Last Name:________________First Name__________________ID__________________
Discussion Section:_________Discussion TA Name:________________________________

Instructions—

!!!!!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!!!!!

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 10 ***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 111 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.

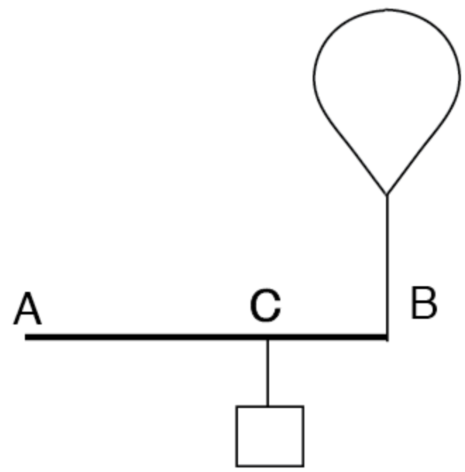
(a) If you mark only one answer and it is the correct answer, you earn **2** points.
(b) If you mark the wrong answer or neither answer, you earn **0** points.

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:

There is a massless rod of length 3m. A balloon is attached at the right end B, which pulls the rod upward with a force of 105 N. At C, which is 1m from the right end B of the rod, hangs a block of mass M. Also, a force is applied at A to keep the rod horizontal and stationary.

Not for HE3



1. What is the mass M of the block?

a. 7.2 kg
b. 9.4 kg
c. 11.6 kg
d. 16.1 kg
e. 17.3 kg

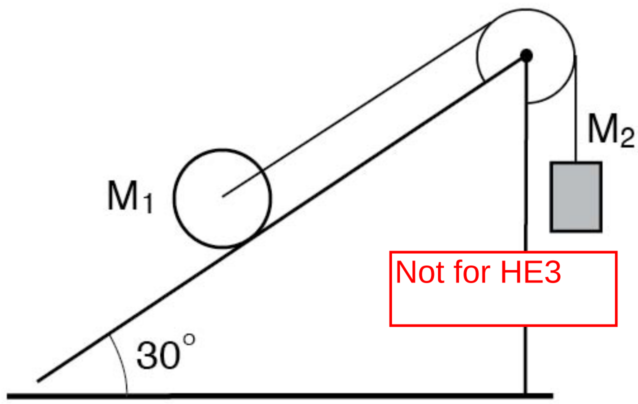
2. The torque around the axis passing through C due to the force applied at A is

a. positive (counterclockwise).
b. negative (clockwise).
c. not decidable due to insufficient information.

Not for HE3

The following 3 questions concern the same physical situation:

A solid homogeneous cylindrical roller of mass M_1 and radius 30cm is connected via a massless pulley and with a massless wire to a block of mass M_2, as shown in the figure below. M_1 is 40 kg and M_2 is 10 kg. The roller does not slip. The roller is placed on the slope of 30 degrees from horizontal. At t = 0, the block M_2 is going down, pulling the roller M_1 along the slope. That is, the mass M_1 is climbing up the slope due to the initial push. The total kinetic energy of the system is 300 J.



3. What is the kinetic energy of the block M_2?

a. 31.8J
b. 42.9 J
c. 54.0 J
d. 65.1J
e. 76.2 J

4. What is the magnitude of the angular acceleration of the roller?

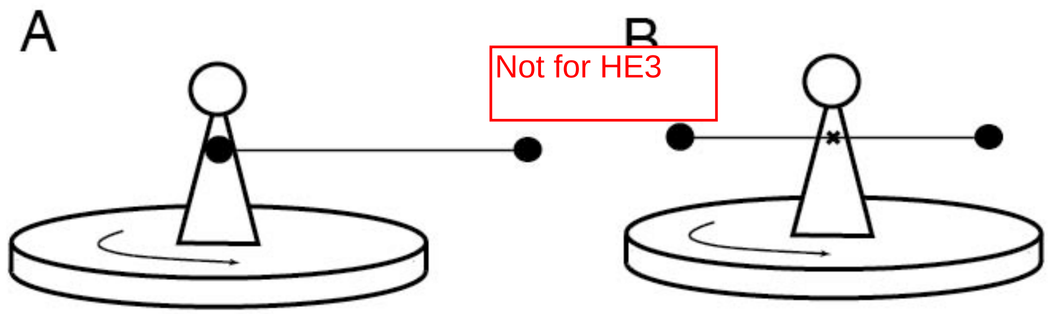
a. 3.2 rad/s^2
b. 4.3 rad/s^2
c. 4.7 rad/s^2
d. 6.5 rad/s^2
e. 7.6 rad/s^2

5. Suppose all the masses are doubled. The magnitude of the angular acceleration of the roller would be

a. unchanged.
b. multiplied by square root of 2.
c. halved.

The following 2 questions concern the same physical situation:

A person is standing at the center of a rotating disk. She holds a horizontal weightless stick with two identical small masses attached to its ends, as shown in the figure.



Initially, she holds one end of the stick as in figure A.

6. Now, she pulls in the stick and holds its center as is illustrated in B. What happens to the angular speed?

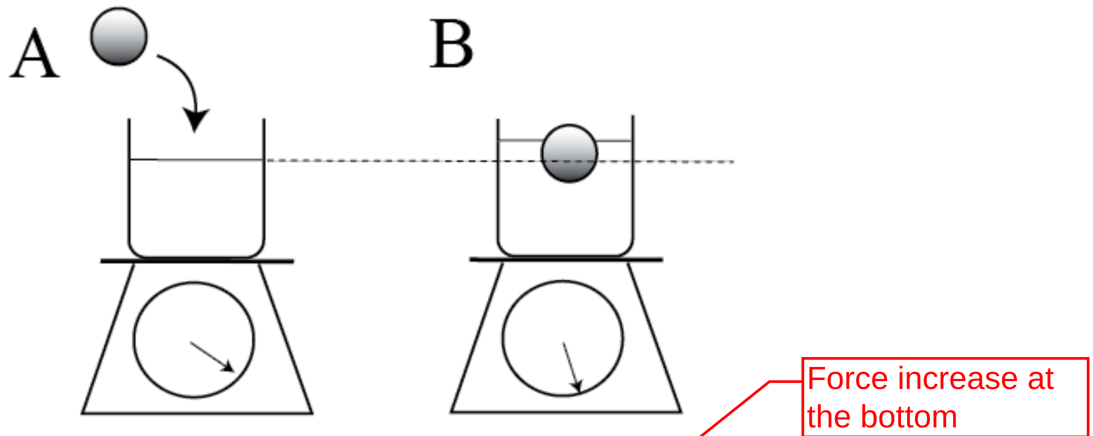
a. It increases.
b. It stays the same.
c. It decreases.

7. Does she have to do positive work to pull in the stick?

a. Yes.
b. No.
c. Not necessarily.

The following 4 questions concern the same physical situation:

A cylindrical container filled with water having cross section 0.04 m^2 is placed on a scale as illustrated in figure A below. The scale reads 24 kg. Now, a uniform ball is put into the container as shown in figure B. The ball floats on the water, and the reading of the scale becomes 27.3 kg. The density of water is 1000 kg/m^3.



8. How much larger is the pressure at the bottom of the container in B than in A?

a. 123.8 Pa
b. 209.4 Pa
c. 351.0 Pa
d. 563.4 Pa
e. 808.5 Pa

```
(27.3 - 24)g = 3.3g = P A, so
P = 3.3g/0.04 = 808.5 Pa.
```

9. What is the rise of the water surface in B compared with A? (To solve this, you do not need the answer to the previous problem.)

a. 2.5 cm
b. 3.6 cm
c. 5.8 cm
d. 6.6 cm
e. 8.3 cm

```
3.3 g is just the buoyant force, which must be the
weight of the displaced water according to Archimedes.
The volume v of the displaced water obeys
     3.3g = 1000 v g
or v = 3.3/1000 m^3. Since A = 0.04 m^2, so the rise h is
     h = v/A = 3.3/40 = 0.0825 m.
```

10. To immerse the ball totally under the water's surface requires a downward force of at least 13 N. What is the density of the ball?

a. 615 kg/m^3
b. 713 kg/m^3
c. 815 kg/m^3
d. 889 kg/m^3
e. 921 kg/m^3

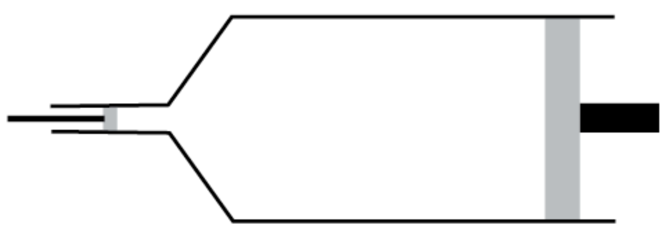
```
The mass M of the ball is M = 3.3 kg.
The force needed to immerse the whole volume V under
water requires 13 N extra.  Thus, the total buoyant
force acting on the immersed volume is
     3.3g + 13N = 1000 V g.
Therefore, V = (3.3 + 13/g)/1000.
rho = M/V = 3300/(3.3 + 13/9.8) = 713.27 kg/m^3
```

This situation continues from the previous page.

11. Now, suppose that the ball (with the same mass) is hollow inside. The ball is cut into two halves and sinks to the bottom of the container. The height of the water surface would be

a. the same as in B.
b. lower than in B.
c. higher than in B.

12. A force of 10N applied to the piston on the left side of the jack shown in the figure. This causes the working fluid inside the jack to exert a force of 1500N on the piston on the right. The piston on the left is pushed 5cm into the cylinder. What is the displacement of the piston on the right?

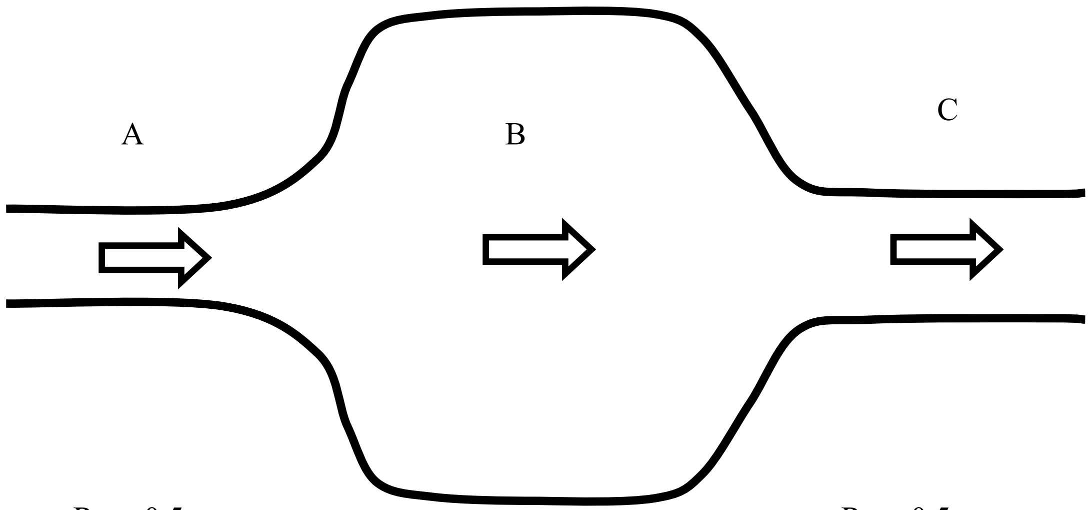


a. 0.33 mm
b. 0.44 mm
c. 0.55 mm
d. 0.66 mm
e. 0.77 mm

```
Pascal tells us 10/A_L = 1500/A_R.  This gives
     A_L/A_R = 1/150.
 `5cm pushed in' implies volume 0.05A_L is pushed in, so
0.05 A_L/A_R must be the displaced distance of the right
piston. Therefore, 0.05/150 = 3.33 x 10^{-4} m.
```

The following 3 questions concern the same physical situation.

Consider blood (density 1025 kg/m^3) flowing through an artery with circular cross section that looks like this:



$R_A = 0.5$ cm
$V_A = 30$ cm/s

$R_B = 2.5$ cm

$R_C = 0.5$ cm

Ignore viscosity. Assume that the change in height is negligible between regions A, B, and C.

13. What is the mass flow rate through region A?

a. 0.011 kg/s
b. 0.024 kg/s
c. 0.039 kg/s
d. 0.052 kg/s
e. 0.128 kg/s

```
Area is \pi R^2, so the volume flow rate is
     \pi R_A^2 V_A
Therefore, 1025 x \pi x (0.005)^2 x 0.3 = 0.02415 kg/s
```

14. What is the difference, $P_B - P_A$, in the pressure between region B and region A?

a. +46 Pa
b. +13 Pa
c. 0 Pa
d. –13 Pa
e. -46 Pa

```
To use Bernoulli, we may need V_B, ut its not large
and certainly its square may be ignored (V_B = 0.012 m/s,
actually).
     P_A + (1/2)rho V_A^2 = P_B,
so   P_B - P_A = (1/2)1025 x V_A^2 = +46.125 Pa.
```

15. Suppose that the total pressure in region B is 230 mm/Hg (30670 Pa) above atmospheric pressure, and that a small hole in region B tears open during surgery. A narrow stream of blood rises vertically from the hole. Approximately how far above the hole will the stream rise?

a. 0.19 m
b. 0.38 m
c. 0.75 m
d. 1.5 m
e. 3.1 m

```
30679 Pa = rho g d gives the `depth' we need.
d = 30679/9800 = 3.131 m.
```

The following 5 questions concern the same physical situation.

Consider a spring with spring constant k = 30 N/m suspended vertically from a hook. A block of mass 1.0 kg is attached to the bottom of the spring.

16. How much longer is the spring after the mass is attached?

a. 0.16 m
b. 0.24 m
c. 0.33 m

F = kx, so x = F/k = g/30 = 0.327 m.

Recall the harmonic-circular motion correspondence.

17. The block is displaced vertically downward from its equilibrium position at y = 0 to y = – 6cm and then released from rest at t = 0. Which of the following best describes the *acceleration* of the block?

a. $a_y = 0.06$ □^{2} cos □t
b. $a_y = 0.06$ □^{2} sin □t
c. $a_y = -0.06$ □^{2} cos □t

At t=0 the displacement is x < 0. x and a are always with opposite signs, so c is out of question. At t = 0 a > 0, so sin (i.e., b) is out.

18. What is the maximum speed of the block?

Recall the harmonic-circular motion correspondence.

a. 0.15 m/s
b. 0.24 m/s
c. 0.33 m/s
d. 1.22 m/s
e. 2.43 m/s

The max speed is A omega. A = 0.06 m. omega = \sqrt{k/m} = \sqrt{30/1}, so
V max = 0.06 x \sqrt{30} = 0.3286 m/s.

You could use the conservation of energy.

19. What is the period with which the block oscillates about its equilibrium position?

a. 0.23 s
b. 0.49 s
c. 1.15 s
d. 2.30 s
e. 5.86 s

T = 2\pi \sqrt{m/k} = 2\pi/\sqrt{30} = 1.147 s.

20. Suppose the block+spring system is placed on the surface of the moon. The period calculated above would

a. increase.
b. stay the same.
c. decrease.

The formula for T does not contain g.

The following 2 questions concern the same physical situation.

The motion of the human leg during walking can be modeled (very roughly) as a simple pendulum; while one leg is on the ground, the other leg is off the ground and swinging forward with a pendulum-like motion. One period of the pendulum corresponds to two steps, and each step involves rotating the leg through a fixed angle (which is the same for everyone) about the hip.

21. Following this model, if you are walking next to a child who is half your height, you expect the child's walking speed to be:

a. the same as yours.
b. $1/\sqrt{2}$ times yours.
c. 1/2 of yours.

```
The walking speed v must be v = L/T (T: period).
We know T is proportional to \sqrt{L}, so
L/T is proportional to \sqrt{L}.
```

22. Following this model you would expect that, compared to the Earth, the walking speed of astronauts on the moon (g = 1.6 m/s2) is

a. faster.
b. the same.
c. slower.

```
Since T is proportional to 1/\sqrt{g}, v is
proportional to \sqrt{g}.
```

23. A medical MRI device emits bursts of radio waves during operation. A typical frequency for these waves is 64 MHz. What is the corresponding wavelength?

a. 1.1 m
b. 4.7 m
c. 5.9 m

```
c = 64 x10^6 lambda = 3 x 10^8, so
\lambda = 4.688 m.
```

24. A piano's middle C string vibrates at its fundamental frequency of 261.6 Hz. On one piano the total mass of the string is 0.01 kg and the length of the string is 64 cm. What is the tension in the string?

a. 9.8 N
b. 122 N
c. 385 N
d. 980 N
e. 1752 N

```
v = lambda f.  lambda = 2 x 0.64 m.  Therefore,
v = 1.28 x 261.6 = 334.85 m/s.  This is given by
v = \sqrt{F/mu}, so F = v^2 mu.  mu is the linear density,
mu = 0.01/0.64.  F = 334.85^2 x 0.01/0.64 = 1751.9 N.
```

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