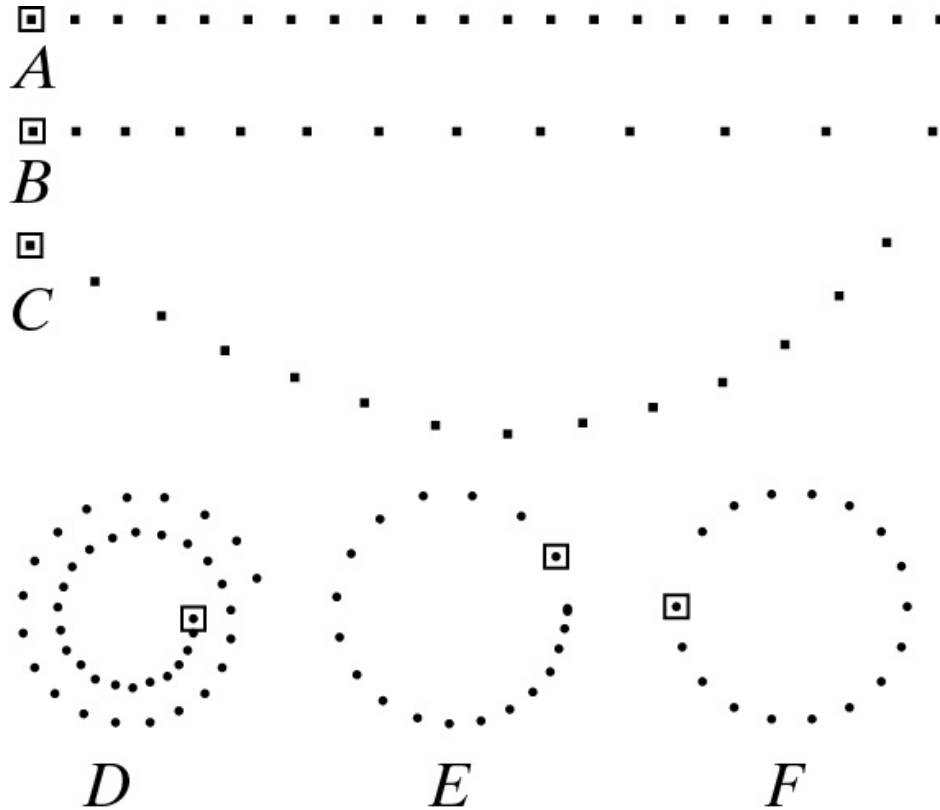


Figure 11: Traces left by moving objects.

- (5 points) 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.
- (5 points) 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.
- (5 points) 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.
- (5 points) 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.
- (5 points) 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**

There is no general analytical solution for the motion of a gravitational system consisting of more than two bodies. However, there do exist analytical solutions for multiple-body systems with very special initial conditions. Consider the four-star system shown in the Fig. 12.

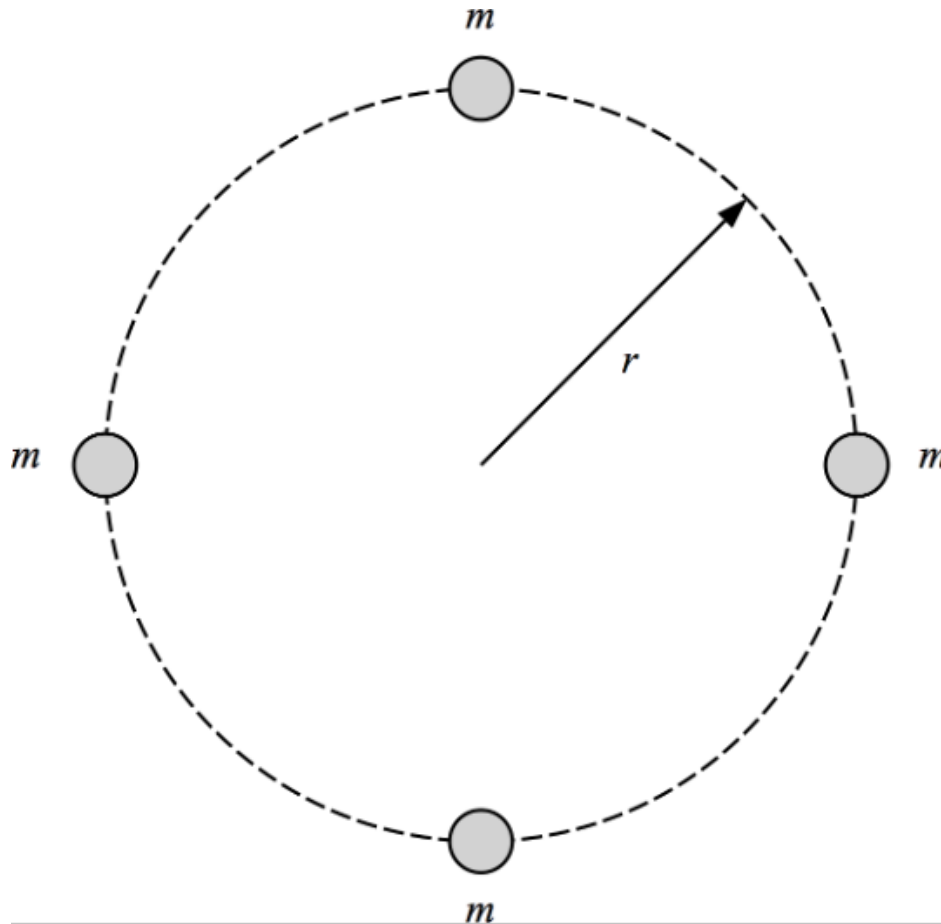


Figure 12: Four star system.

The system consists of four stars, each of mass m , moving with the same speed in the plane of the page along a circle of radius r .

- (15 points)** Determine the magnitude and the direction of the gravitational force exerted on one star by the other three stars.
- (10 points)** Calculate how long it takes one star to make one complete revolution.

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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