Last Name:_______________First Name__________________Network-ID____________
Discussion Section:_________Discussion TA Name:________________________________

Instructions—
Turn off your cell phone and put it away.
Keep your calculator on your own desk. Calculators cannot be shared.
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 a pen. Fill in completely (until there is no white space visible) the circle for each intended input – both on the identification side of your answer sheet and on the side on which you mark your answers. 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.

2. Print your last name in the **YOUR LAST NAME** boxes on your answer sheet and print the first letter of your first name in the **FIRST NAME INI** box. Mark (as described above) the corresponding circle below each of these letters.

3. Print your NetID in the **NETWORK ID** boxes, and then mark the corresponding circle below each of the letters or numerals. Note that there are different circles for the letter "I" and the numeral "1" and for the letter "O" and the numeral "0". **Do not** mark the hyphen circle at the bottom of any of these columns.

4. **This Exam Booklet is Version A**. Mark the **A** circle in the **TEST FORM** box at the bottom of the front side of your answer sheet.

5. Stop **now** and double-check that you have bubbled-in all the information requested in 2 through 4 above and that your marks meet the criteria in 1 above. Check that you do not have more than one circle marked in any of the columns.

6. Do **not** write in or mark any of the circles in the STUDENT NUMBER or SECTION boxes.

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

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

Before starting work, check to make sure that your test booklet is complete. You should have 11 ***numbered pages*** *plus two Formula Sheets.*

*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 dismissal from the University.**

Exam Grading Policy—
The exam is worth a total of **120** points, and is composed of three 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.

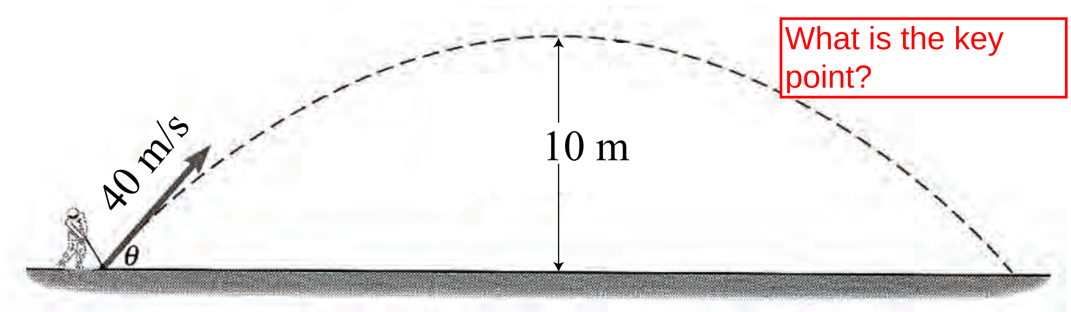
TF: *true-false questions, each worth 2 points.*
No partial credit.

(a) If you mark only one answer and it is the correct answer, you earn **2** points.
(b) If you mark the wrong answer or neither answer, you earn **0** points.

Unless told otherwise, you should assume that the acceleration of gravity near the surface of the earth is 9.8 m/s^2 *downward and ignore any effects due to air resistance.*

Usually, Greek letters are written as
\Delta (upper case\delta), \omega, \theta, \alpha (or sometimes \a), \eta, \mu, etc.

The following three problems concern the same physical situation.



What is the key point?

A golf ball is hit upward at an angle θ from the horizontal and speed v = 40 m/s. It reaches a maximum height of 10 m as illustrated above. Assume the ballistic trajectory starts at ground level and ignore air resistance. Assume the shot is made on a wide, level field.

1. What is the initial angle θ?

a. θ = 20.5 deg
b. θ= 46.4 deg
c. θ = 57.3 deg
d. θ = 70.2 deg
e. θ = 81.1 deg

Since I have no clear idea what to do, let me try to calculate the max y coordinate H (= 10 m). Let the initial velocity be (u_x, u_y). Then, 0 = u_y^2 - 2 g H. This gives u_y = \sqrt{2gH} = 14 (m/s). 40 sin \theta = u_y = 14, so sin \theta = 0.35. That is, \theta = 20.48 deg.

Later, you will learn the conservation of energy, and the argument here will become quite natural; you do not need any special formula.

2. How long is the ball in the air?

a. 1.15 s
b. 2.86 s
c. 3.12 s
d. 3.37 s
e. 3.59 s

If it take t sec to climb up to the highest point, then 2t is the answer we wish to have.

At the highest point v_y = 0. We know v_y = u_y - gt. Thus, t = 14/9.8 = 1.43 s.

Another way (better): t is equal to the time needed to fall from the height H: H = (1/2) gt^2, so t = \sqrt{2H/g} = 1.43.

3. Suppose we are free to vary the angle θ ($0 < \theta \leq 90$ deg), but everything else remains the same. The ball will have the highest speed when it hits the ground if

a. θ = 90 deg
b. θ = 45 deg
c. All angles hit at the same speed.

Let the initial velocity be (u_x,u_y) and the final velocity (U_x, U_y). Then, we know u_x = U_x and u_y = -U_y, so the speed must change.

If you know the conservation of mechanical energy, the answer is trivial.

4. Which of the following most nearly is in free fall? Allow for air resistance.

a. A feather dropped from the top of Loomis Lab.
b. A bowling ball dropped from a height of 1m.
c. A bungee jumper suspended from a taut bungee cord at the lowest point on her trajectory.

5. A man of mass 80 kg is in an elevator in the Burj Khalifa in Dubai (now the tallest building in the world). The elevator has a cruising speed of 8 m/s and reaches this speed at t = 4 s after starting from rest at t = 0 s. What is the man's apparent weight while the elevator is accelerating upward? Assume constant acceleration.

a. 660 N
b. 770 N
c. 940 N
d. 1010 N
e. not enough information given.

This asks the relation between the force and the acceleration, so let us write down Newton's equation of motion:
ma = -mg + N, where N is the normal force from the floor. N = m(a + g) = gives the apparent weight. m = 80 and a = 8/4 = 2 m/s^2. Thus, N = 944 (N).

6. Two boats A and B are moving on the surface of Lake Michigan. We will describe their motion using x and y coordinates; assume that x is to the east and y is to the north. Boat A has velocity $v_x = 5$ m/s, $v_y = -1$ m/s. Boat B has velocity $v_x = 4$ m/s, $v_y = 1$ m/s. What is their relative speed?

a. 2.0 m/s
b. 2.2 m/s
c. 4.1 m/s
d. 5.0 m/s
e. 25 m/s

The relative speed of A and B is |V_A - V_B|.
We know
V_A - V_B = (5, -1) - (4, 1) = (1, -2).
Therefore, \sqrt{5}= 2.236 m/s is the answer.

The following two problems concern the same physical situation.

7. Two astronauts with masses $m_1 = 50$ kg and $m_2 = 70$ kg are floating freely in orbit, watching the sun set. The little one pushes the big one. During the push, which astronaut experiences the larger force?

a. The little one.
b. The big one.
c. They're the same.

This is the third law: the action-reaction principle.

8. Which astronaut experiences the larger acceleration?

a. The little one.
b. The big one.
c. They're the same.

This is the second law: a = F/M. Since F is the same, the lighter the larger.

Recall Newton's three laws.

9. Which of the following must be moving at constant velocity?

a. A car moving down a straight road at constant speed.
b. A car moving around a circular race track at constant speed.
c. A car moving on a circular race track at varying speed.

Don't forget that a circular motion is an accelerated motion.

What is the key issue of these problems?

The following three problems concern the same physical situation.

10. A 30 kg boy is attached by a taut, ideal rope to a pole in the middle of an ice skating rink. The boy circles the pole at a speed v = 2.1 m/s and distance 3 m. What is the tension in the rope?

a. 9 N
b. 11 N
c. 22 N
d. 33 N
e. 44 N

This is about circular motion dynamics: The equation of motion in the radial direction reads
mv^2/r = F (the tension in this case).
Therefore, F = 30 (2.1)^2/3 = 44.1 (N).

11. What is the boy's angular speed?

a. 0.7 rad/s
b. 0.9 rad/s
c. 1.1 rad/s
d. 1.3 rad/s
e. 1.5 rad/s

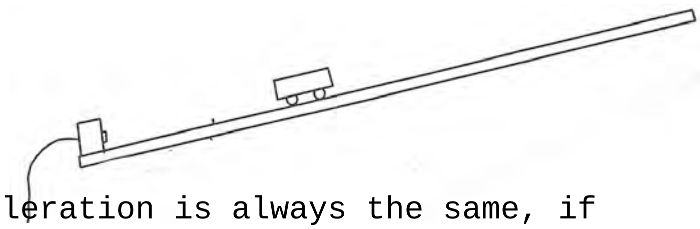
This is about circular kinematics: v = r \omega, so
\omega = 2.1/3 = 0.7 (rad/s).

12. Suppose that the boy is actually moving with angular speed 0.5 rad/s, and begins to slow down at a rate of 0.01 rad/s^2. How many times does he go around the pole before stopping?

a. once.
b. twice.
c. three times.

This is about circular kinematics, in particular,
\omega^2 = \omega_0^2 + 2 \alpha \Delta \theta.
\alpha = - 0.01 (slowing down!), so
\Delta \theta = 0.5^2/0.02 = 12.5 rad = 1.989 x (2\pi).
That is about twice.

13. You give the cart a push up a ramp, as shown in the following figure. The cart rolls up and then rolls back down the ramp. When the cart reaches the top, its acceleration is:



a. zero
b. downward
c. upward

Notice that in this case acceleration is always the same, if there is no friction.

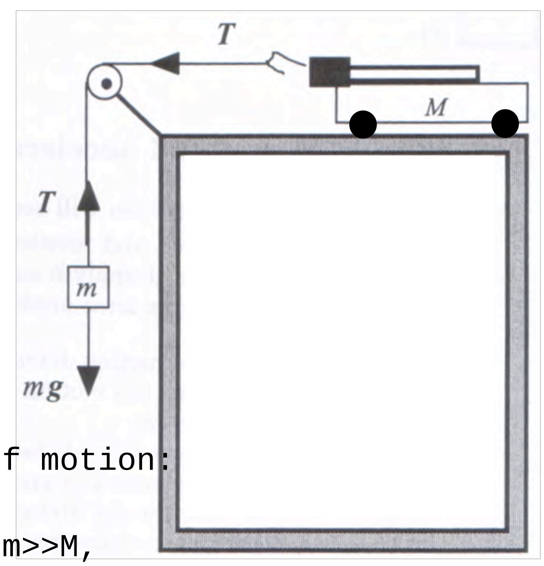
14. A block is sliding up an incline, turns around, and slides back down. There is friction between the block and the incline. Which of the following is true?

a. The magnitude of the acceleration is larger going up than going down.
b. The magnitude of the acceleration is larger going down than going up.
c. The magnitude of the acceleration is the same going up and going down.

Because of friction which decelerates the motion in any direction, the question boils down to whether the acceleration due to gravity is in the same direction as friction or not. The same when going up.

The following two problems concern the same physical situation.

A cart of mass M is on the frictionless horizontal table, and is connected to a mass m with an ideal string through a massless and frictionless pulley as shown in the figure at right.



15. When m is very large compared to M, what is the acceleration, a, of the cart?

a. a = 0
b. a is very large compared to g.
c. a is close to g.

Should be obvious, but you can use the equation of motion:
ma = mg - T (downward positive)
Ma = T (leftward positive), so a = mg/(m+M). If m>>M,
a = almost g.

16. When m = M, what is the acceleration, a, of the cart?

a. a = 0
b. a = g/2
c. a = g

See the above formula for a.

17. There are three forces **F₁**, **F₂**, and **F₃** acting on the same mass, as illustrated below. The mass has zero acceleration. Using the coordinates shown in the figure, the force vectors in components read $\mathbf{F_1} = (0.2, 2.1)$ and $\mathbf{F_3} = (-4.1, -3.8)$ (in N). Find the magnitude of $\mathbf{F_2}$.

a. 2.8 N
b. 3.3 N
c. 3.8 N
d. 4.3 N
e. 4.7 N

```
zero acceleration -> the net force = 0,
so
F_2 + F_1 + F_3 = 0 or
F_2 = -(0.2, 2.1) - (-4.1, -3.8)
     = (3.9, 1.7)
Thus |F_2| = \sqrt{3.9^2 + 1,7^2}
     = 4.25 (N).
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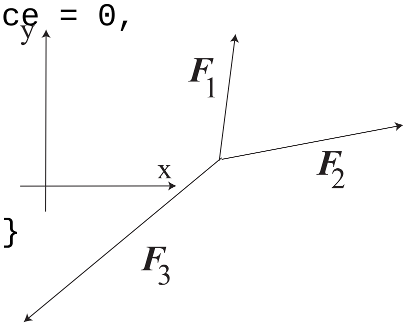


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This is mainly a vector question.
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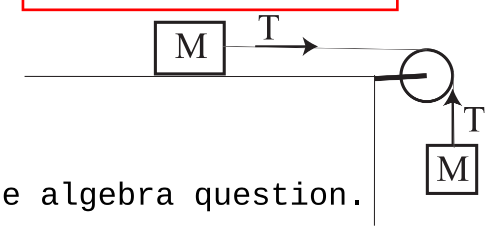
18. Consider the two blocks connected with an ideal string through a massless and frictionless pulley as shown in the figure. There is kinetic friction between the table and the block. The coefficient of kinetic friction between the block on the table and the table is μ_k.

Pure algebra question

Let "a" be the acceleration of block on the table to the right. The masses of the blocks are both equal to M. The tension in the string is T. Newton's second law tells us the following two equations.



$$Ma = T - \mu_k Mg$$
$$-Ma = T - Mg$$

```
This is a a pure algebra question.
```

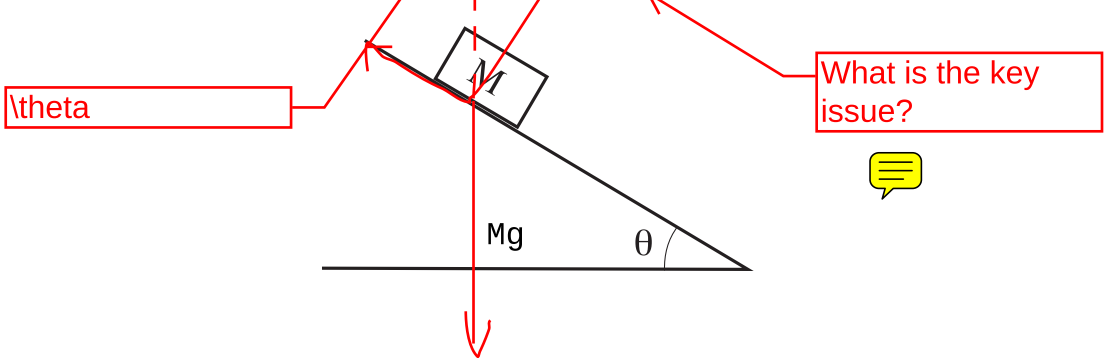
Solving these simultaneous equations, obtain the acceleration a.

a. $a = (1 - \mu_k)g/2$
b. $a = (1 + \mu_k)g/2$
c. $a = (1 - \mu_k)g$
d. $a = (1 + \mu_k)g$
e. $a = \mu_k g$

```
Subtracting the second from the first equation,
we get
     2Ma = Mg(1- \mu_k),
so
     a = g(1-\mu_k)/2.
```

The following 2 questions concern the same physical situation:

There is a block of mass M on the slope that makes an angle $\theta = 30^o$ to the horizontal. The coefficient of static friction is 0.7.



19. The block is stationary on the slope. What is the magnitude of the friction force?

a. Mg cos 30^o
b. 0.7 Mg cos 30^o
c. Mg sin 30^o

You are NOT asked to obtain the max static friction!

The actual friction is determined by the force balance condition. Loking at the above figure (arrows), we see f = Mg sin(30\deg). (b is the max static friction).

20. How large can the angle θ be before the block starts to slip?

a. $\theta = 25$ deg
b. $\theta = 35$ deg
c. $\theta = 47$ deg
d. $\theta = 55$ deg
e. $\theta = 63$ deg

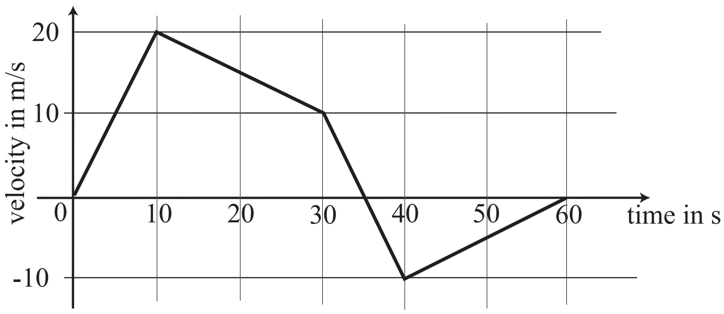
Froom the above explanation, max friction is realized when

Mg sin \theta = \mu_s cos\theta
or
\mu_s = tan\theta.

That is, \theta = Arctan \mu_s = Arctan 0.7
= 34.98 deg.

The following 2 questions concern the same physical situation:

A block of mass 23 kg is under various forces and moves along the x-axis. The x-component of its velocity is plotted as a function of time as follows.



21. What is the largest magnitude of the net force acting on the block before 60 s?

a. 23 N
b. 30 N
c. 39 N
d. 46 N
e. 52 N

```
force = mass x acceleration
The acceleration is the slope of the curve above.
Max slope = 2 m/s^2, so 23 x 2 = 46 N is the max force.
```

22. What is the average velocity of the block during 60 s?

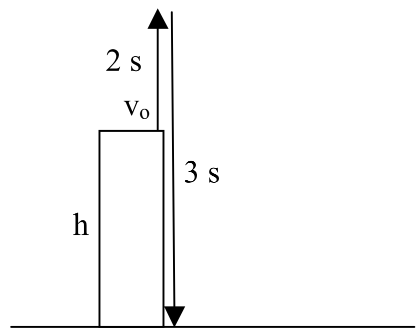
Recall the meaning of the signed area.

a. 3.3 m/s
b. 5.0 m/s
c. 6.7 m/s
d. 8.3 m/s
e. 10 m/s

```
Average velocity = total displacement/time.
The total displacement is the (signed) area of below the
graph: There are 4 positive squares and one negative square.
3 squares = 300 m in 60 s, so 5 m/s.
```

The following 2 questions concern the same physical situation:

A ball is thrown upward with a certain initial velocity v_0 from the top of a tower of height h at time t = 0. It reaches the highest point at time t = 2 seconds, and the ground at time t = 5 seconds.



23. What is the height of the tower?

a. 7.5 m
b. 11.5 m
c. 16.5 m
d. 20.5 m
e. 24.5 m

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The highest height H = h + 2 v_0 - (1/2)g 2^2.
After 2 s, the y-component of the velocity vanishes:
     v_0 -2g = 0, so v_0 = 2g.
Therefore, H = h +3 g -2g = h + 2g.
Also from the free fall: H = (1/2) g 3^2 = 44.1 m.

From these formulas, h = 44.1 - 2g = 24.5 m.
```

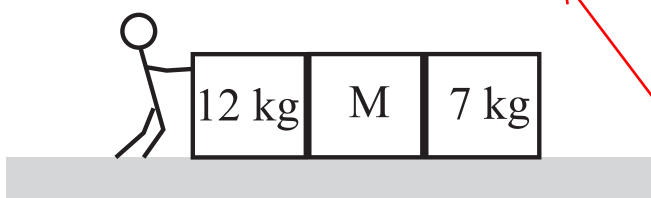
24. Suppose the mass of the ball is doubled and the same experiment is repeated from the same tower with exactly the same initial velocity. How long does it take for the ball to reach the ground?

a. 2 s
b. 5 s
c. 10 s

```
The mass does not matter.
```

The following 2 questions concern the same physical situation:

There are three boxes on a horizontal surface as illustrated in the following figure. The masses of two of the boxes are known, as shown in the figure. A person pushes the leftmost box to the right with a force of 320 N. The boxes accelerate to the right at 8 m/s^2.



This tells you that you must use the second law.

25. What is the mass M of the middle box?

a. 7 kg
b. 9 kg
c. 13 kg
d. 17 kg
e. 21 kg

The equation of motion reads
(12+M+7) 8 = 320, so 19 + M = 40, or M = 21 kg.

26. What is the force exerted by the middle box on the leftmost box?

a. 153 N
b. 167 N
c. 224 N
d. 253 N
e. 289 N

The equation of motion for the leftmost box is
12 x 8 = 320 - F,
where F is the force exerted by the middle box.
F = 320 - 96 = 224 N.

Check to make sure you bubbled in all your answers.
Did you bubble in your name, exam version and network-ID?