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

Instructions—
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 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 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 m/s^2 *downward and ignore any effects due to air resistance.*

1. A block of copper is placed into a large beaker of mercury and floats on top. What fraction of the copper block's volume is submerged? The density of copper is 8920 kg/m^3 and that of mercury 13500 kg/m^3.

a. 0.80
b. 0.66
c. 0.33

```
8920/13500 = 0.66

Let V be the volume of the block, and the fraction we
want be f.  Then, Archimedes tells us that
    8920 V g = 13500 fV g.
Thus we get the above answer for f..
```

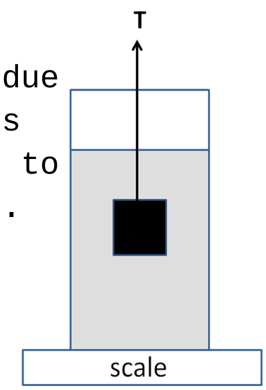
The weight of the cupper block

The weight of the displaced mercury = buoyant force

2. A tank of water of mass m = 100 kg is placed on a scale. A block of steel hanging from a massless string is lowered into the water, but not touching the bottom of the tank; that is, the steel is completely immersed in the water, and the steel block is held in place by the tension of the string (T). The block of steel has a volume of 0.01 m^3. What is the reading of the scale now with the tank of water plus the steel hanging in the water? The density of water is 1000 kg/m^3.

a. 24 kg
b. 66 kg
c. 110 kg
d. 280 kg
e. 320 kg

```
The increase of the reading must be due
to the buoyant force the water exerts
on the iron block.  It is, according to
Mr Archimedes, 0.01 x 1000 x g = 10g.
Thus the reading of the scale must
increase by 10 kg.
```



The formula on the formula sheet is complicate, but its essence is this.

3. A rectangular tank is filled with gasoline to a depth of 1 meter. What is the pressure difference between the top and the bottom of the tank? The density of gasoline is 750 kg/m^3.

a. 7.35×10^3 Pascals
b. 7.50×10^4 Pascals
c. 1.07×10^5 Pascals

```
P(d) = P(0) + rho g d,
so the pressure difference is equal to
     rho g d = 750 x 9.8 x 1 = 7350 Pa.
```

The unit `pascals' must not start with the upper case letter.

The following 3 questions concern related physical situations:

A glass cylinder (closed on the bottom) is filled to a depth of 0.10 m with water. The cross section of the cylinder is 0.01 m^2. The glass cylinder, filled with the water, gives a scale reading of 2 kg. A uniform ball is put into the water, and it floats. The scale reading of the glass + water + ball is now 2.1 kg. The density of water is 1000 kg/m^3.

4. What is the pressure difference between the top and bottom of the water in the glass before the ball is inserted?

a. 480 Nm^{-2}
b. 980 Nm^{-2}
c. 1860 Nm^{-2}

```
This is just as the previous problem:
     P difference = rho g d
     = 1000 x 9.8 x 0.1= 980 Pa.
```

d = depth

5. What is the pressure difference between the top and bottom of the water in the glass after the ball is inserted?

a. 120 Nm^{-2}
b. 420 Nm^{-2}
c. 660 Nm^{-2}
d. 1078 Nm^{-2}
e. 1860 Nm^{-2}

```
Since the force increase is (2.1 - 2.0)g = 0.1g,
the pressure difference must increase by 0.1g/0.01
= 10g. That is, 980 + 98 = 1078 Pa.
```

We use P = F/A.

6. To push the ball completely under water requires 2 N of downward force. What is the density of the ball?

a. 120 kg/m^3
b. 329 kg/m^3
c. 660 kg/m^3
d. 1078 kg/m^3
e. 1860 kg/m^3

```
M = 0.1 kg given, so we need the volume V of the ball.
The total buoyant force when the ball is completely
under water is 0.1 g + 2, which is 1000Vg according to
Mr Archimedes.  V = (0.1+2/g)/1000.

M/V = 0.1x1000/(0.1+2/g) = 328.8 kg/m^3.
```

7. A block of 0.1 kg is hanging from a spring. When set in motion, the spring and the block oscillate together with a frequency of 2.5 Hz. When a second block is attached to the first block, the oscillation frequency changes to 1.5 Hz. What is the mass of the 2nd block?

a. 0.06 kg
b. 0.15 kg
c. 0.18 kg

```
f = omega/2\pi  = \sqrt{k/m}/2\pi .
2.5 = \sqrt{k/0.1}/2\pi.
1.5 = \sqrt{k/(0.1 + m)}/2\pi.
Therefore,
2.5/1.5 = \sqrt{(0.1+m}/0.1}.
Hence, m = 0.17777 kg.
```

The following 2 questions concern related physical situations:

A 5 kg block is hanging from a spring. The spring is supported rigidly from above. The equilibrium position of the block is where the block hangs when it is not oscillating. The block is made to oscillate such that the displacement of the block from its equilibrium position is 0.1 m. The speed of the block is measured, and it is determined that the speed of the block when it passes through the equilibrium position is 1 m/s.

This is provided by the formula sheet

8. What is the spring constant?

a. 500 N/m
b. 750 N/m
c. 1500 N/m

```
Max speed (which is omega A) is 1 m/s.  The
amplitude A is 0.1 m.
Therefore, omega = 10 (rad/s).
Since omega^2 = k/m,
     k = m x omega^2 = 5 x 10^2 = 500 N/m.
```

9. What is the approximate period of the oscillation?

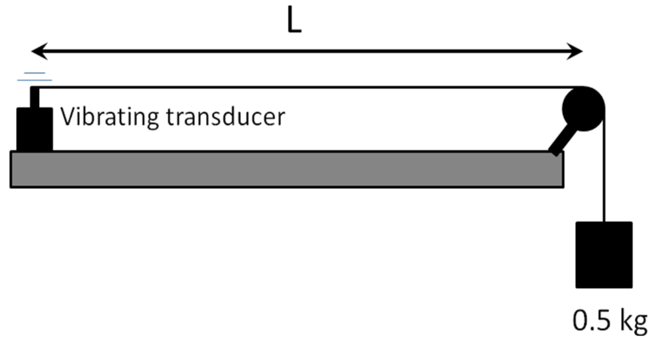
a. 0.34 s
b. 0.43 s
c. 0.63 s

```
T = 2\pi/omega = 0.628... s.
```

This exam continues on the next page.

The following 2 questions concern related physical situations:

In an experiment in lab you worked with an apparatus shown in the figure. A string is attached at one end to a mechanical vibrating transducer. The other end of the string is hung over a pulley, and a weight of 0.5 kg is attached to this end of the string. The vibrating transducer causes the string to vibrate. The wavelength of the lowest frequency of vibration (the fundamental mode) is 6 m.



10. What is the length of the string between the transducer and the pulley?

a. 3 m
b. 6 m
c. 12 m

```
For the lowest frequency (fundamental) lambda = 2L = 6m.
L = 3 m.
```

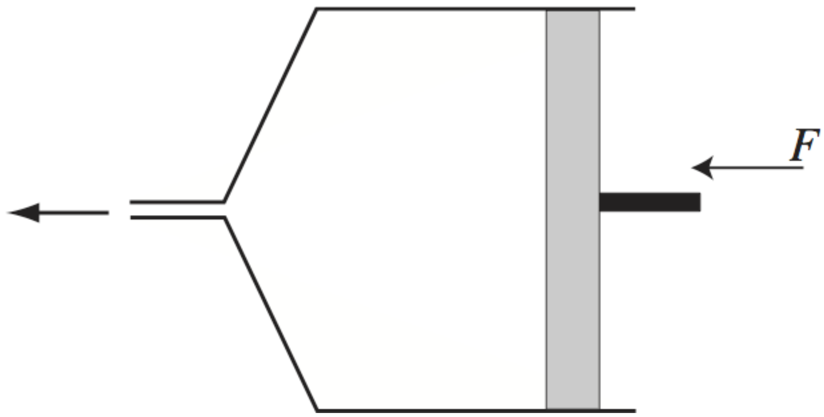
11. By adjusting the frequency of the vibrating transducer, you determine that the frequency of this fundamental mode is 10 Hz. What is the mass per unit length of the string?

a. 1.8×10^{-5} kg/m
b. 1.2×10^{-4} kg/m
c. 7.4×10^{-4} kg/m
d. 1.4×10^{-3} kg/m
e. 2.4×10^{-3} kg/m

```
 v = lambda x f = 60 m/s
which is given by
v = \sqrt{F/\mu}.  Here, F = 0.5 g = 4.9 N.
\mu = F/v^2 = 4.9/60^2 = 1.36x10^{-3} kg/m.
```

The following 2 questions concern related physical situations:

Illustrated below is an ejector of liquid with a piston. A force F is applied to the piston and the liquid comes out of a small nozzle on the left with a high speed. The ejector is in air at ambient atmospheric pressure, which also acts on the piston. The device is horizontal. The area of the small hole at the tip of the nozzle is 10^{-6} m^2 and the area of the piston is 10^{-2} m^2. The liquid is assumed to be incompressible and its density is 700 kg/m^3.



12. What is the force F you must apply on the piston to eject the liquid at a speed of 12 m/s?

a. 504 N
b. 605 N
c. 706 N
d. 807 N
e. 908 N

```
We can use Bernoulli's law, but we may ignore the speed
of the fluid on the right-hand side.  Therefore, we use
     P difference due to F  = (1/2) rho v^2
     = (1/2)700 x 12^2 = 50400 Pa.
Therefore, F = A P = 504 N.
```

13. Suppose the ejector is refilled with a different liquid that is twice as dense as the previous one. The same force F is applied to the piston as in the previous problem. What is the speed of the liquid coming out of the hole? You do not need to know the answer to the last question to answer this.

a. 6.0 m/s
b. 8.5 m/s
c. 10 m/s
d. 12 m/s
e. 15 m/s

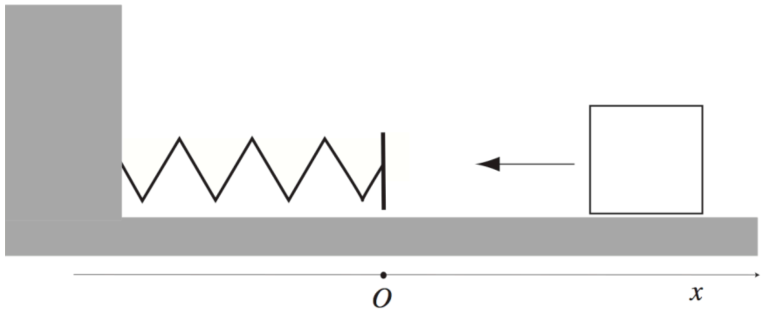
```
If the density is doubled, the speed changes from v
to v/\sqrt{2} according to the formula for F above.

Thus, 12/sqrt{2}= 8.49 m/s.

In any case, it should be obvious intuitively that the
speed must be smaller; you are trying to move something
heavier!
```

The following 3 questions concern related physical situations:

A massless spring with spring constant k = 920 N/m is attached to a wall as shown. A block of mass m = 12 kg is sliding toward the spring across a frictionless floor with a speed of 2 m/s.



14. After touching the spring the mass decelerates. What is the maximum displacement of the spring's right end?

a. 7 cm
b. 12 cm
c. 18 cm
d. 21 cm
e. 23 cm

```
This is an energy conservation problem:
Total mechanical energy is provided by the initial
kinetic energy = (1/2) 12 2*2 = 24 J.
This must be equal to (1/2) kA^2, where A is the amplitude
= the max displacement.  A^2 = 48/k = 48/920.
Thus A = 0.228 m.
```

15. After touching the spring, when does the magnitude of the acceleration of the mass reach its maximum for the first time?

a. 0.971 s later
b. 0.115 s later
c. 0.132 s later
d. 0.142 s later
e. 0.179 s later

```
The acceleration becomes max, when the displacement
is the max.  Therefore, it is after (1/4) of the period.

t = (1/4) (2\pi)\sqrt{m/k} = 0.179 s.
```

The formula for the period

Recall the harmonic-circle motion correspondence.

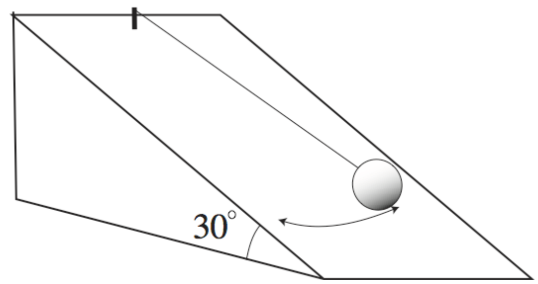
16. The same experiment is performed, but the speed of the block is doubled. Now the answer to the previous problem

a. becomes shorter.
b. becomes longer.
c. the same.

```
The amplitude has nothing to do with the period.
```

The following 2 questions concern related physical situations:

A pendulum is attached at the top of a frictionless slope that makes angle of 30 degrees with the horizontal surface as illustrated below.



Assume that the mass does not fall off the sides of the slope.

17. If the angle of the slope is 90° (that is, when the pendulum is hanging vertically), its period is τ s. What is the period of the pendulum on the slope as illustrated in the figure when the angle is 30°?

This is the component parallel to the slope. sin 30deg = 1/2.

a. 2τ s
b. $2^{1/2}\tau$ s
c. τ s
d. $\tau/2^{1/2}$ s
e. $\tau/2$ s

```
The period is given by
     T = 2\pi \sqrt{L/g}.
Now, the effective g is g/2 on the slope, so T is
multiplied by \sqrt{2}.
```

18. Now, the mass of the pendulum is doubled. What happens to the period of the pendulum on the slope compared to the last problem?

a. The period does not change.
b. The period becomes longer.
c. The period becomes shorter.

```
The mass has nothing to do with the
period of the pendulum.
```

19. A wire is strung taut between two poles. The wire is plucked and it is determined that the wave speed is 10 m/s. The tension in the wire is then increased by 30%. By how much does the wave speed change?

a. –3.0 m/s
b. –1.4 m/s
c. 0 m/s
d. +1.4 m/s
e. +3.0 m/s

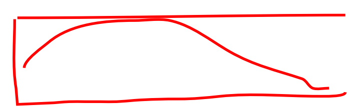
```
v = \sqrt{F/\mu}, so if F -> 1.3 F, then
v -> \sqrt{1.3} v = 1.14 v = 11.4 m/s
```

20. The displacement associated with a wave on a string has the functional form $y = 0.2 \cos(10\,x - 4\,t)$. What is the wave speed?

a. 0.4 m/s
b. 0.8 m/s
c. 2.5 m/s
d. 3.1 m/s
e. 5.0 m/s

```
4/10 = 0.4 by inspection. (You can do this:
10x -4t = 0 implies v = x/t = 4/10.)

Or 2\pi f = 4, 2\pi/lambda = 10.  Therefore,
v = f x lambda = 4/10.
```



21. An organ pipe is initially open at both ends. The fundamental frequency of the standing sound wave is 100 Hz. Now one end of the pipe is closed. What is the frequency of the first harmonic?

a. 100 Hz
b. 150 Hz
c. 200 Hz

```
Let L be the length of the pipe.
2L x 100 = v, the wave speed (sound speed).
The wavelength of the first harmonic of the
pipe with one end closed is 4L/3.
Therefore, (4L/3) f = v = 200 L.
Thus, f = 150 Hz.
```

22. The speed of sound in air is about 340 m/s. A typical frequency in a human voice is 1000 Hz. The associated wavelength is closest in size to

a. the width of your finger.
b. the width of your head.
c. your height.

```
lambda x 1000 = 340, so lambda = 0.34 m.
```

23. You are at a party standing a distance D from the loudspeaker. The music is too loud, so you move to a distance 2D from the speaker. By how much does the loudness of the music decrease?

a. 2 dB
b. 4 dB
c. 6 dB
d. 8 dB
e. 10 dB

```
\b_D = 10 log_{10}(I_D/I_0),
\b_{2D} = 10 log_{10}(I_{2D}/I_0).
Therefore,
\b_{2D} - \b_{D} = 10 \log_{10} (I_{2D}/I_{D}).
Since I_D is proportional to 1/D^2, I_{2D}/I_{D} = 1/4.
Thus, \b_{2D} - \b_{D} = 10\log_{10}(1/4) = -6.02 dB.
```

I = P/(4\pi r^2) is provided by the formula sheet.

24. The speed limit on a highway is 65 mph (1 mph = 0.448 m/s). Suppose a car carries a horn that emits an 800 Hz tone. What is the largest difference between the highest and lowest frequencies you hear as the car passes by you, supposing the car keeps within the legal limits? Assume the speed of sound is 340 m/s.

a. 22 Hz
b. 46 Hz
c. 79 Hz
d. 101 Hz
e. 138 Hz

```
f_s = 800, v_o = 0, v_s = + or -0.448 x 65 = 29.1 m/s
Therefore,
f_o max = 800 x 340/(340-29.1) = 874.87 Hz,
f_o min = 800 x 340/(340+29.1) = 736.92 Hz.

The difference is 137.9 Hz.
```

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