Last Name:________________ First Name ________________ ID ________________

Discussion Section:________ Discussion TA Name:__________________________

Instructions—
Please turn off your cell phone and put it away.
Calculators may not be shared. Please keep yours on your own desk.
This is a closed book exam. You have ninety (90) minutes to complete it.

1. Use a #2 pencil. Do not use a mechanical pencil or pen. Darken each circle completely, but stay within the boundary. If you decide to change an answer, erase vigorously; the scanner sometimes registers incompletely erased marks as intended answers; this can adversely affect your grade. Light marks or marks extending outside the circle may be read improperly by the scanner. Be especially careful that your mark covers the center of its circle.

2. Print your **NETWORK ID** in the designated spaces at the right side of the answer sheet, starting in the left most column, then **mark the corresponding circle** below each character. If there is a letter "o" in your NetID, be sure to mark the "o" circle and not the circle for the digit zero. If and only if there is a hyphen "-" in your NetID, mark the hyphen circle at the bottom of the column. When you have finished marking the circles corresponding to your NetID, check particularly that you have not marked two circles in any one of the columns.

3. Print **YOUR LAST NAME** in the designated spaces at the left side of the answer sheet, then mark the corresponding circle below each letter. Do the same for your **FIRST NAME INITIAL**.

4. **You may find the version of this Exam Booklet at the top of the next page.** Mark the version circle in the TEST FORM box at the bottom right on your answer sheet. **DO THIS NOW!**

5. Print your UIN# in the **STUDENT NUMBER** designated spaces and mark the corresponding circles. You need not write in or mark the circles in the SECTION box

6. Sign your name (**DO NOT PRINT**) on the **STUDENT SIGNATURE** line.

7. On the **SECTION** line, print your **DISCUSSION SECTION**. You need not fill in the COURSE or INSTRUCTOR lines.

Before starting work, check to make sure that your test booklet is complete. In addition to these instructions, you should have 8 numbered pages plus one (1) Formula Sheet.

Academic Integrity: **Giving assistance to or receiving assistance from another student or using unauthorized materials during a University Examination can be grounds for disciplinary action, up to and including expulsion.**

This Exam Booklet is Version A. Mark the **A** circle in the TEST FORM box at the bottom right on your answer sheet. **DO THIS NOW!**

Exam Grading Policy—

The exam is worth a total of **105** points, composed of two types of questions.

MC5: *multiple-choice-five-answer questions, each worth 6 points.*
Partial credit will be granted as follows.

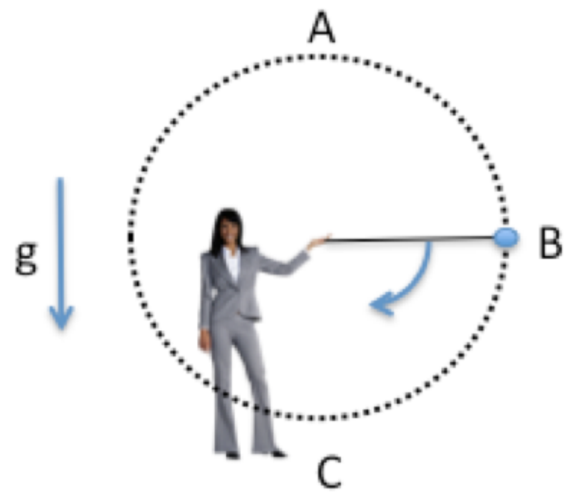
A) If you mark only one answer and it is the correct answer,
you earn **6** points.
B) If you mark two answers, one of which is the correct answer,
you earn **3** points.
C) If you mark three answers, one of which is the correct answer,
you earn **2** points.
D) If you mark no answers, or more than three, you earn 0 points.

MC3: *multiple-choice-three-answer questions, each worth 3 points*.
No partial credit.

A) If you mark only one answer and it is the correct answer,
you earn 3 points.
B) If you mark a wrong answer or no answers, you earn 0 points.

The next three questions pertain to the situation described below.

A girl whirls a tennis ball attached to a string of length l = 1.6 m in a circle at a constant angular speed of ω = 4.5 rad/s, clockwise in the vertical plane. Neglect air resistance and assume the string is massless and does not stretch.



1) In one complete revolution, the ball experiences:

a. Constant speed, and an acceleration that is constant in magnitude.
b. Constant velocity and varying acceleration.
c. Constant speed, and an acceleration that varies in magnitude.

2) What is the acceleration of the ball at point B ?

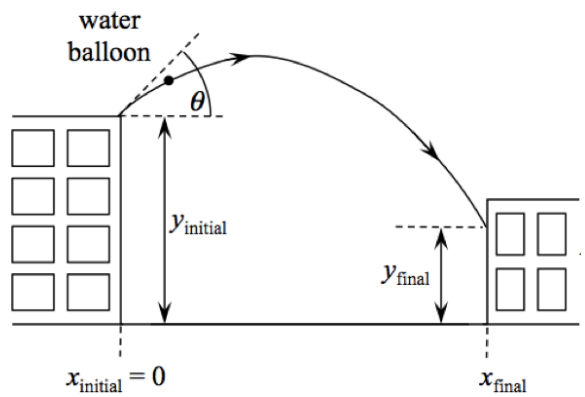
a. 20.25 m/s^2 to the right
b. 7.2 m/s^2 to the right
c. 32.4 m/s^2 to the right
d. 20.25 m/s^2 to the left
e. 32.4 m/s^2 to the left

3) At which point in the revolution shown in the diagram is the tension in the string the greatest ?

a. The tension in the string is constant.
b. Point C
c. Point B

The next four questions pertain to the situation described below.

Physics students construct a cannon from rubber tubing and a funnel which will launch water-filled balloons. They assemble their device on the roof of Loomis and fire a test shot, which strikes the closest wall of the Astronomy Building, as shown in the figure.



The shot is launched from initial position $(x_{initial}, y_{initial})$ = (0 m, 26 m) and strikes the Astronomy Building at time t_{final} = 3.4 s and at the final position (x_{final}, y_{final}) = (280 m, 13 m).

4) The water balloon's speed is greatest

a. When it is launched.
b. When it strikes the Astronomy Building.
c. When it reaches its maximum altitude.

5) Which of the following best describes the magnitude of the vertical component of the water balloon's velocity during its flight towards the Astronomy Building?

a. It is constant.
b. It increases then it decreases.
c. It decreases then it increases.

6) What is the initial horizontal component of the balloon's velocity, v_{0x}?

a. v_{0x} = 16.68 m/s
b. v_{0x} = 41.18 m/s
c. v_{0x} = 82.35 m/s
d. 0 m/s
e. v_{0x} = 3.82 m/s

7) What is the initial vertical component of the balloon's velocity, v_{0y}?

a. v_{0y} = 82.35 m/s
b. v_{0y} = 3.82 m/s
c. v_{0y} = 0 m/s
d. v_{0y} = 33.35 m/s
e. v_{0y} = 12.85 m/s

8) Imagine that you are asked to calculate the velocity as a function of time for an object which experiences a *time dependent* acceleration $a(t)$. To solve for $v(t)$ you would

a. Calculate the integral $\int a(t)dt$
b. Use the formula $v(t) = at$
c. Calculate the derivative $\frac{da(t)}{dt}$

9) An object is initially at rest at the origin. At time $t = 0$ it begins to accelerate along the x axis. Its (time dependent) position is observed to be $x(t) = qt^3$, where q is constant. How fast is the object moving at time t when $t > 0$?

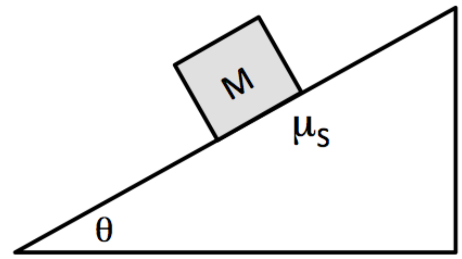
a. $qt^4/4$
b. qt^3
c. $3qt^2$
d. qt^5
e. $qt^2/2$

At $t_{initial} = 0$ s, an object is observed to have velocity components $(v_{initial,x}, v_{initial,y})$ = (7 m/s, 0 m/s). Later, at $t_{final} = 5$ s, object is observed to have velocity components $(v_{final,x}, v_{final,y})$ = (0 m/s, 4 m/s).

10) What is the object's *average* acceleration during the time interval between $t_{initial}$ and t_{final}?

a. (-3.5 m/s^2, -2 m/s^2)
b. (-7 m/s^2, 4 m/s^2)
c. (-1.4 m/s^2, 0.8 m/s^2)
d. (-3.5 m/s^2, 2 m/s^2)
e. (7 m/s^2, -4 m/s^2)

A block of mass M = 7 kg is placed on an inclined plane that makes an angle θ = 35 degrees with horizontal, as shown in the figure. The coefficient of static friction is μ_S.



11) What is the minimum coefficient of static friction necessary to prevent the block from sliding down the ramp ?

a. 0
b. 0.82
c. 0.29
d. 0.7
e. 0.57

The next two questions pertain to the situation described below.

A boy starts on the south bank of a river that runs from the East to the West and wants to paddles to the other side. The river is d = 200 meters wide and is flowing to the west at 0.8 m/s relative to the land. He points the front of his canoe toward the North and paddles the canoe at 1.9 m/s with respect to the water.

12) What is his speed relative to the land ?

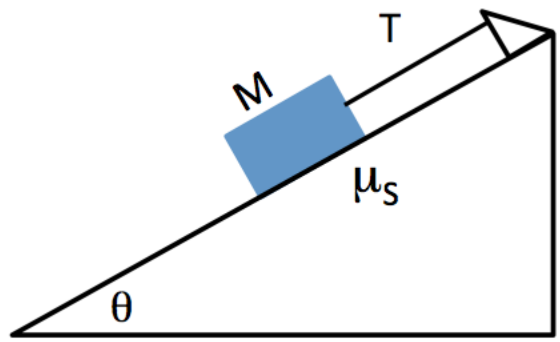
a. 2.06 m/s
b. 2.7 m/s
c. 1.9 m/s
d. 1.72 m/s
e. 1.1 m/s

13) When he reaches the opposite bank, how far West has he moved from his starting point ?

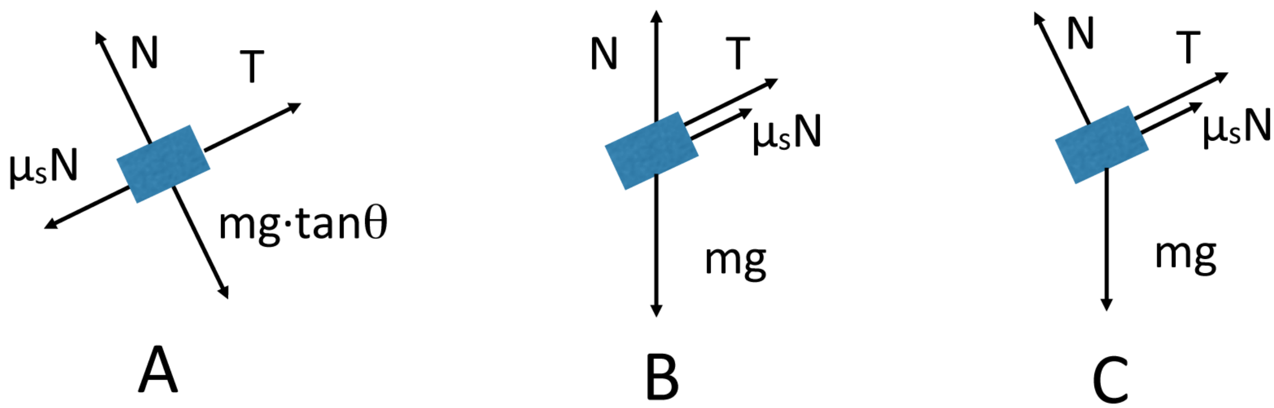
a. 284.21 m
b. 200 m
c. 400 m
d. 84.21 m
e. 118.74 m

The next two questions pertain to the situation described below.

A block of mass M = 3 kg is placed on an inclined plane with an angle θ = 40 degrees. A string anchored near the top of the ramp is attached to the block in order to prevent the block from sliding down the ramp. (Without the string, static friction alone would be insufficient to keep the block from slipping.) The coefficient of static friction is $\mu_S = 0.12$ and the tension in the string is T.



14) Which is the correct free body diagram of the forces on the block when it is at rest?

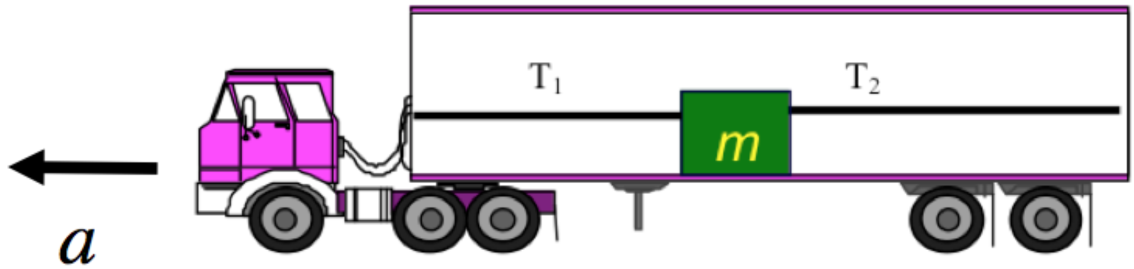


a. A (left diagram)
b. C (right diagram)
c. B (center diagram)

15) What is the minimum tension in the string needed to hold the block in place ?

a. 16.21 N
b. 5.4 N
c. 20.27 N
d. 21.62 N
e. 24.81 N

The next three questions pertain to the situation described below.



A 150 kg box is placed on the bed of a truck moving to the left. The box is held in the center of the truck by two ropes as shown, rope 1 toward the front and rope 2 toward the back. The ropes' tensions are T_1 and T_2 respectively. Assume there is NO FRICTION between the bed of the truck and the box.

16) If the truck has a constant acceleration toward the left as shown in the picture, which of the following is true?

a. $T_1 > T_2$
b. $T_1 < T_2$
c. $T_1 = T_2$

17) While moving to the left as shown in the picture, the truck suddenly brakes and decelerates (slows down) with 5 m/s^2 magnitude. The ropes can each withstand a tension of 300 N without breaking. Which of the following is true?

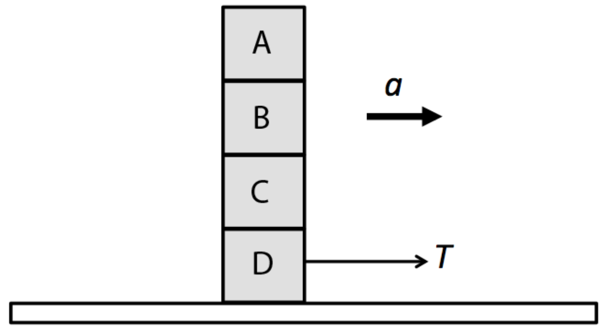
a. Rope 1 breaks.
b. Rope 2 breaks.
c. Neither rope breaks.

18) Now suppose that rope 2 is replaced by a spring with spring constant k = 750 N/m, and rope 1 is removed entirely. If the truck decelerates at 5 m/s^2 as in the previous question, what is the change in the length of the spring relative to its equilibrium length ?

a. It is 1 m longer
b. Its length is unchanged
c. It is 1 m shorter
d. It is 0.2 m longer
e. It is 0.2 m shorter

The next three questions pertain to the situation described below.

Four identical M = 7 kg blocks are pulled across a horizontal frictionless surface by a horizontal rope tied to the bottom block. Static frictional forces between the surfaces of the blocks keep them from slipping with respect to each other. The pile has a constant acceleration a = 4.5 m/s^2.



19) What is the tension in the rope?

a. 31.5 N
b. 126 N
c. 18 N

20) What is the net horizontal force on block D ?

a. 63 N
b. 0 N
c. 126 N
d. 94.5 N
e. 31.5 N

21) What is the magnitude of the vertical force on block C due to block B ?

a. 68.67 N
b. 137.34 N
c. 0 N

The next two questions pertain to the situation described below.

A satellite of mass M_S = 350 kg is in a circular orbit around the Earth. It orbits the earth 7 times a day at a radius of R from the center of the earth.

22) What is the angular velocity of the satellite, ω, as it orbits the Earth ?

a. $\omega = 50.91 \times 10^{-5}$ rad/s
b. $\omega = 7.27 \times 10^{-5}$ rad/s
c. $\omega = 8.1 \times 10^{-5}$ rad/s

23) Which expression gives the orbital radius of the satellite ?

a. $R = (GM_{Earth}M_S/\omega)^{1/2}$
b. $R = (GM_{Earth}M_S/\omega^2)^{1/3}$
c. $R = (GM_{Earth}/\omega)^{1/2}$
d. $R = (GM_{Earth}/\omega^2)^{1/3}$
e. $R = (\omega/M_S g)^{1/2}$

Phys 211 Formula Sheet

Kinematics

$\mathbf{v} = \mathbf{v}_0 + \mathbf{a}t$

$\mathbf{r} = \mathbf{r}_0 + \mathbf{v}_0 t + at^2/2$

$v^2 = v_0^2 + 2a(x-x_0)$

$g = 9.81\ m/s^2 = 32.2\ ft/s^2$

$\mathbf{v}_{A,B} = \mathbf{v}_{A,C} + \mathbf{v}_{C,B}$

Uniform Circular Motion

$a = v^2/r = \omega^2 r$

$v = \omega r$

$\omega = 2\pi/T = 2\pi f$

Dynamics

$\mathbf{F}_{net} = m\mathbf{a} = d\mathbf{p}/dt$

$\mathbf{F}_{A,B} = -\mathbf{F}_{B,A}$

$F = mg$ (near earth's surface)

$F_{12} = -Gm_1m_2/r^2$ (in general)

(where $G = 6.67 \times 10^{-11}\ Nm^2/kg^2$)

$\mathbf{F}_{spring} = -k\,\boldsymbol{\Delta}\mathbf{x}$

Friction

$f = \mu_k N$ (kinetic)

$f \leq \mu_S N$ (static)

Work & Kinetic energy

$W = \int \mathbf{F}\cdot\mathbf{dl}$

$W = \mathbf{F}\cdot\boldsymbol{\Delta}\mathbf{r} = F\,\Delta r\,\cos\theta$

(constant force)

$W_{grav} = -mg\Delta y$

$W_{spring} = -k(x_2^2 - x_1^2)/2$

$K = mv^2/2 = p^2/2m$

$W_{NET} = \Delta K$

Potential Energy

$U_{grav} = mgy$ (near earth surface)

$U_{grav} = -GMm/r$ (in general)

$U_{spring} = kx^2/2$

$\Delta E = \Delta K + \Delta U = W_{nc}$

Power

$P = dW/dt$

$P = \mathbf{F}\cdot\mathbf{v}$ (for constant force)

System of Particles

$\mathbf{R}_{CM} = \Sigma m_i\mathbf{r}_i / \Sigma m_i$

$\mathbf{V}_{CM} = \Sigma m_i\mathbf{v}_i / \Sigma m_i$

$\mathbf{A}_{CM} = \Sigma m_i\mathbf{a}_i / \Sigma m_i$

$\mathbf{P} = \Sigma m_i\mathbf{v}_i$

$\Sigma\mathbf{F}_{EXT} = M\mathbf{A}_{CM} = d\mathbf{P}/dt$

Impulse

$\mathbf{I} = \int \mathbf{F}\,dt$

$\Delta\mathbf{P} = \mathbf{F}_{av}\Delta t$

Collisions:

If $\Sigma\mathbf{F}_{EXT} = 0$ in some direction, then $\mathbf{P}_{before} = \mathbf{P}_{after}$ in this direction:

$\Sigma m_i\mathbf{v}_i$ (before) $= \Sigma m_i\mathbf{v}_i$ (after)

<u>In addition, if the collision is elastic:</u>

* $E_{before} = E_{after}$
* *Rate of approach = Rate of recession*
* *The speed of an object in the Center-of-Mass reference frame is unchanged by an elastic collision.*

Rotational kinematics

$s = R\theta,\ v = R\omega,\ a = R\alpha$

$$\left.\begin{aligned} \theta &= \theta_0 + \omega_0 t + \tfrac{1}{2}\alpha t^2 \\ \omega &= \omega_0 + \alpha t \\ \omega^2 &= \omega_0^2 + 2\alpha\Delta\theta \end{aligned}\right\}$$

Rotational Dynamics

$I = \Sigma m_i r_i^2$

$I_{parallel} = I_{CM} + MD^2$

$I_{disk} = I_{cylinder} = {}^1/_2 MR^2$

$I_{hoop} = MR^2$

$I_{solid\text{-}sphere} = {}^2/_5 MR^2$

$I_{spherical\ shell} = {}^2/_3 MR^2$

$I_{rod\text{-}cm} = {}^1/_{12} ML^2$

$I_{rod\text{-}end} = {}^1/_3 ML^2$

$\tau = I\alpha$ (rotation about a fixed axis)

$\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$, $|\tau| = rF\sin\phi$

Work & Energy

$K_{rotation} = {}^1/_2 I\omega^2$,

$K_{translation} = {}^1/_2 MV_{cm}^2$

$K_{total} = K_{rotation} + K_{translation}$

$W = \tau\theta$

Statics

$\Sigma\mathbf{F} = 0$, $\Sigma\tau = 0$ (about any axis)

Angular Momentum:

$\mathbf{L} = \mathbf{r} \times \mathbf{p}$

$L_z = I\omega_z$

$\mathbf{L}_{tot} = \mathbf{L}_{CM} + \mathbf{L}^*$

$\boldsymbol{\tau}_{ext} = d\mathbf{L}/dt$

$\boldsymbol{\tau}_{cm} = d\mathbf{L}^*/dt$

$\Omega_{precession} = \tau / L$

Simple Harmonic Motion:

$d^2x/dt^2 = -\omega^2 x$

(differential equation for SHM)

$x(t) = A\cos(\omega t + \phi)$

$v(t) = -\omega A\sin(\omega t + \phi)$

$a(t) = -\omega^2 A\cos(\omega t + \phi)$

$\omega^2 = k/m$ (mass on spring)

$\omega^2 = g/L$ (simple pendulum)

$\omega^2 = mgR_{CM}/I$ (physical pendulum)

$\omega^2 = \kappa/I$ (torsion pendulum)

General harmonic transverse waves:

$y(x,t) = A\cos(kx - \omega t)$

$k = 2\pi/\lambda$, $\omega = 2\pi f = 2\pi/T$

$v = \lambda f = \omega/k$

Waves on a string:

$$v^2 = \frac{F}{\mu} = \frac{(\text{tension})}{(\text{mass per unit length})}$$

$$\bar{P} = \frac{1}{2}\mu v\omega^2 A^2$$

$$\frac{d\bar{E}}{dx} = \frac{1}{2}\mu\omega^2 A^2$$

$$\frac{d^2y}{dx^2} = \frac{1}{v^2}\frac{d^2y}{dt^2} \quad \text{Wave Equation}$$

Fluids:

$$\rho = \frac{m}{V} \qquad p = \frac{F}{A}$$

$$A_1v_1 = A_2v_2$$

$$p_1 + \tfrac{1}{2}\rho v_1^2 + \rho g y_1 = p_2 + \tfrac{1}{2}\rho v_2^2 + \rho g y_2$$

$$F_B = \rho_{liquid} g V_{liquid}$$

$$F_2 = F_1\frac{A_2}{A_1}$$