Last Name:_____ First Name_____ ID_____
Discussion Section:_____ Discussion TA Name:_____

Instructions—

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 12 ***numbered pages*** *plus three 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 108 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.

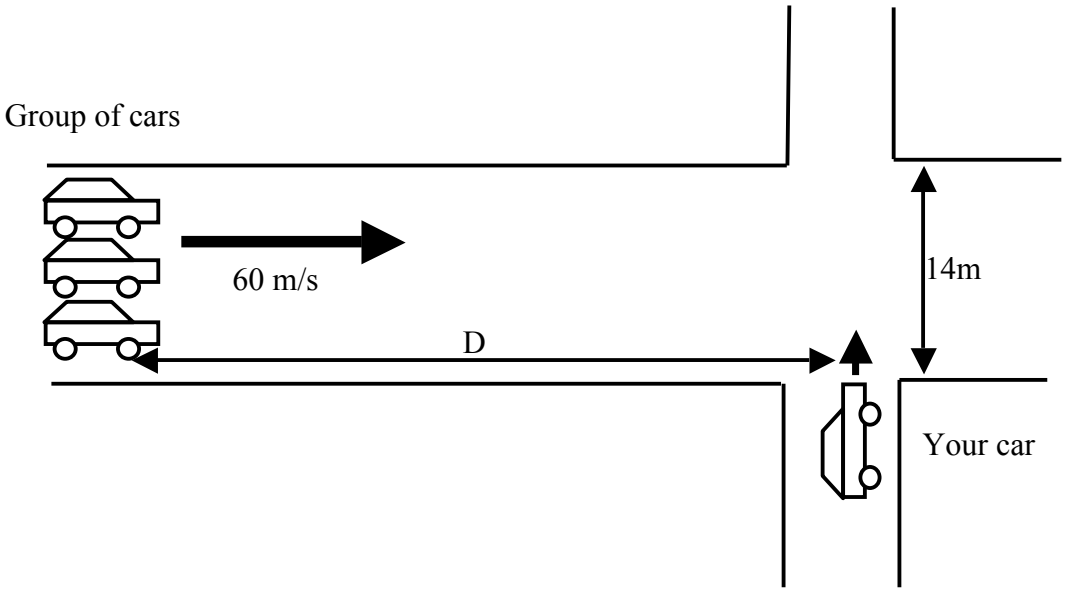
TF: *true-false questions, each worth 2 points.*
No partial credit.

(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 $\mathrm{m/s^2}$ *downward and ignore any effects due to air resistance.*

The following 2 questions concern the same physical situation:

Your car is stopped at the edge of a 14m wide road. Your car can accelerate at 3.5 m/s^2 (see diagram).



1. What is the shortest time for your car to cross the 14m wide road?

a. 1.0s
b. 2.8s
c. 9.8s

```
14 = (1/2)3.5 t^2, so t = \sqrt{8} = 2.83 s.
```

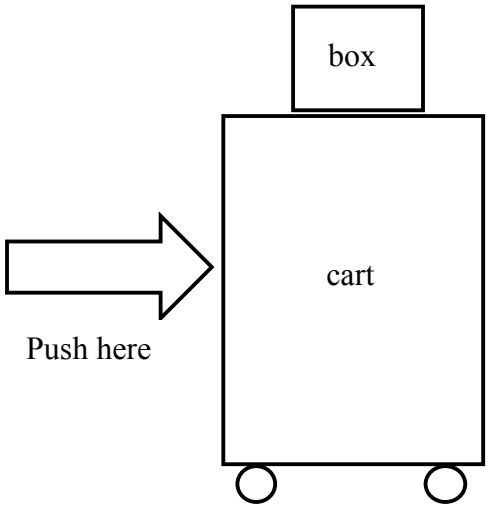
2. Suppose that you stall in the middle of the road, when the group of cars are 200m away. What is the minimum braking acceleration magnitude necessary for them to come to a stop before they hit you?

a. 3.6 m/s^2
b. 9 m/s^2
c. 9.8 m/s^2

```
0 = 60^2 - 2 a x 200, so a = 3600/400 = 9 m/s^2.
```

The following 3 questions concern the same physical situation:

A box of mass m_{box}=1 kg sits on a wheeled cart of mass m_{cart}=14 kg. The wheels roll freely (without friction). The coefficient of static friction between the box and the cart is μ_s=0.4. You begin to push the cart horizontally.



3. What is the magnitude of the maximum static friction force on the box?

a. $0.4\ m_{box}\ g$
b. $0.4\ m_{cart}\ g$
c. $0.4\ (m_{cart} + m_{box})g$

```
Max friction force is Normal Force x \mu_s, where
Normal Force is m_{box} g.
```

Excellent question

4. How much horizontal force can you exert on the cart before the box begins to slide?

a. 147N
b. 58.8N
c. 40.0N
d. 19.6N
e. 3.14N

```
Assume that the two blocks move together: F = (m_b + m_c)a.
The force on the box is m_b a which is supplied by the friction
force, which cannot exceed \mu_s m_b g.  Therefore,
m_b a < \mu_s m_b g or a <\mu_s g.
This implies F = (m_b+m_c)\mu_sg is the limit: F = 6g = 58.8 N.
```

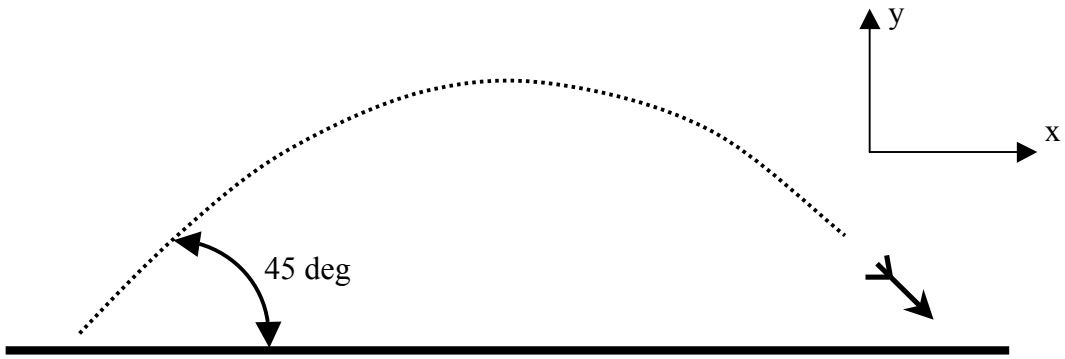
5. Suppose now that the friction coefficient between the box and the cart is zero. At t=0 you start pushing the cart with a force F. What is the acceleration of the box (a_{box}) at t=0?

a. a_{box}=0
b. a_{box}=F/m_{box}
c. a_{box}=F/(m_{box}+m_{cart})

```
Since there is no friction, the box does not feel
any force.
```

The following 4 questions concern the same physical situation:

I shot an arrow in the air (see diagram). The initial speed is 50 m/s, and the arrow is oriented at 45deg to the horizontal. Neglect air resistance and assume the arrow started at the same height as the ground.



6. What is the arrow's vertical (y) acceleration just before it hits the ground?

a. +9.8m/s^2
b. 0 m/s^2
c. -9.8 m/s^2

The force acting on the arrow is gravitational force, which is constant, so the acceleration due to it is also constant -g.

7. What is the arrow's speed just before it hits the ground?

a. 30 m/s
b. 40 m/s
c. 50 m/s

No change: if the initial velocity is (u,v), then the final velocity is (u,-v).

8. How far does the arrow go before it hits the ground?

a. 144 m
b. 201 m
c. 255 m
d. 301 m
e. 355 m

The time needed to reach the highest point is
t = v_{0y}/g = 50/\sqrt{2}g = 3.6 s. Therefore, the total flight time is 7.2 s.
The x component of the velocity is constant = 50/\sqrt{2} m/s.
Therefore, L = (50/\sqrt{2})x 7.2 = 254.6 m.

9. Suppose that the answer to the previous question is L. What would the answer be if the initial speed were 25 m/s?

a. L/4
b. L/√2
c. 2 L

If you look at the above calculation, you see L is proportional to v^2.

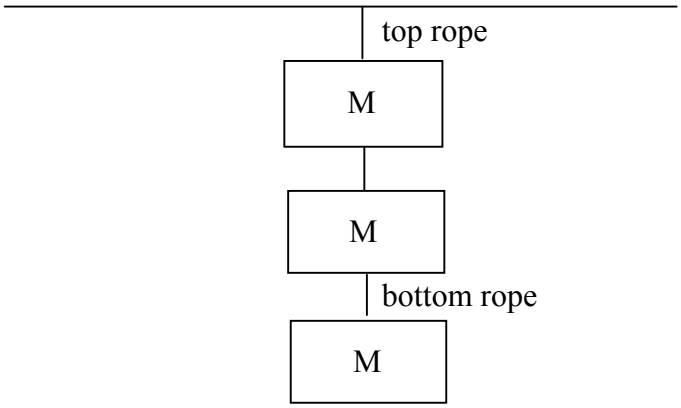
10. An astronaut free falls toward the Earth at a distance of 3 Earth radii from the center of the Earth. What is his acceleration?

a. 0.01 m/s^2
b. 0.11 m/s^2
c. 1.1 m/s^2
d. 9.8 m/s^2
e. It is impossible to tell from the information given.

```
mg = GmM/r^2, so g = GM/r^2, generally speaking.
Therefore, if r -> 3r, then g -> g/9.
```

The following 2 questions concern the same physical situation:

Three weights of mass M are hung from the ceiling using three ropes. The top one is hung directly from the ceiling, the second is hung below the first one, and the third one is hung below the second one (see diagram).



11. Which of the following is true?

a. the tension in the top rope is the same as that in the bottom rope.
b. the tension in the top rope is less than that in the bottom rope.
c. the tension in the top rope is more than that in the bottom rope.

```
Obvious.
```

12. Suppose that the mass of the lowest weight was doubled. By what factor would the tension in the top rope increase?

a. 1.33
b. 1.5
c. 2

```
Initially, it must sustain 3M; later, 4M, so 4/3 is
the ratio.
```

13. A box of mass m sits inside a funicular railway that is moving up and to the left at constant velocity V (see the picture). Which of the following is true?

Since the motion is not an accelerated motion, there should not be any change.

a. the apparent weight $F_N < mg$
b. the apparent weight $F_N = mg$
c. the apparent weight $F_N > mg$

14. A professor walking west at 1 m/s on Green St runs into a student bicycling south on Goodwin Ave at 5 m/s. What is their relative speed?

a. 1 m/s
b. 5 m/s
c. 5.1 m/s
d. 6 m/s
e. 6.1 m/s

The relative velocity vector corresponds to the hypotenuse of an orthogonal triangle:

\sqrt{1 + 5^2} = 5.099 m/s.

The following 2 questions concern the same physical situation:

There is an ocean current of 7m/s from west to east. A cruise ship can move at the speed of 18 m/s relative to the water.

15. What is the speed v of the cruiser *relative to the water* in knots (1 knot = 1.852 km/hr)?

a. v = 10 knots
b. v = 15 knots
c. v = 25 knots
d. v = 35 knots
e. v = 50 knots

```
x knot = 18 m/s,
so
x = 18 (m/1.852 km)(hr/s) = 18 x 3.6/1.852
     = 34.98
```

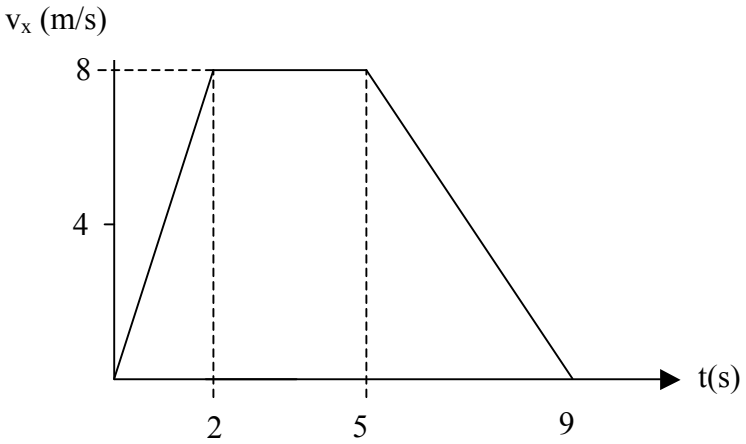
16. If one wishes to go due north with this cruise ship on this current, what is the angle θ of the ship from north?

a. θ = 17 degrees
b. θ = 19 degrees
c. θ = 21 degrees
d. θ = 23 degrees
e. θ = 25 degrees

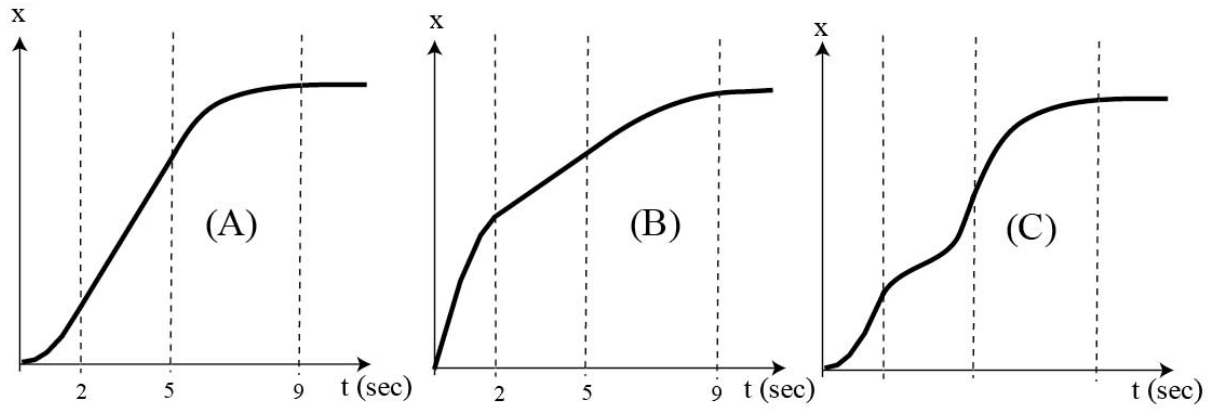
```
The flow vector (relative to the earth) is
(7,0).  The velocity of the ship relative to
water may be written as 18(sin \theta, cos \theta).
The velocity of the ship relative to the earth is
required to be (7 + 18 sin \theta, 18 cos \theta)
= (0, something).
Therefore, \theta = Arcsin (-7/18) = 22.88 deg.
```

The following 3 questions concern the same physical situation:

A block of mass 15 kg sits in on a horizontal surface. The coefficient of kinetic friction between the block and the surface is μ_k. The x component of its velocity (which is parallel to the surface) is graphed below.



17. The position (x coordinate) of the block is graphed versus time. Which of the three graphs below is the correct one?



a. A
b. B
c. C

The curve should be parabolic before 2 s, and straight between 2 and 5 s, so (A).

These two questions continue from the previous page.

18. What is the absolute value of the x-component of the acceleration at t=1 sec?

a. $|a_x| = 2.0$ m/s^2
b. $|a_x| = 3.0$ m/s^2
c. $|a_x| = 4.0$ m/s^2
d. $|a_x| = 5.0$ m/s^2
e. $|a_x| = 6.0$ m/s^2

```
8/2 m/s^2
```

19. To maintain the velocity between 2 and 5 sec, you have to push the block horizontally in the positive x direction with a force of magnitude 85 N. What is the coefficient of kinetic friction μ_k?

a. $\mu_k = 0.13$
b. $\mu_k = 0.29$
c. $\mu_k = 0.58$
d. $\mu_k = 2.9$
e. $\mu_k = 5.8$

```
That is, to make the net force vanish 85 N is needed,
so 85 = \mu_k x Normal Force = \mu_k 15 g.

Thus, \mu_k = 85/15g = 0.578.
```

The following 3 questions concern the same physical situation:

A 70 kg person steps onto an elevator with a 10 kg dumbbell. While riding in the elevator, the person notices that the dumbbell actually weighs 11 kg on a scale.

20. What do you know about the direction the elevator is moving (its velocity)?

a. up
b. down
c. Not enough information

21. What is the magnitude of the force N on the person from the elevator floor? You may assume that he leaves the dumbbell on the floor and stands still relative to the floor.

a. F = 530 N
b. F = 690 N
c. F = 739 N
d. F = 755 N
e. F = 815 N

```
70 x 1.1 x g = 754.6 N,
```

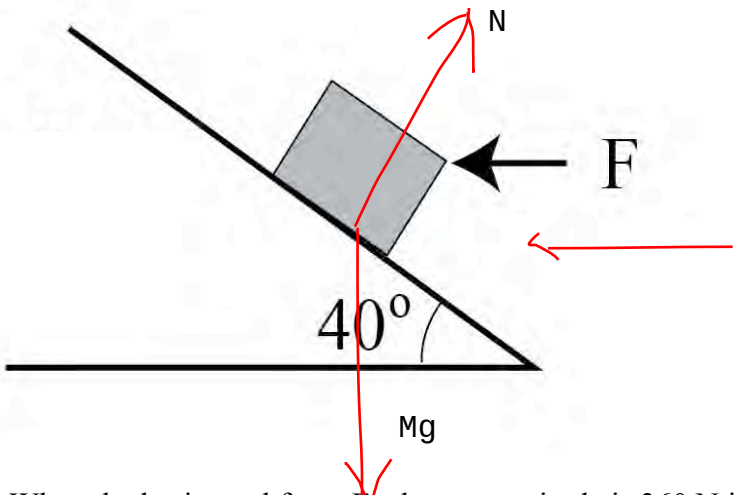
22. What is the magnitude |a| of the acceleration of the elevator? Choose the closest answer.

a. $|a| = 1.0\ m/s^2$
b. $|a| = 2.0\ m/s^2$
c. $|a| = 4.0\ m/s^2$
d. $|a| = 9.8\ m/s^2$
e. $|a| = 10.8\ m/s^2$

```
Write down the equation of motion:
ma = -mg + N, where N is the formal force from the
floor of the elevator.   N = m_{apparent}g, so
m(a+g) = m_{apparent}g.  Therefore,
a = 1.1 g - g = 0.1 g = 0.98 m/s^2.
```

The following 2 questions concern the same physical situation:

There is an incline and a block of mass 20 kg on it as shown in the figure. The angle of the slope is 40^o.



There may be some friction, but it is orthogonal to the normal force, so we can ignore it.

23. When the horizontal force F whose magnitude is 360 N is applied as shown in the figure, the block stays stationary on the slope. What is the magnitude of the normal force acting on the block from the slope?

a. 150 N
b. 231 N
c. 250 N
d. 331 N
e. 382 N

The force balance condition in the normal direction reads

N = F sin(40deg) + Mg cos(40deg)
= 360sin(40deg) + 20g cos(40deg)
= 381,54 (N)

24. Then, oil is applied between the block and the inclined surface to make the surface frictionless. The horizontal force F = 360N is still applied as in the figure. What is the magnitude of the acceleration of the block?

a. 7.5 m/s^2
b. 8.6 m/s^2
c. 9.7 m/s^2
d. 10.8 m/s^2
e. 11.9 m/s^2

Now, there is no friction, so all the forces are shown in the figure above. The block may move along the surface, and the force component parallel to the surface is F cos(40deg) + Mg sin(40deg). Therefore, the equation of motion in the plane direction reads

ma = F cos(40deg) - Mg sin(40deg) = 149.78

Thus, a = 7.49 m/s^2.

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