First Name____________________ Last Name____________________ NetID__________

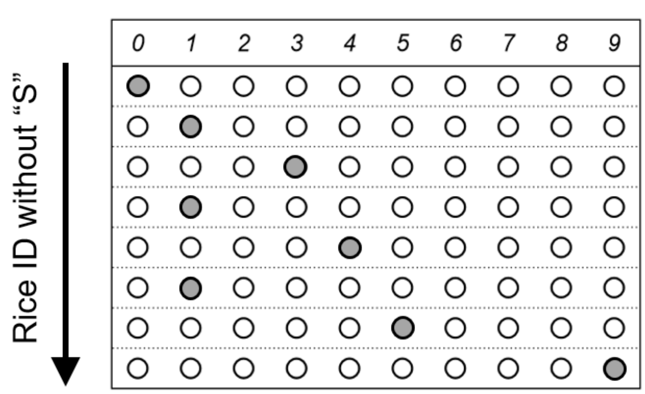
Physics 101 Fall 2022 Exam 2

Time allowed: 90 minutes, closed book

Instructions:
Please print your name and NetID in **two** places: on the top of this cover sheet, and on the multiple-choice answer sheet. If you use any additional paper for your work, please make sure to print your name on the top of each sheet and staple the extra sheets to this exam packet when you hand in your work at the end of the session. **(No name, No credit!)**

- There are 10 multiple choice questions and 3 free response questions in total.
- The maximum possible points are 100 points.
- Mark your answers to the multiple-choice questions on the answer sheet provided. Make sure to fill the appropriate bubble **completely** using a #2 pencil, or a black pen. Any multiple-choice responses written on pages other than the answer sheet will NOT be graded.
- Write all your solutions to the free response questions in the space provided in the exam packet, or on the extra space provided at the end of the exam packet. Make sure that it is very clear which problem your work corresponds to. If needed, extra papers will be provided at the front of the exam room. Remember to print your name on any extra sheets and staple them to the exam packet.
- When you finish, please place the exam packets and the multiple-choice answer sheet in two separate piles at the front of the exam room. If you use additional sheets of paper, make sure to staple them to the exam packet. Hand in all your work at the end of the 90-minute exam period.
- You are not allowed to take anything written away from the exam room.
- You may not use phones, computers, tablets, or any other web-connected device during the exam.
- You may not use the symbolic manipulation or graphing capabilities of your calculator. (You can look up trig functions, *i.e.*, calculating sin(45) is not a symbolic manipulation.)
- You may not store or use pre-stored formulae, saved in your calculator's memory, or anything written down in advance of entering the exam.

On your multiple-choice answer sheet, you will need to fill in your Rice ID. Beginning with the number “01”, enter your Rice ID by bubbling in one number per row. In the example below, the Rice ID entered is "S01314159".



Potentially Useful Constants, Integrals and Derivatives:

g = 9.8 m/s^2

$$\int x^n\,dx = \frac{x^{n+1}}{n+1} \quad \text{(provided n} \neq \text{-1)}$$

$$\int \frac{dx}{x} = \ln x$$

$$\int \sin ax\,dx = -\frac{1}{a}\cos ax$$

$$\int \cos ax\,dx = \frac{1}{a}\sin ax$$

$$\int e^{ax}\,dx = \frac{1}{a}e^{ax}$$

$$\frac{d}{dx}\left(ax^n\right) = nax^{n-1}$$

$$\frac{d}{dx}\left(\sin ax\right) = a\cos ax$$

$$\frac{d}{dx}\left(\cos ax\right) = -a\sin ax$$

$$\frac{d}{dx}\left(e^{ax}\right) = ae^{ax}$$

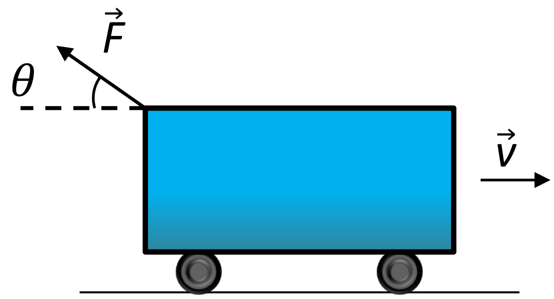
Rice Honor Code:

On my honor, I have neither given nor received any unauthorized aid on this exam.

Signature: ____

Multiple-Choice Questions: (4 points each)

1. A cart running on friction-free wheels is being slowed by a force of 80 N directed at 35° above the horizontal as shown in the figure. The power output of the cart when its velocity is 0.5 ms^{-1} is most nearly



A. 17.8 W

B. 22.9 W

C. 28.0 W

D. 32.8 W

E. 40.0 W

2. Consider two vectors $\vec{A} = 3\,\hat{\imath} + 4\,\hat{\jmath}$ and $\vec{B} = 5\,\hat{\imath} + 12\,\hat{\jmath}$. The angle between the two vectors is most nearly _____.

A. 9.8°

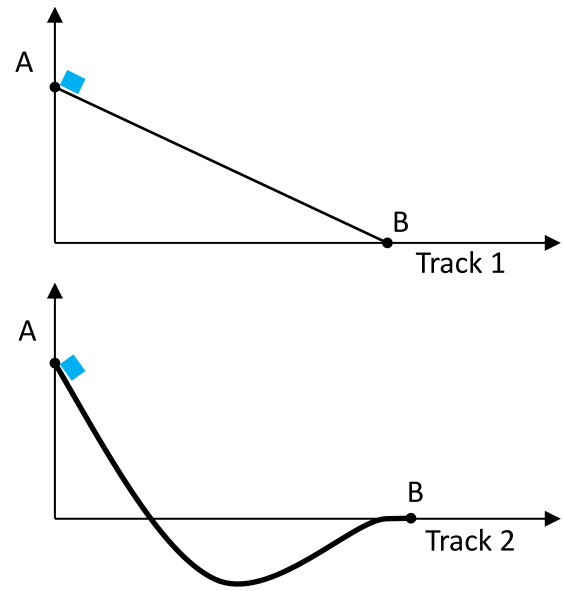
B. 14.3°

C. 27.5°

D. 42.3°

E. 75.7°

3. Consider two identical masses that slide without friction along the two different tracks shown in the figure. Each mass descends the same vertical distance *h* and travels the same horizontal distance *d* between points A and B. If the two masses are released from rest at points A at the same time, which of the following statements is/are true?



I The mass on track 2 has a faster speed at the end point B than the mass on track 1.

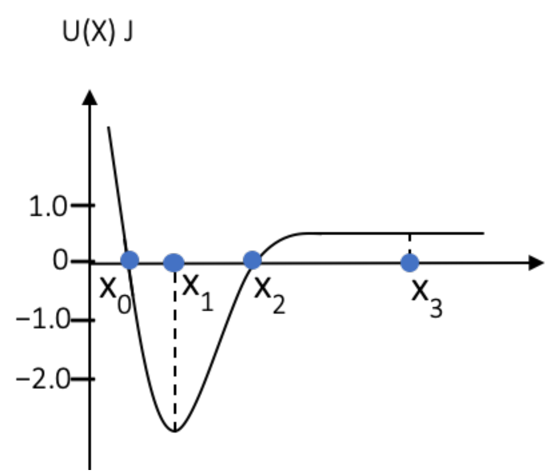
II. The mass on track 2 has a slower speed at the end point B than the mass on track 1.

III The mass on track 2 takes more time to reach point B than the mass on track 1.

IV. The mass on track 2 takes less time to reach point B than the mass on track 1.

A. I and III B. I and IV C. II and III D. II and IV E. IV only

4. The potential energy function U(*x*) associated with some conservative force is shown by the graph. A particle is moving on the *x*-axis under the influence of this force and has a kinetic energy of 1.0 J when it is at position x_1. Which of the following is a correct statement about the motion of the particle?



A. It oscillates with a maximum position of x_2 and minimum position of x_1.

B. It moves to the right of x_3 and does not return.

C. It moves to the left of x_0 and does not return.

D. It comes to rest at either x_0 or x_2.

E. It cannot reach either x_0 or x_2.

5. A child is throwing stones at a balloon trying to pop it. He finds he can hit it by throwing stones on a variety of different trajectories as shown in the figure. Assuming that he always throws the stones with the same initial speed, for which trajectory will the speed of the stone be greatest when it hits the light? Neglect air resistance.

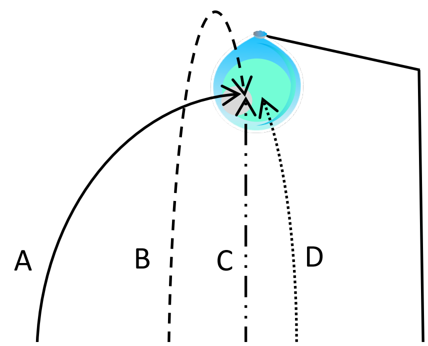
A. A

B. B

C. C

D. D

E. It doesn't matter, the speed will be the same for each.



6. A shell is fired at a target a horizontal distance R from the gun. At the top of its trajectory the shell explodes into two equal pieces, one of which subsequently falls straight down. At what horizontal distance from the gun does the second fragment land? Neglect air resistance.

A. R

B. $\frac{3}{2}R$

C. $2R$

D. $\frac{5}{2}Rmv_0$

E. This cannot be determined without knowing the energy released during the explosion.

7. Consider two different peas of mass m and $2m$ shot by a student from the same pea-shooter. If the force exerted by the student's lungs in both cases is the same, which of the following statements is true?

A. The peas acquire equal momenta.

B. The pea of mass $2m$ acquires twice the momentum of the pea of mass m.

C. The peas acquire equal kinetic energies.

D. The pea of mass $2m$ acquires twice the kinetic energy of the pea of mass m.

E. The pea of mass $2m$ acquires half the kinetic energy of the pea of mass m.

8. A car of mass m traveling with speed v_0 rear-ends a stationary truck of mass $3m$ whose brakes are not being applied. If the two stick together after the collision, the magnitude of the impulse exerted on the car is _____.

A. zero

B. mv_0

C. $\frac{2}{3}mv_0$

D. $\frac{3}{4}mv_0$

E. $\frac{3}{5}mv_0$

9. Two particles of equal mass m_0 moving with equal speeds v_0, as shown in the figure, collide and stick together. Their speed after collision is _____.

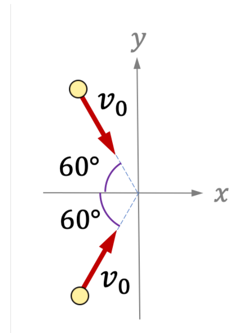
A. $\frac{v_0}{4}$

B. $\frac{v_0}{2}$

C. $\frac{\sqrt{2}v_0}{2}$

D. $\frac{\sqrt{3}v_0}{2}$

E. v_0



10. A cannon of mass $m_c = 400$ kg sits atop a narrow wall as shown and fires a ball of mass $m_b = 2$ kg horizontally across a level plane. Unfortunately, the gunner forgot to lock the (friction-free) wheels of the cannon which immediately rolls backwards off the wall, landing a distance 6m from the wall. Neglecting air resistance, at what distance d from the base of the wall does the cannon ball land?

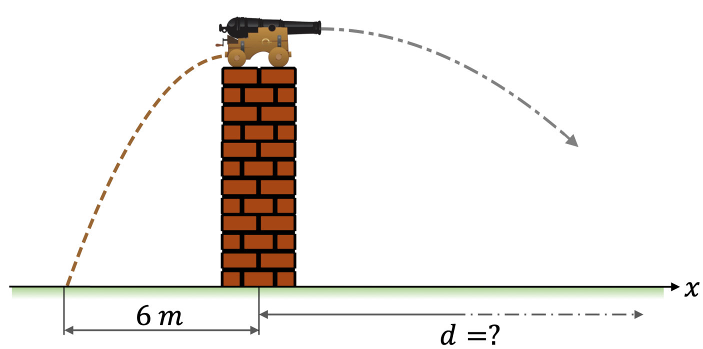
A. 360 m

B. 600 m

C. 1200 m

D. 3,600 m

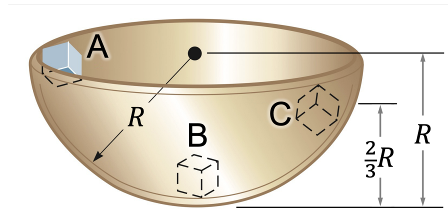
E. 6,000 m



Free Response Questions: (20 points each)

1) A small object of mass $m = 0.2$ kg is released from rest at point **A** along the horizontal diameter on the inside surface of a hemispherical bowl with radius $R = 0.5$ m, as shown in the figure below. The coefficient of kinetic friction between the object and the inside surface of the bowl is $\mu_k > 0$. The speed of the object at point **C** is $v_c = 0.8$ m/s.

For this problem, you may treat the object like a point particle and consider only its translational motion. You should also define the gravitational potential energy of the object-bowl-Earth system as zero when the object is at the lowest point inside the bowl (point **B** in the figure).



(a) What is the gravitational potential energy of the object-bowl-Earth system when the object is at point **A**?

(b) What is the kinetic energy of the object when it is at point **C**?

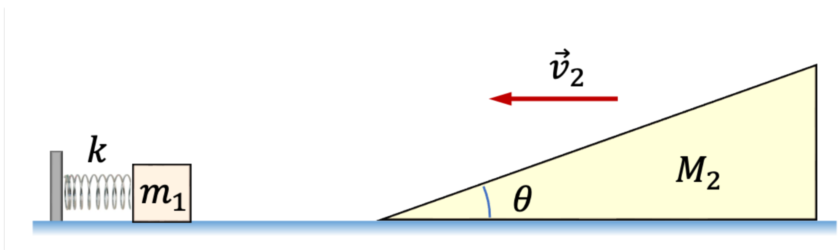
1) (cont.):

(c) How much energy is dissipated from the object-bowl-Earth system due to kinetic friction from the time when the object is at point **A** until it is at point **C**?

(d) What is the magnitude of the normal force applied to the object from the bowl at point **C**?

2) A massless, ideal spring with spring constant $k = 200\,\frac{\mathrm{N}}{\mathrm{m}}$ has been compressed by a distance $\Delta x = 0.2\ \mathrm{m}$ from its equilibrium length. A block of mass $m_1 = 0.5\ \mathrm{kg}$ is placed against the compressed spring. The spring is released from rest and then propels the block in the $+x$-direction along a horizontal frictionless surface. After losing contact with the spring, the block moves towards an inclined plane of mass $M_2 = 2\ \mathrm{kg}$ that is moving toward the block with velocity $\vec{v}_2 = -0.5\,\frac{\mathrm{m}}{\mathrm{s}}\,\hat{\imath}$, as shown in the figure below. The inclined plane makes an angle of $\theta = 35°$ with the frictionless surface on which it moves.

You should assume that the surface of the inclined plane is frictionless, so that no energy is lost when the block moves along its surface. You should also assume that the inclined plane does not encounter the spring while sliding along the horizontal surface.



(a) What is the speed of the block between the instant it loses contact with the spring and the instant that it reaches the base of the inclined plane?

(b) What is the center-of-mass speed of the block-inclined plane system immediately before the block reaches the base of the inclined plane?

2) (cont.):

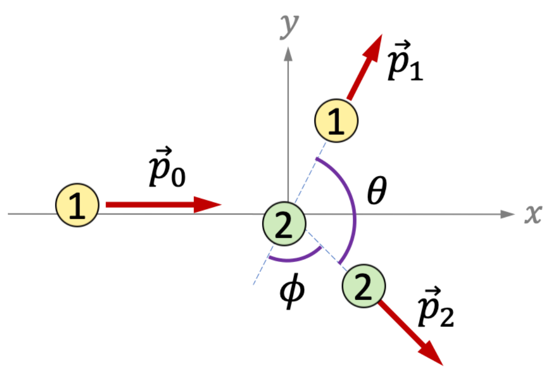
(c) What is the speed of the inclined plane when the block reaches the highest point on the inclined plane?

(d) What is the maximum vertical height reached by the block on the inclined plane? (You can assume the incline plane is taller than the maximum height reached by the block.)

(e) What is the <u>total</u> work done on the block from the time when it reaches the base of the inclined plane until the block is at its maximum height on the inclined plane?

3) Particle 1 has mass $m_1 = 0.5\ \mathrm{kg}$ and is moving in the positive x-direction with speed $v_0 = 10\ \mathrm{m/s}$. Particle 1 collides elastically with particle 2 which has $m_2 = 1.4\ m_1$ and is initially stationary, as shown below. Immediately after the elastic collision, particle 1 moves away with momentum $\vec{p}_1$ and particle 2 moves away with momentum $\vec{p}_2$. The magnitude of the momentum of particle 1 immediately after the collision is $p_1 = 2\ \frac{\mathrm{kg\ m}}{\mathrm{s}}$, and the momentum vectors $\vec{p}_1$ and $\vec{p}_2$ make an angle θ with respect to one another.

You can assume no external forces act on the two-particle system during the elastic collision. Both the angle θ and its compliment ϕ, are shown in the figure below.



(a) What is the speed of particle 1 immediately after the collision?

(b) Considering that the collision is elastic, what is the magnitude of the momentum of particle 2 immediately after the collision?

3) (cont.):

(c) What is the magnitude of the impulse applied to particle 1 during the collision?

(d) What is the angle θ between the vectors $\vec{p}_1$ and $\vec{p}_2$, as measured in degrees?
Hint: You may wish make use of either the Law of Sines or the Law of Cosines.

$$\frac{\sin\theta_a}{a} = \frac{\sin\theta_b}{b} \qquad \& \qquad c^2 = a^2 + b^2 - 2ab\cos\phi$$

Extra Work Space (Clearly indicate which problem your work corresponds to):