Last Name:______________First Name_________________Network-ID____________
Discussion Section:________Discussion TA Name:______________________________

Write your seat number on the answer sheet

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 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.

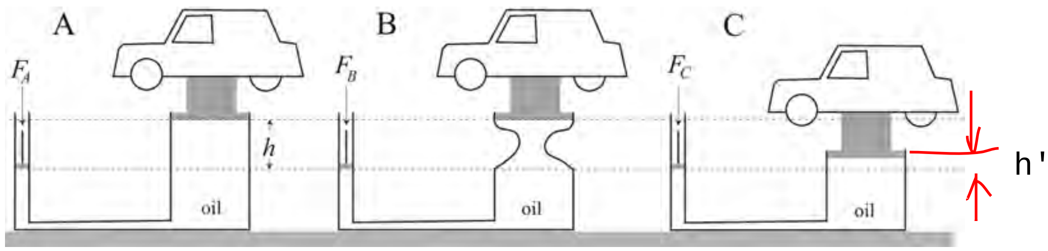
TF: *true-false questions, each worth 2 points.*
No partial credit.

(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. Always mark the answer that is closest to the exact answer.*

The following 2 questions concern the same physical situation:

Hydraulic lifts illustrated below all use the same hydraulic oil. They all have the same input-piston cross section and the same output-plunger cross section. The plunger and the car are also identical. 2, 6b, 3c



1. Choose the correct statement about the forces required to keep the car stationary.

a. $F_A > F_B > F_C$
b. $F_A = F_B > F_C$
c. $F_B > F_A > F_C$
d. $F_A > F_C > F_B$
e. $F_A > F_B = F_C$

Pascal tells us that FA = Mg +\rho h'g A', where M is the mass of the car, A is the area of the input piston, A' is the area of the plunger and h' is the actual height difference between the two piston surfaces.

Therefore, A and B need the same F. C is definitely less.

2. Now, the oil in the hydraulic lifts above is replaced by different oil with smaller density. In which case, A, B or C, is the reduction of the force needed to maintain the car stationary the smallest?

a. A
b. B
c. C

From FA = Mg +\rho h'g A', if h' is the smallest, the change of the density affects F the least.

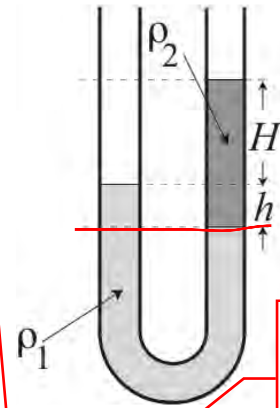
The following 2 questions concern the same physical situation:

There is a vertical U-shaped tube containing two distinct liquids that do not mix, as illustrated below. Their densities are ρ_1 and ρ_2, respectively, and the column lengths are indicated in the figure. The ends of the tube are open to the external atmosphere. 2, 3a, 6b

3. What is the relationship between ρ_2 and ρ_1 ?

a. $\rho_1 > \rho_2$
b. $\rho_1 < \rho_2$
c. $\rho_1 = \rho_2$

Obviously, `2' is lighter than `1'.



just below the bottom of `2'

The atmospheric pressure is ignored, because it is the same on both openings.

P(d) = P(0) + \rho dg, where d is the depth.

Pascal says that **in the same fluid** at the same height, the pressure is the same.

4. What is the ratio ρ_2/ρ_1?

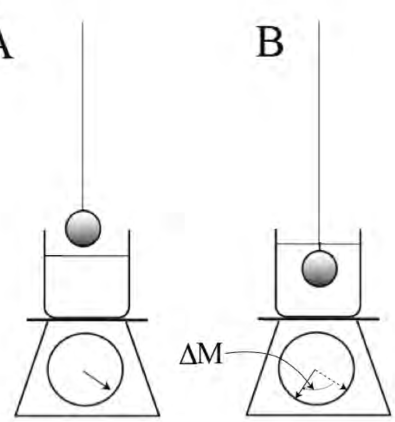
a. $\rho_2/\rho_1 = h/H$.
b. $\rho_2/\rho_1 = h/(H + h)$.
c. $\rho_2/\rho_1 = (H - h)/(H + h)$.
d. $\rho_2/\rho_1 = H/(H + h)$.
e. $\rho_2/\rho_1 = H/h$.

```
The pressure at the red line must be identical,
so
     h\rho_1g = (H + h) \rho_2 g.
Hence,
     \rho_2/\rho_1 = h/(H + h).
Needless to say, this is less than 1.
```

This exam continues on the next page.

5. On a scale is a container with liquid of density ρ_l. A solid ball of density ρ_b is lowered into the liquid. The ball does *not* float, but is still maintained above the bottom of the container, as illustrated in B. The reading on the scale changes by ΔM from the initial situation shown in A. ~~2, 3e, 6e~~

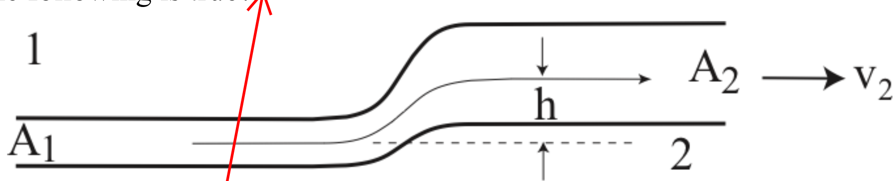
What is the volume of the ball?



a. $V = \Delta M / (\rho_b - \rho_l)$
b. $V = \Delta M / \rho_b$
c. $V = \Delta M / \rho_l$

```
The liquid exerts the buoyancy force
V\rho_l g. This upward force need a
`helper' from below. That is, the
container bottom eventually supports
this force, which is, of course,
supported by the scale.  If the scale is pushed by the force of magnitude
F, its reading is F/g.  Therefore, \Delta M g = V\rho_l g.
```

6. An incompressible ideal liquid is flowing in the pipe illustrated below. The ratio of the cross sections of the ends is 2 (i.e., $A_2/A_1 = 2$), and the height difference at the ends is h. Which of the following is true?



a. $v_2^2 = gh/4$
b. $v_2^2 = gh/2$
c. $v_2^2 = 2gh/3$
d. $v_2^2 = gh$
e. $v_2^2 = 3gh/2$

```
Bernoulli (conservation of energy!) says that
(1/2) \rho v_1^2 + P = (1/2) \rho v_2^2 + P + \rho gh
so
     v_1^2 = v_2^2 + 2gh.
The continuity (conservation of matter!) equation says
     A_1v_1 = A_2 v_2
That is, v_1 = v_2(A_2/A_1) = 2v_2.
Hence,
     4v_2^2 = v_2^2 + 2gh
or
     v_2^2 = 2gh/3.
```

The pressures on both sides are identical. This condition was miraculously dropped in the final version of the exam, making the problem unsolvable. Everybody got 100%!

There is no `directional driving', but still there is a flow. Strange? Yes, but this is one of the strange features of the so called ideal fluid which has no viscosity. If some initial condition determines the fluid flow, it lasts forever, just like a particle motion without friction; after all, viscosity is friction among moving parts in the fluid.

7. A mass attached to a spring with a spring constant k = 2.0 N/m is oscillating along the x axis. Its velocity at time t reads ~~3, 6b, 3c, 6d~~

$$v(t) = 3.5 \cos(2.2\ t) \quad \text{m/s}.$$

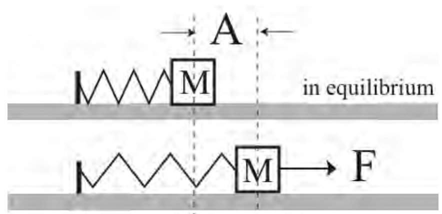
What is the maximum acceleration a_{max} of the oscillating mass in the x direction?

a. $a_{max} = 6.3\ m/s^2$
b. $a_{max} = 7.7\ m/s^2$
c. $a_{max} = 9.8\ m/s^2$
d. $a_{max} = 11.3\ m/s^2$
e. $a_{max} = 16.9\ m/s^2$

```
v_max = A\omega = 3.5 m/s
a_max = A\omega^2 = v_max \omega.
\omega = 2.2 rad/s.
Therefore,
a_max = 3.5 x 2.2 = 7.7 m/s^2.
```

8. An ideal horizontal spring on a frictionless table is fixed at one end (see diagram). The other end is attached a mass M. When a horizontal force of F is applied to the mass, it is displaced by distance A from its equilibrium position. Then, the force is turned off. What is the maximum speed V of the mass?

a. $V^2 = 2A^2/F$
b. $V^2 = AF/2M$
c. $V^2 = AF/M$




```
Energy conservation.  The spring
constant k = F/A, so the total potential energy supplied by the force
is (1/2)kA^2 = FA/2.  This must be the total energy.
Therefore,
     (1/2)MV^2 = AF/2.
```

9. A pendulum made from an ideal string of length L and a mass M is hung from the ceiling. It is undergoing very small oscillations with angular amplitude θ (in radians) and period P. M, L, and θ are all doubled. What is the new period of oscillation?

a. 0.5 P
b. 0.7 P
c. P
d. 1.4 P
e. 2 P

```
P = 2\pi \sqrt{L/g},
so P is multiplied by \sqrt{2}.
```

This is not a standard parlance.

10. Consider two containers with the same volume, each containing the same mass of gas. One is filled with water vapor (each molecule has an atomic weight of about 18), the other with nitrogen (each molecule has an atomic weight of about 28). Which has the larger number density? ~~5, 3a, 6e, 3b, 6e, 3e~~

a. water vapor
b. nitrogen
c. not enough information given

For the same mass the larger the molecular mass, the smaller the number of molecules in it.

This must be in grams; NOT in kg

11. A container of hydrogen gas (atomic weight 2) at atmospheric pressure and temperature (290 K) has a volume of 1 m^3. What is the mass of gas inside the container?

a. 4.0 g
b. 12 g
c. 26 g
d. 41 g
e. 83 g

```
PV = (M/mol mass) RT
1 x 10^5 x 1 = n x 8.31 x 290, so n = 41.5 mols.
That is, M = 83 grams.
```

12. Consider a sealed container at constant temperature containing 8 moles of hydrogen gas. If the volume of the container is increased by a factor of 2, what happens to the pressure?

It must be understood that everything is under T = const. The problem is not very carefully stated.

a. It increases by a factor of 2.
b. It decreases by a factor of 2.
c. It stays the same.

```
PV = nRT, so P is proportional to 1/V.
```

For this formula M is the molar mass in kg.

13. In a container of oxygen gas (mass = 32 atomic mass units) the root-mean-square speed of the molecules is 400 m/s. What is the temperature?

a. 185 K
b. 190 K
c. 205 K
d. 220 K
e. 230 K

```
v_rms = \sqrt{3RT/M}
Hence,
     T = Mv_rms^2/3R = 205.38 K.
```

14. The temperature in Champaign-Urbana last reached a record low of –25° F in January 1999. What is this temperature in K?

a. 231 K
b. 236 K
c. 241 K

```
T_c = (5/9)(T_F - 32) = (5/9)(-57) = - 31.67 degC,
so 273 - 31.67 - 241.3 K.
```

15. Polyethylene has a large coefficient of volume expansion, $\beta = 200 \times 10^{-6}\ K^{-1}$. Suppose a warm (30º C) piece of polyethylene is thrown into a large vat of water at 1º C. As the polyethylene cools, will it float higher or lower in the water? At all relevant temperatures, polyethylene floats. ~~4, 3b, 6e, 2b, 6c~~

a. higher
b. lower
c. not enough information given.

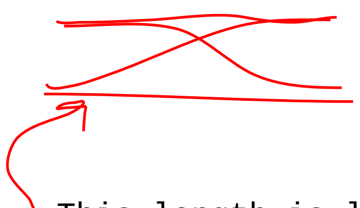
```
If T decreases, the density goes up, so it
must sink more.
```

The following three questions concern the same physical situation.

16. A low C (sub-contra C, or C0) has a frequency of 16.35 Hz. If you wanted to produce this note with the fundamental of an organ pipe that was open at both ends, how long would you have to make the pipe? Assume the speed of sound is 340 m/s.

a. 3 m
b. 5.4 m
c. 6.6 m
d. 9.2 m
e. 10.4 m

```
The wavelength is = 340/16.35 = 20.795 m
```



```
This length is lambda/2 = 10.4 m.
```

17. If you were to close one end of the organ pipe, would you have to make the pipe longer or shorter to produce the same frequency?

a. longer
b. shorter

```
Now, roughly \lambda/4.
```

18. You want to produce a 16.35 Hz note from the fundamental on a 3 meter string with mass per unit length of 10^{-3} kg/m. What should the tension in the string be?

a. 2.8 N
b. 4.9 N
c. 9.6 N
d. 17.6 N
e. 33.1 N

```
The wavelength on the string must be 6m, so the speed of
sound on the string is 98.1 m/s.

v = \sqrt{F/\mu}, so F = \mu v^2 = 10^{-3} x (98.1)^2
= 9.62 N.
```

19. Suppose you are standing a certain distance D from a loudspeaker, and using a digital loudness meter, you measure a certain loudness Q dB. At what distance will the loudness drop off by 10 dB? ~~3, 3b, 6c, 6d~~

a. 2D
b. 3.2D
c. 10D

```
Q = 10 \log(I_1/D^2I_0).
Q - 10 = 10\log(I_1/D'^2I_0).
Therefore,
     10 =10\log(D'^2/D^2).
That is, (D'/D)^2 = 10, or D' = \sqrt{10}D.
```

The following two questions concern the same physical situation.

20. A heavy ball with a hole drilled straight through it is dropped from a platform 20 m above the ground. You are standing almost (but not quite!) under the ball. The hole acts as a whistle and produces a note at 1700 Hz if you were to blow over the hole when the ball was at rest. As the ball falls toward you, the frequency you hear is

a. < 1700 Hz and decreasing.
b. < 1700 Hz and constant.
c. 1700 Hz.
d. > 1700 Hz and constant.
e. > 1700 Hz and increasing.

Coming toward you with an increasing speed.

21. Suppose the ball falls past you at 20 m/s. Just after it passes you, and is moving directly away from you, what frequency do you hear? Assume the speed of sound is 340 m/s.

a. 1900 Hz
b. 1800 Hz
c. 1700 Hz
d. 1600 Hz
e. 1500 Hz

```
v_o = 0
v_s = -20 (against the sound you observe),
so
f = 1700 (340)/(340 + 20) = 1605.5 Hz
```

22. A harmonic wave is excited on a string with the form 0.01 cos(200 t – 30 x). Here the amplitude is measured in meters, the time in seconds, and the position x in meters. What is the wavelength of the wave? ~~3, 3b, 2a, 3c~~

a. 15 cm
b. 21 cm
c. 31 cm

2\pi/\lambda = 30. Hence, \lambda = 20.94 cm.

23. When you blew on a pipe to make some sound, one end was open. Despite this, there was some reflection between the open end of the instrument and the surrounding air.

a. True
b. False

without reflection no standing wave can be maintained.

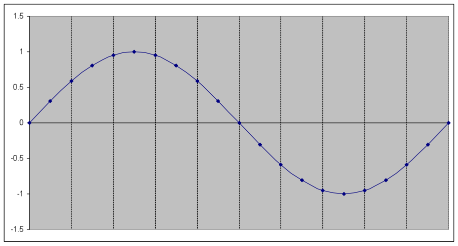
24. A spring with a mass M on its end is undergoing Simple Harmonic Motion. Which is *false*?

a. Its frequency is dependent on the mass M.
b. Its frequency is dependent on what the spring is made of.
c. The amplitude of motion is dependent on the mass.

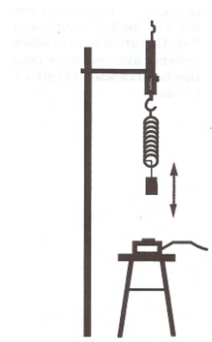
This exam continues on the next page.

25. A mass is bobbing up and down on a spring as shown.
Its displacement from the equilibrium position vs. time looks like: ~~1, 3c~~

d



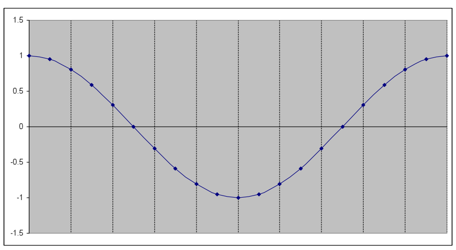
Tim



Which of the following, a, b, or c, is correct for the velocity (v), acceleration (a), and force (F)?

(a)

v



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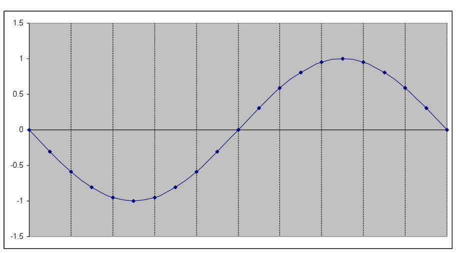
a



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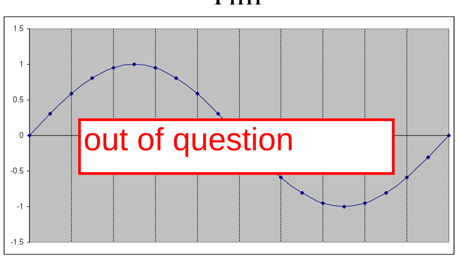
F



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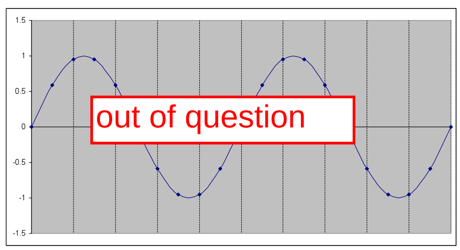
(b)

v



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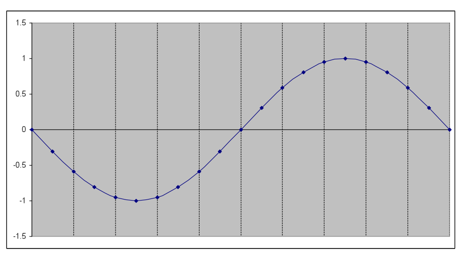
a



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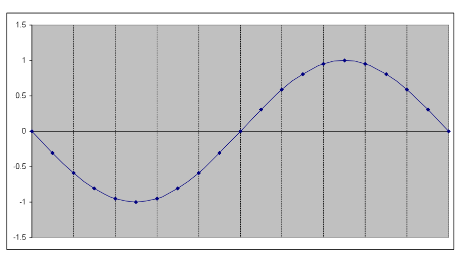
F



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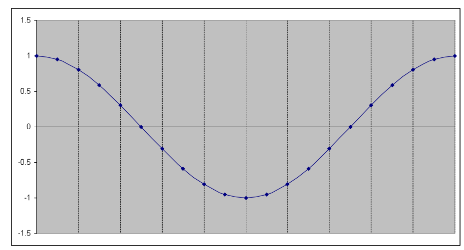
(c)

v



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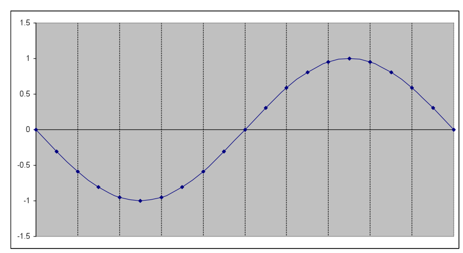
a



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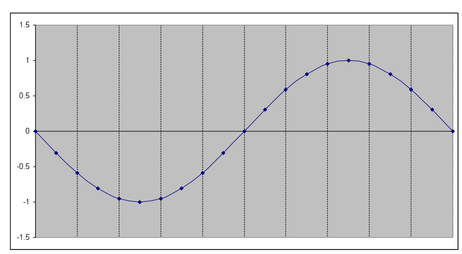
F



Tim

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