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 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 113 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.

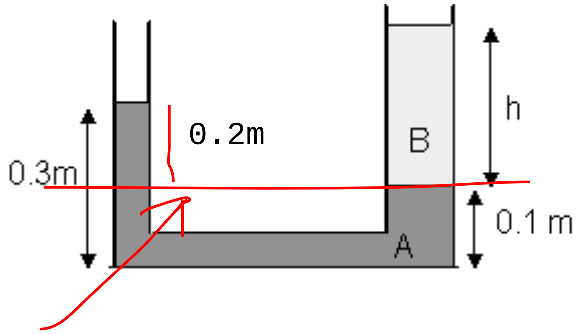
(a) If you mark only one answer and it is the correct answer, you earn **2** points.
(b) If you mark the wrong answer or neither answer, you earn **0** points.

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.*

1. Fluids A and B are poured into a U-shaped pipe, shown below. Fluid A is water (ρ=1000 kg/m^3). It rises 0.3 m above the bottom of the left pipe, and 0.1m above the bottom of the right pipe. Fluid B of density (ρ_B=500 kg/m^3) in the right pipe rises height h above the level of water. (Drawing not to scale)

1. Calculate h.

a. 0.2 m
b. 0.4 m
c. 0.6 m
d. 0.8 m
e. 1.0 m

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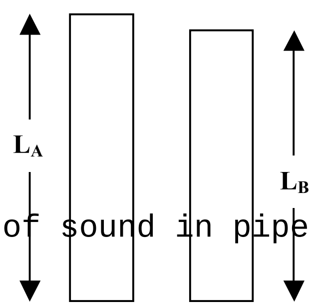
The pressure at the height 0.1 m must be the same on both sides.
Pressure on the right: P_0 + 500 gh  (P_0 = atmospheric pressure)
Pressure on the left P_0 + 0.2 x 1000 g.
These are identical, so 200 = 500 h, or h = 0.4 m.
```

2. Two organ pipes are open at both ends and are excited at their fundamental (i.e. lowest) frequency. Pipe A has length L_A = 3.5 m and pipe B has length L_B = 3.4 m. Pipe A is held at a constant temperature T=23°C. At what temperature must pipe B be held so that the two pipes generate the same frequency? You may neglect the change in length of the pipe. The speed of sound is v = 331m/s + (0.6m/s/°C) T, where T is measured in °C.

a. 3.5 °C
b. 6.6 °C
c. 15.4 °C
d. 24.8 °C
e. 34.5 °C

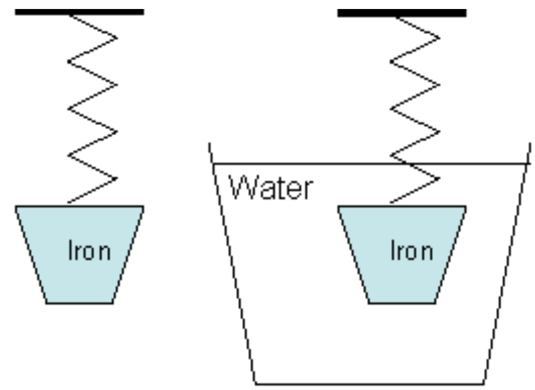



```
f = v/\lambda, and
\lambda = 2L, so v/L  must be
identical.  At T = 23 deg
v = 344.8 m/s. The velocity V of sound in pipe
B must satisfy
344.8/L_A = V/L_B, so
V = 344.8(L_B/L_A) = 335 m/s = 331 + 0.6 T.
So T = 6.58 deg C.
```

The following two questions pertain to the same situation.

When a block of iron of mass 39.30 kg is suspended from a spring with spring constant 500 N/m, the length of the spring is 4.7 m.

3. A tub of water is placed so that the iron is completely submerged in the water. What is the length of the spring now? (Drawing not to scale.) Density of iron is $\rho_{iron} = 7860$ kg/m^3. Density of water is $\rho_{water} = 1000$ kg/m^3.



a. 3.2 m
b. 3.7 m
c. 4.1 m
d. 4.6 m
e. 4.7 m

Here, 39.30/7860 is the volume of the iron block.

```
The buoyant force = 39.30(1000/7860)g = 49 N, so the spring
shrinks by 49/500 = 0.1 m.  Thus, the length is now 4.6 m.
```

4. Next, the iron block is detached from the spring and water is replaced with mercury (density $\rho_{mercury} = 13500$kg/ m^3). What fraction of the iron block will be submerged in mercury?

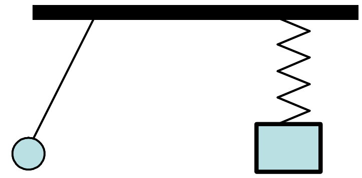
a. $V_{submerged}/V_{total} = 0.48$
b. $V_{submerged}/V_{total} = 0.58$
c. $V_{submerged}/V_{total} = 0.65$

```
7860/13500 = 0.58

Let V be the volume of the iron block and v the volume submerged.
Archimedes tells us that
     7860 Vg = 13500vg,
so v/V = 7860/13500.
```

The following four questions pertain to the same situation

A 2 kg pendulum is placed on an elevator next to a 2 kg mass hung vertically by a spring with spring constant 200 N/m. When the elevator is at rest, the spring oscillates twice as fast as the pendulum: $0.5T_{pendulum} = T_{mass\ on\ spring}$.



5. What is the length of the pendulum?

a. 8.9 cm
b. 15.1 cm
c. 23.2 cm
d. 39.2 cm
e. 42.5 cm

T_s = 0.5T_p = 2\pi\sqrt{m/k}
= 0.2 \pi.
T_p = 0.4 \pi = 2\pi \sqrt{L/g}
so L/g = 0.04, L = 0.392 m.

6. The equilibrium length of the spring with the 2kg mass attached when the elevator is at rest is 1.2m. What is the length of the relaxed spring without the mass attached to it?

a. 0.98 m
b. 1.03 m
c. 1.10 m

The displacement is mg/k = 2g/200 = 0.098, so
1.2 - 0.1 = 1.1 m.

7. The mass on the spring oscillates with the amplitude 0.3 m. What is the speed of the mass when it is 0.2 meters from its equilibrium position? (Ask a TA if you are unsure what we mean by the equilibrium position.).

a. 2.1 m/s
b. 2.2 m/s
c. 2.7 m/s
d. 3.1 m/s
e. 3.8 m/s

The total energy = (1/2) kA^2 = (1/2)200(0.3)^2
= (1/2) kx^2 + (1/2) mv^2
= (1/2)200(0.2)^2 + (1/2) 2v^2 = 9 J
Therefore, v^2 = 5, or v = \sqrt{5} m/s.

The elevator now accelerates downward with constant acceleration a= 2.5 m/s^2.

8. Compare $0.5T_{pendulum}$, half the period of the pendulum, to $T_{mass\ on\ spring}$, the frequency of the mass on the spring when the elevator is accelerating down.

a. $0.5T_{pendulum} < T_{mass\ on\ spring}$
b. $0.5T_{pendulum} = T_{mass\ on\ spring}$
c. $0.5T_{pendulum} > T_{mass\ on\ spring}$

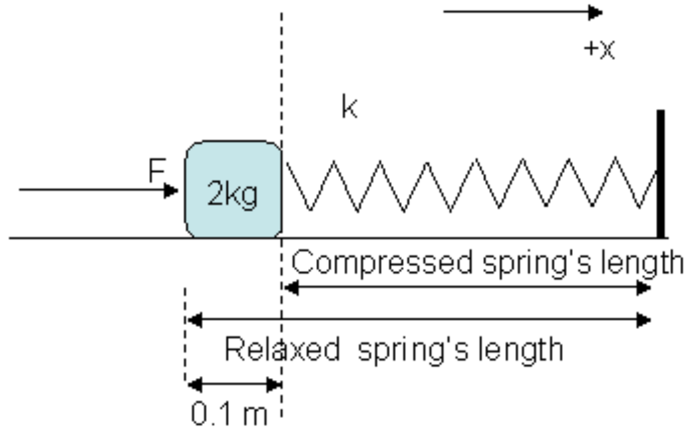
Since the effective gravity weakens,
T_p becomes longer, but T_s does not
change.

The following three questions pertain to the same situation.

A block of mass 2.0 kg resting on a horizontal frictionless surface is attached to a spring with spring constant k. A force F is applied to the block in the +x direction compressing the spring. After the spring compresses 0.1m, at time t=0, the force is removed and the block on the spring starts to oscillate with angular frequency ω=11/s.

9. What is the magnitude of the spring constant k?

a. 207 N/m
b. 220 N/m
c. 242 N/m

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omega = \sqrt{k/m}, so
k = m omega^2 = 242 N/m.
```

10. At which of these three stages is the magnitude of the acceleration the greatest?

a. when the spring is at its relaxed length.
b. when the spring is at its minimum length.
c. when the spring's length is half way between its relaxed length and its minimum length.

```
The acceleration is the largest when the displacement is
the largest. Remember the correspondence to circular motions.
```

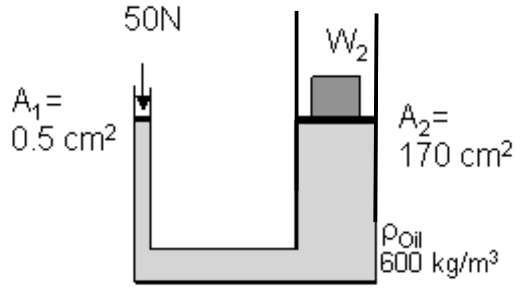
11. The displacement of the mass from the equilibrium position is described by the expression

a. $\Delta x = 11\cos(11t)$
b. $\Delta x = 0.1\sin(11t)$
c. $\Delta x = 0.1\cos(0.1t)$
d. $\Delta x = 0.1\cos(11t)$
e. $\Delta x = 11\sin(11t)$

```
A = 0.1 and omega = 11, so b or d remains.
At t= 0, the displacement is the largest.
Thus, it cannot be a sine function.
```

The following two questions pertain to the same situation:

A hydraulic lift is filled with oil (ρ = 600 kg/m^3). The cross section area of the large piston in the cylinder on the right is A_2 = 170 cm^2. The area of the small piston in the cylinder on the left is A_1 = 0.5 cm^2.



12. Force F_1= 50N needs to be applied to the small piston to lift weight W_2 on the right so the bottom of both pistons is at the same height. What is the magnitude of the weight W_2?

a. W_2 = 1700 N
b. W_2 = 17000 N
c. W_2 = 170000 N

```
Pascal says 50/A_1 = W_2/A_2.
Therefore,
W_2 = 50 (A_2/A_1) = 17000 N.
```

13. How far do we have to push down the small piston for the load on the right to go up 0.03 cm?

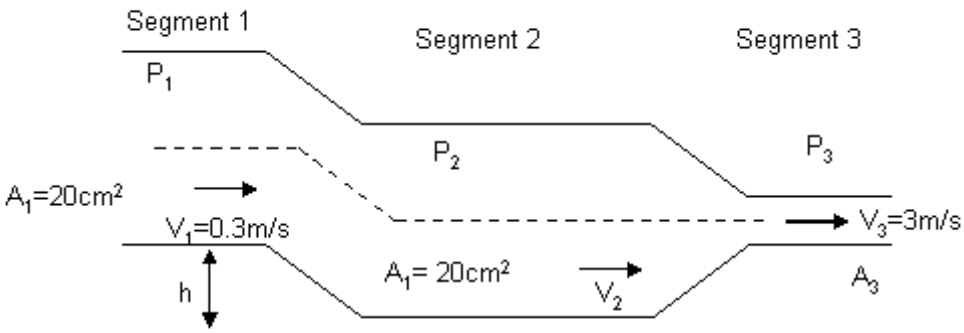
a. 5.5 cm
b. 7.5 cm
c. 10.2 cm

```
0.03 A_2 = h A_1 (volume conservation)
so h = 0.03 (A_2/A_1) = 10.2 cm
```

This exam continues on the next page.

The following <u>five</u> questions pertain to the same situation:

Water flows through the pipe as shown below. Segment 1 has a cross sectional area $A_1 = 20cm^2$. Segment 2 has the same cross section but its center (indicated by the dashed line) is h = 0.11 m lower. Finally, the water flows into a narrower Segment 3 with a cross sectional area A_3. The center of pipe in Segments 2 and 3 is at the same height, as indicated by the dashed line. The velocity of water in Segment 1 is $v_1 = 0.3$ m/s, and in Segment 3 it is v_3= 3m/s. The density of water is 1000 kg/m^3.
Note: Drawing not to scale.



14. What is the cross section of the narrow pipe, A_3?

a. $A_3 = 2.00$ cm^2
b. $A_3 = 2.75$ cm^2
c. $A_3 = 3.00$ cm^2

```
A_1v_1 = A_3v_3,
so A_3 = A_1(v_1/v_3) = 20 x 0.1 = 2 cm^2.
```

Define P_1 = the water pressure Segment 1, P_2 = the water pressure in Segment 2, and P_3 = the water pressure in Segment 3.

15. Which statement is correct about pressure P_1 and P_2?

a. $P_1 < P_2$
b. $P_1 = P_2$
c. $P_1 > P_2$

```
v_1 = v_2 due to continuity (and incompressibility).
Bernoulli says P_1 + (1/2) rho v_1^2 + rho g h_1
= P_2 + (1/2) rho v_2^2 + rho g h_2,
so
P_1 - P_2 = \rho g (h_2 - h_1) < 0.
```

16. What is the absolute value of the water pressure difference, $|\Delta P_{12}| = |P_1 - P_2|$?

a. $|\Delta P_{12}| = 0$
b. $|\Delta P_{12}| = 245$ Pa
c. $|\Delta P_{12}| = 490$ Pa
d. $|\Delta P_{12}| = 980$ Pa
e. $|\Delta P_{12}| = 1078$Pa

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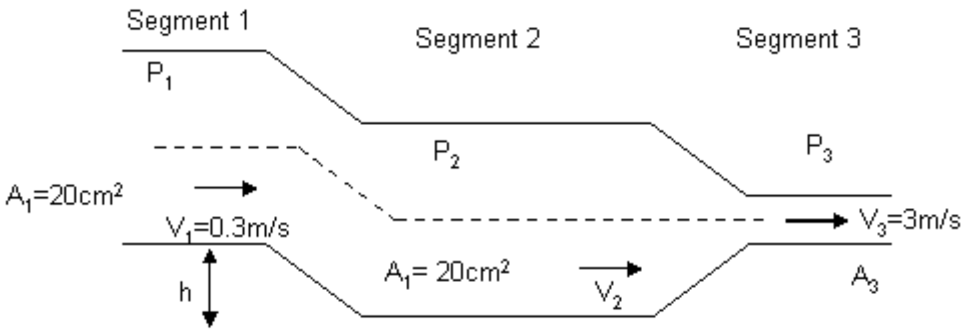
h_1 -h_2 = 0.11 m given. Therefore,

Delta P = 1000 x 9.8 x 0.11 = 1078 Pa.
```

These two questions continue on from the previous page



17. Which statement is correct about pressure P_2 and P_3?

a. $P_2 < P_3$
b. $P_2 = P_3$
c. $P_2 > P_3$

```
3 is faster, so P_3 < P_2 must hold.

Or, more in detail, Bernoulli says
P_2 + (1/2) rho v_2^2 = P_3 + (1/2) rho v_3^2,
but we know v_2 = v_1 due to continuity, so
v_2 < v_3.  This implies P_2 > P_3.
```

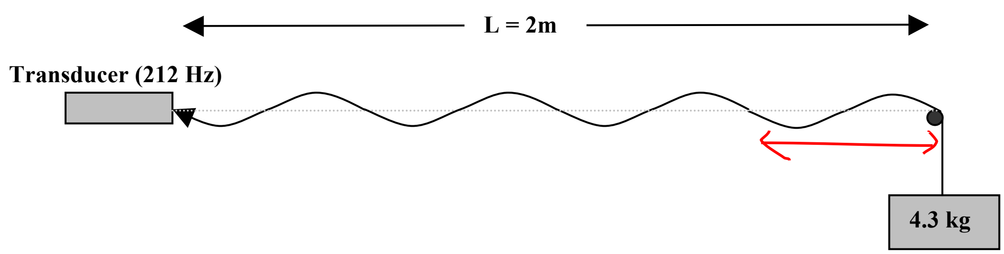
18. What is the absolute value of the water pressure difference, $|\Delta P_{23}| = |P_2 - P_3|$ between Segments 2 and Segment 3 of the pipe?

a. $|\Delta P_{23}| = 0$
b. $|\Delta P_{23}| = 1230$ Pa
c. $|\Delta P_{23}| = 2450$ Pa
d. $|\Delta P_{23}| = 4455$ Pa
e. $|\Delta P_{23}| = 6980$Pa

```
From the above formula
Delta P = (1/2) rho (v_3^2 - v_1^2)
        = (1/2) x 1000 x (9 - 0.09) = 4455 Pa
```

The next two questions pertain to the same situation.

One end of a string with length L = 2 m and mass density μ is attached to a weight with mass 4.3 kg. The other end of the string is fixed to a transducer that vibrates at a frequency of 212 Hz. A standing wave results, with the wavelength as shown in the snapshot below



19. What is the mass density, μ, of the string?

a. 2.27 g/m
b. 3.75 g/m
c. 5.56 g/m
d. 8.27 g/m
e. 12.1 g/m

```
v = \sqrt{F/\mu}, so we need v, the wave speed.
v = f x lambda.  lambda = L/4 from the figure, so
v = 212 x 2/4.
\mu = F/v^2 = 4.3 g/(212/2)^2 = 3.75 x 10^{-3} kg/m.
```

20. If the mass of the weight were quadrupled (i.e. increased to 17.2 kg), what would happen to the number of wavelengths in the standing wave?

a. It would quadruple.
b. It would double.
c. It would not change.
d. It would decrease by a factor of two.
e. It would decrease by a factor of four.

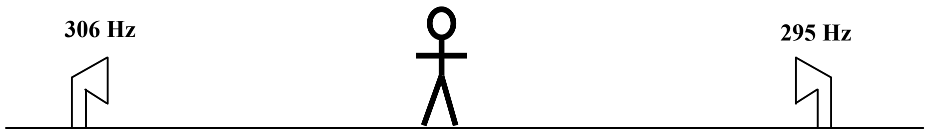
```
This means F is quadrupled,
so v is doubled. Then,
lambda = v/f is doubled, so the
number of nodes is roughly halved.

(As you see, n = 9 originally, so d
is strictly speaking, impossible.)
```

Strictly speaking, none of a-e is correct.

The next two questions pertain to the same situation.

You are standing between two speakers. The speaker on the left is emitting a tone with frequency 306 Hz. The speaker on the right is emitting a tone with frequency 295 Hz. Irritated by the beats, you try to eliminate them by Doppler shifting the frequencies so you hear them as the same. The speed of sound is 343 m/s.



21. In which direction would you have to run to eliminate the beats?

a. left, towards the speaker with 306 Hz
b. right, towards the speaker with 295 Hz

Doppler!

22. How fast would you have to run?

a. 6.3 m/s
b. 10.2 m/s
c. 14.8 m/s
d. 19.4 m/s
e. 26.6 m/s

Let the speed to the right be V.
For the sound coming from right: f_s = 295, v_o = -V.
For the sound coming from left: f_s =306, v_o = V.

f_o for both cases must agree. Therefore, we obtain
295x(343+V)/343 = 306x(343-V)/343.

That is,
(306 - 295) x 343 = (295 + 306)V.
V = 343 x 11/601 = 6.28 m/s.

This exam continues on the next page.

23. A pipe organ with length 3.2 m is open at both ends. What is its fundamental frequency (corresponding to the longest possible wavelength)? The speed of sound is 343 m/s.

a. 53.59 Hz
b. 107.2 Hz
c. 214.4 Hz

```
lambda = 2L = 6.4.
v = lambda f, so f = v/lambda = 343/6.4 = 53.594 Hz.
```

24. An aluminum plate at T = 20°C has a hole in the middle whose diameter is *exactly* 3 cm. What is the diameter of the hole if the plate is heated to 90°C? $\alpha_{Al} = 2.25\times10^{-7}\ K^{-1}$.

a. 2.99990550 cm
b. 2.99995275 cm
c. 3 cm
d. 3.00004725 cm
e. 3.00009450 cm

```
L (1 + \a Delta T) is the new
length.
3(1+2.25x10^{-7}x70)
= 3.00004725 cm.
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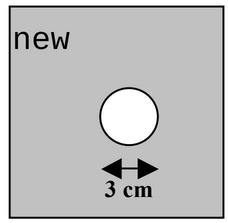

25. A bar of copper (Cu) with length 2.635 m and a bar of aluminum (Al) with length 2.628 m are sitting at room temperature, T=25°C. At what temperature will the two have the same length? $\alpha_{Cu} = 1.60\times10^{-7}\ K^{-1}$ $\alpha_{Al} = 2.25\times10^{-7}\ K^{-1}$.

a. 6266 °C
b. 21715 °C
c. 21740 °C
d. 41249 °C
e. 41274 °C

Bad Problem, physically meaningless. The correct answer is: ``there is no such temperature."

```
Cu at T  2.635[1 + 1.6 x 10^{-7}(T-25)]
Al at T  2.628[1 + 2.25 x 10^{-7}(T-25)].

They agree:
2.635 - 2.628
= (2.628 x 2.25 x 10^{-7} - 2.635 x 1.6 x 10^{-7})(T - 25)
= (2.628 x 2.25 - 2.635 x 1.6) x 10^{-7}) (T - 25).
or
0.007 = 1.697 x 10^{-7} (T - 25)
Thus T- 25 = 41249, so T = 41274 deg C.  This is much
hotter than the surface of the sun! No solid remains intact!
```

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