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

Instructions—
Turn off your cell phone and put it away.
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 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 $\mathrm{m/s^2}$ *downward and ignore any effects due to air resistance.*

Some special notations are used to type in the formulas:

Greek letters are with a backslash \ \alpha, \beta, \omega, \pi, \lambda, etc.

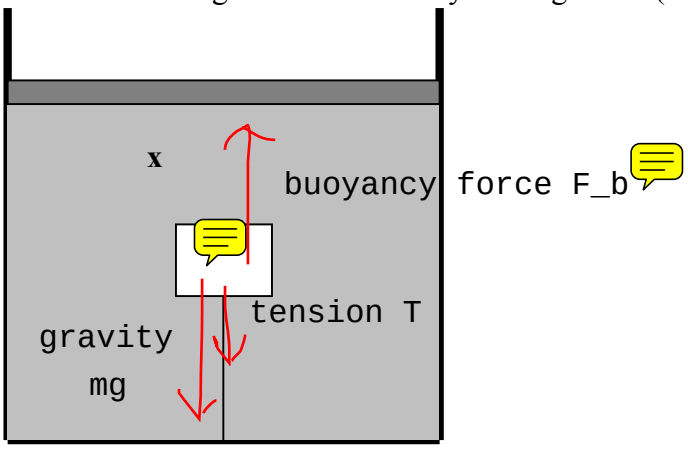
F_a means F suffix a

x^3 means x to the power 3,
if the exponent is complicated, it is in { } as x^{-1} = 1/x or a^{1/2} = square root of a.

Send questions ABOUT THE NOTATION to yoono@illinois.edu

The following 4 questions concern related physical situations:

A piston of area A = 0.3 m^2 sits on top the water in a tank (= 1000 kg/m^3), in which a block of mass m = 0.2kg that is tethered by a string floats (see figure).



1. Another mass M = 30kg is placed on top of the piston. By how much does the pressure increase at the position marked X?

a. 980 Pa
b 1100 Pa
c. 1730 Pa
d. 2000 Pa
e. 5010 Pa

P = force/area, so extra P = extra force/A.
Pressure increase = 30g/A = 30x9.8/0.3 = 980 Pa.

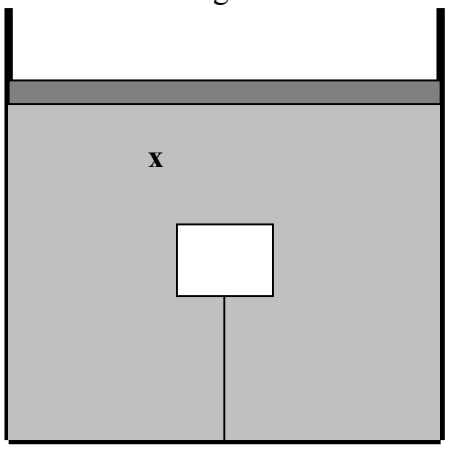
2. Compared to the magnitude of the buoyant force on the floating mass, the tension in the string has

a. smaller magnitude.
b. the same magnitude.
c. greater magnitude.

See the `free body diagram' above. The small mass is stationary, so F_b = mg + T, or
T = F_b - mg < F_b.

The following two questions continue from the previous page.

A piston of area A = 0.3 m^2 sits on top the water in a tank (ρ = 1000 kg/m^3), in which a block of mass m = 0.2kg that is tethered by a string floats (see figure).



3. Suppose the tension in the string is T = 0.5 N. What is the density of the floating mass m?

a. 344 kg/m^3
b. 419 kg/m^3
c. 501 kg/m^3
d. 699 kg/m^3
e. 797 kg/m^3

Density \rho = m/V, where V is the volume of the floating body. Archimedes tells us that

F_b = \rho V g = 0.2g + 0.5 = 2.46 (N)

Therefore,

V = 2.46/9800 = 0.000251

Thus,

\rho = 0.2/V = 796.7 kg/m^3

4. Suppose the water in the tank is 1.3m deep. How much greater is the pressure at the bottom than at the top?

a. 980 Pa
b. 1402 Pa
c. 3870 Pa
d. 8880 Pa
e. 12740 Pa

P(depth h) = P(0) + \rho gh

P(1.3) - P(0) = 1000 x 9.8 x 1.3 = 12740 Pa

5. A string of mass density $\mu = 3 \times 10^{-4}$ kg/m is stretched between two fixed points which are 1.7 m apart.

If the fundamental frequency is 330 Hz, what is the tension in the string?

a. 39 N
b. 120 N
c. 190 N
d. 250 N
e. 380 N

The wavelength is 3.4 m, so
wave speed v = 3.4 x 330 = 1122 m/s.
Since v = (T/\mu)^{1/2}, the tension is obtained as
T = \mu v^2 = 3 x 10^{-4} x 1122 = 377.7 N.

6. The electronic tags, used in high tech libraries to locate books, use microwaves of frequency 2.45 GHz (1 GHz = 10^9 Hz). What is the wavelength of this microwave?

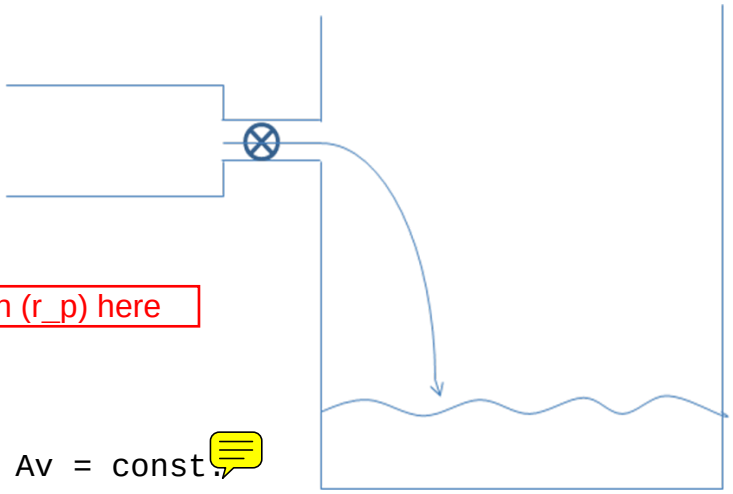
a. 0.6 cm
b. 1.2 cm
c. 6.0 cm
d. 12 cm
e. 21 cm

v = \lambda x f, so
\lambda = 3 x 10^8/(2.45 x10^9) = 0.1224 m

This exam continues on the next page.

The following 4 questions concern related physical situations:

Oil (density = 800 kg/m^3) flows through a cylindrical pipe, then through a narrower valve with circular cross section, and finally emerges into an open, cylindrical tank of radius 15 m where the pressure is 10^5 Pa (i.e. equals atmospheric pressure). (See diagram.) The speed of fluid in the pipe is 1.59 m/s. The speed of fluid in the valve is 25.5 m/s.



written (r_v) here

written (r_p) here

7. What is the ratio of the radius r_p of the pipe to the radius r_v of the valve?

a. $r_p/r_v = 4$
b. $r_p/r_v = 2$
c. $r_p/r_v = 1$
d. $r_p/r_v = 0.5$
e. $r_p/r_v = 0.063$

Mass conservation Av = const.
A = \pi r^2, so
\pi(r_p)^2 v_p = \pi (r_v)^2 (v_v)
so (r_p)^2/(r_v)^2 = (v_v)/(v_p) = 16.0. That is,
(r_p)/(r_v) = 4.

(v_v): speed in the valve,
(v_p) speed in the pipe

8. If F_p is the volume flow rate in the pipe and F_v is the volume flow rate in the valve, which of the following is true?

a. $F_p > F_v$
b. $F_p = F_v$
c. $F_p < F_v$

Volume flow rate = Av = constant.

9. Suppose it takes 1 hour to fill the tank to a depth of 1m. What is the radius of the valve?

a. 0.01 m
b. 0.05 m
c. 0.2 m
d. 0.8 m
e. 1.6 m

The volume V of the fluid to be in the tank
= \pi 15^2 x 1 (m^3)
The volume flow rate = \pi (r_v)^2 (v_v),
\pi (r_v)^2 (v_v) = V = \pi 15^2.

Therefore, (r_v)^2 = 15^2/(3600 x 25.5). That is,
(r_v) = 0.0495 m.

10. What is the pressure in the pipe? (Hint: the pressure just outside the valve is equal to atmospheric pressure.)

a. 240000 Pa
b. 360000 Pa
c. 480000 Pa
d. 600000 Pa
e. 720000 Pa

Bernoulli tells us
P_p + (1/2)\rho (v_p)^2 = P_v + (1/2)\rho (v_v)^2
P_p = 10^5 + (1/2)800(25.5^2 - 1.59^2)
= 359088.8 Pa

The following 4 questions concern related physical situations:

A mass M = 2 kg is suspended by a spring with spring constant k = 8 N/m. Initially the mass is at its resting position, y = 0. At t = 0 it is struck sharply from below by a hammer so that the mass begins to move with speed 0.1 m/s.

11. What is the period with which the mass oscillates?

a. 1.1 s
b. 2.1 s
c. 3.1 s
d. 4.1 s
e. 5.1 s

Period = 2\pi[(m/k)^{1/2}] = 2\pi[(2/8)^{1/2}] = \pi (s)

12. Suppose the setup was placed on the moon (where the gravitational acceleration is smaller than for Earth); the period of oscillation would be

a. smaller
b. larger
c. the same.

The formula for the period does not contain g.

13. Which of the following equations best describes the position of the mass?

a. y = 0.05 sin(2 t) m
b. y = 0.05 cos(2 t) m
c. y = 0.1 sin(2 t) m
d. y = 0.1 cos(2 t) m
e. y = 0.1 cos(4 t) m

V_{max}/\omega = A, where A is the amplitude.
\omega = (k/m)^{1/2) = 2. Therefore,
A = V_{max}/2 = 0.05 (m),
so the answer must be a or b.

At t= 0 the position is y = 0, so b is out.

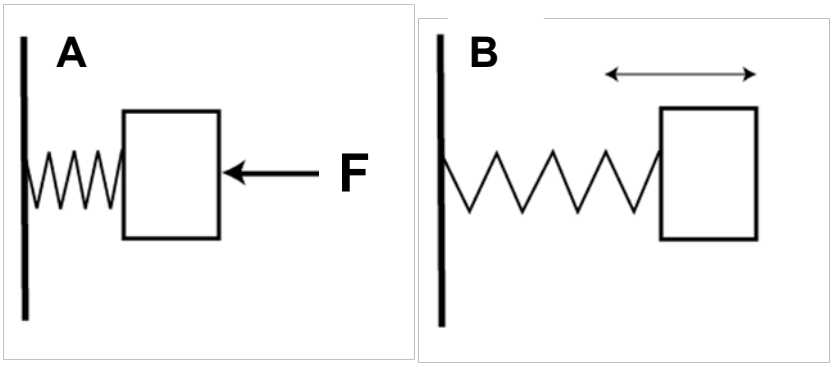
14. What is the maximum acceleration of the mass?

a. 0.1 m/s^2
b. 0.2 m/s^2
c. 0.3 m/s^2
d. 0.4 m/s^2
e. 0.5 m/s^2

max acceleration = A\omega^2 = A(k/m) = 0.05x8/2
= 0.2 m/s^2

The following 2 questions concern related physical situations:

A spring with a block of mass 3.8 kg attached at one end is fixed to the wall. A leftward force of F = 35 N is applied on the mass, compressing the spring (Fig. A). The mass is then released with zero initial velocity and starts to oscillate (Fig. B). The spring constant is k = 150 N/m.



15. What is the maximum kinetic energy of the mass?

a. 4 J
b. 8 J
c. 10 J
d. 11 J
e. 15 J

This must be equal to total energy:

$E_{total} = (1/2)k(F/k)^2 = F^2/(2k) = 35^2/300 = 4.08$ J

16. Now suppose the force F is doubled. How does the period of the oscillation change?

a. It is halved.
b. It is doubled.
c. It remains the same.

The period is independent of the amplitude.

This exam continues on the next page.

The following 2 questions concern related physical situations:

A pendulum consists of a point mass M = 7.3 kg suspended at the end of a string of length L = 1.3 m.

17. The maximum speed of the point mass is v = 0.75 m/s. What is the difference in the height Δh of the mass between its highest and lowest positions while oscillating?

a. Δh = 1.2 cm
b. Δh = 2.1 cm
c. Δh = 2.9 cm
d. Δh = 3.7 cm
e. Δh = 4.1 cm

```
The total energy = (1/2)M v^2 = 2.053 = mgh,
so h = 2.053/mg = 0.0287 m.
```

18. What is the period of the pendulum?

a. 1.2 s
b. 2.3 s
c. 3.4 s
d. 4.5 s
e. 5.6 s

```
T = 2\pi (L/g)^{1/2} = 2.288 s.
```

The following 2 questions concern related physical situations:

A sound wave with frequency 520 Hz hits a balloon containing a mixture of gases. Inside the balloon the wavelength is increased by 30% compared with that in the air (in which the sound speed is 340 m/s).

19. What is the speed of sound inside the balloon?

a. 200 m/s
b. 260 m/s
c. 340 m/s
d. 440 m/s
e. 570 m/s

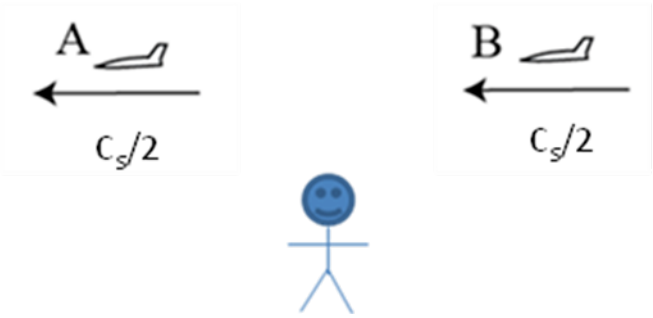
```
The frequency does not change, so f = v/\lambda = constant.
If \lambda increases by 30%, then the wave speed also
increases by 30%, so v = 340 x 1.3 = 442 m/s.
```

20. What is the frequency of the sound wave inside the balloon?

a. 400 Hz
b. 520 Hz
c. 680 Hz

```
We have already answered this question.
```

21. Jet planes A and B are flying along the same flight-path at speed $c_s/2$, where c_s is the speed of sound (see diagram). Each has an engine that emits sound at a frequency f (as heard by the pilot on each plane). An observer on the ground between the two planes hears frequencies f_A and f_B.



What is the ratio of the frequencies (where f_A is from plane A and f_B is from plane B)?

a. $f_B/f_A = 1/9$
b. $f_B/f_A = 1/3$
c. $f_B/f_A = 1$
d. $f_B/f_A = 3$
e. $f_B/f_A = 9$

```
f_A = f_s c_s/(c_s + c_s/2) = (2/3) f_s
f_B = f_s c_s/(c_s - c_s/2) = 2 f_s

Therefore, f_B/f_A = 2/(2/3) = 3.
```

The following 2 questions concern related physical situations:

The loudness of a trumpet at distance 10 m is 80 dB.

22. How many trumpeters at distance 10 m must play in unison to increase the loudness to 100 dB?

a. 10 players
b. 20 players
c. 50 players
d. 100 players
e. 200 players

```
Let I be the intensity of a single trumpet. If there are
n trumpeters
100 = 10 log_{10}(n I/I_0) = 10 log_{10}n + 80,
so 20 = 10 log_{10}n, or
log_{10}n = 2.  That is, n = 100.
```

23. You ask all the players to recede by 20 m so that all the players to be 30 m away from you. What is the ratio of the new intensity to the old intensity?

a. 0.5
b. 0.33
c. 0.11

```
Recall I_D = I_1/D^2. The distance change is from 10 m to 30 m,
is 1/9, or 0.11.
```

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