Instructions—

**Turn off your cell phone and put it away.**
**You may not share your calculator. Please keep it 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 106 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/s² downward and ignore any effects due to air resistance.
1. A diver swims to a depth of 3.2 m in a freshwater lake. What is the increase in the force pushing on her eardrum, compared to what it was at the lake surface? The area of her eardrum is 0.60 cm$^2$. The density of water is $\rho_w = 1000 \text{ kg/m}^3$.

   (You must assume that she never swallows saliva while diving!)

   P(d) = P(0) + $\rho$ g d = P(0) + 1000 x 3.2 x 9.8

   So the pressure increase is 3136 Pa.

   F = P A = 31360 x 0.6 x 10^{-4} = 1.88 N,
   if her internal pressure is still P(0), the atmospheric pressure at the lake surface.

   a. 0.0 N
   b. 1.9 N
   c. 3.4 N
   d. 7.3 N
   e. 11.7 N

The following 2 questions concern related physical situations:

A 0.20 kg mass is attached to a massless spring and allowed to oscillate around an equilibrium according to: $y(t) = 2.7 \sin(1.1 t)$, where $y$ is measured in meters and $t$ in seconds.

2. What is the position of the mass at $t = 3.0$ seconds?

   a. $-0.43$ m
   b. 0.19 m
   c. $-1.33$ m

   y(3) = 2.7 x sin(3.3) = - 0.4259 m
   Note: 3.3 is in radians, so it is 180 x (3.3/\pi) = 189.1 deg.

3. What is the maximum speed of the mass?

   a. 2.7 m/s
   b. 3.0 m/s
   c. 3.4 m/s
   d. 5.5 m/s
   e. 9.3 m/s

   Max speed is $A \times \omega = 2.7 \times 1.1 = 2.97 \text{ m/s}$

Recall the harmonic-circular motion correspondence

1 cm$^2 = 10^{-4}$ m$^2$
The following 2 questions concern related physical situations:

Two incompressible fluids are placed in a U-tube as shown in the figure to the right. Both ends of the tube are open. The tube has a cross sectional area $A_1 = 0.02 \text{ m}^2$. One fluid is water (light gray), with density of $\rho_w = 1000 \text{ kg/m}^3$. The second fluid is oil (black), with $\rho_o = 950 \text{ kg/m}^3$. The column of water is observed to be a distance $h = 0.23 \text{ m}$ above the point where the water meets the oil.

4. How high, $d$, does the oil rise above the water?
   a. 5.00 m  
   b. 0.21 m  
   c. 0.005 m  
   d. 0.034 m  
   e. 0.012 m

   Pressure at the 'red line' is:
   \[
   \text{Left: } P = P(0) + 950 \, (d+h)g, \\
   \text{Right: } P = P(0) + 1000 \, hg, \\
   \text{so} \\
   950(d+h) = 1000h \quad \text{or} \quad 950d = 50h. \\
   \text{Thus, } d = \frac{50 \times 0.23}{950} = 0.0121 \text{ m}.
   \]

5. If instead the two ends of the tube were tightly sealed, what could be done to make it so the top of the two columns were at the same height so that $d=0$?
   a. Pump air out of the left side of the tube so that it is at lower pressure.
   b. Pump air out of the right side of the tube so that it is at lower pressure.
   c. It is not possible to make $d=0$.

   To make $d = 0$, $P(0)$ on the left side must be larger than that on the right side.

6. A pendulum consists of an object of mass $m = 2.2 \text{ kg}$ at the end of a string of length $L = 2 \text{ m}$. The pendulum is in an elevator that is accelerating downward at $3 \text{ m/s}^2$. What is the period of the pendulum in the accelerating elevator?
   a. 0.6 s  
   b. 1.7 s  
   c. 2.2 s  
   d. 3.4 s  
   e. 4.4 s

   The effective acceleration of gravity is
   \[
   g' = 9.8 - 3 = 6.8. 
   \]
   Therefore,
   \[
   T = 2\pi \sqrt{\frac{L}{g'}} = 2\pi \sqrt{\frac{2}{6.8}} = 3.407 \text{ s}.
   \]
The following 2 questions concern related physical situations:

An incompressible fluid is moving through a tube. It is originally in the wide part of the tube with cross sectional area $A_1 = 0.44 \text{ m}^2$ moving at speed $v_1 = 6.7 \text{ m/s}$. The fluid then moves into a narrower section of tube with cross sectional area $A_2 = 0.17 \text{ m}^2$.

![Diagram of fluid flow through tubes]

7. Given the pressure in the fluid, $P_1$, in the wide part of the tube, which of the following is a valid expression for the pressure $P_2$ in the narrow part of the tube?

a. $P_2 = P_1 + \frac{1}{2} \rho (v_1^2 - v_2^2)$  
   This is simply Bernoulli.

b. $P_2 = P_1 + \rho g v_2$

c. $P_2 = P_1 \frac{A_2}{A_1}$

8. What is the speed of the fluid in the narrow section of tube, $v_2$?

a. $3.0 \text{ m/s}$  
   Thanks to continuity $A_1 \ v_1 = A_2 \ v_2$.

b. $6.7 \text{ m/s}$

c. $9.9 \text{ m/s}$

d. $12.7 \text{ m/s}$

e. $17.3 \text{ m/s}$  
   $v_2 = v_1 \ (A_1/A_2) = 6.7(0.44/0.17) = 17.34 \text{ m/s}$
The next 2 questions concern the following situation:

A cube of unknown material is \( L = 0.1 \) m on each side. The cube is placed in a container of fluid that is originally filled to the brim. It is observed that one-half of the cube is submerged in the fluid and an amount of fluid weighing 2.4 N has spilled from the container.

9. What is the density of the cube, \( \rho_c \)?

a. 245 kg/m\(^3\)  
b. 332 kg/m\(^3\)  
c. 750 kg/m\(^3\)  
d. 500 kg/m\(^3\)  
e. 1000 kg/m\(^3\)

The weight of the displaced liquid is 2.4 N. Archimedes tells us this is the buoyant force, so the mass \( M \) of the cube is \( M = 2.4/g \). The volume \( V \) = \( 0.1^3 \). Therefore,  
\[ \rho_{c} = \frac{M}{V} = \frac{2.4}{(g \times 0.1^3)} = 244.9 \text{ kg/m}^3. \]

10. How does the density of the fluid, \( \rho_f \), compare to the density of the cube?

a. \( \rho_f > \rho_c \)  
b. \( \rho_f = \rho_c \)  
c. \( \rho_f < \rho_c \)

Of course!
The next two questions refer to the following situation:
A 3kg mass is attached to a massless spring with constant $k = 24 \text{ N/m}$. It is stretched 0.15 m away from its equilibrium position. At time $t = 0$ the mass is released.

11. What is the total energy of the block?

a. 0.03 J  
   $U = \frac{1}{2} k A^2 = \frac{1}{2} 24 \times 0.15^2 = 0.27 \text{ J}$.  
   Initially, all the mechanical energy is in the potential form. $A = 0.15 \text{ m}$

b. 0.17 J

c. 0.27 J

12. What is the period of oscillation?

a. 1.97 s  
   $T = \frac{2\pi \sqrt{m/k}}{2\pi \sqrt{3/24}} = 2.221 \text{ s}$

b. 2.22 s

c. 6.53 s

13. An aluminum plate has a circular hole cut in it. An aluminum ball (solid sphere) has exactly the same diameter as the hole when both are at room temperature, and hence can just barely be pushed through it. If both the plate and the ball are now heated up to a few hundred degrees Celsius, how will the ball and the hole fit?

a. The ball won’t fit through the hole any more.

b. The ball will fit more easily through the hole.

c. Same as at room temperature.

14. What is the root mean square speed of an oxygen molecule in this room?

a. 5.1 m/s

b. 510 m/s

c. 510,000 m/s

The easiest way is to use $v^2 = \frac{3RT}{M}$,

where $R = 8.31 \text{ KPa}$, $T = 300$, and $M = 0.032 \text{ (in kg!)}$.

Therefore, $v^2 = 233719$, so $v = 483 \text{ m/s}$. For nitrogen, the answer seems closer (517 m/s).

15. A balloon is filled at atmospheric pressure $(1.01 \times 10^5 \text{ Pa})$, and at 20 degrees Celsius with an ideal gas to a volume of $0.01 \text{ m}^3$. How many molecules of gas are in the balloon?

a. $0.28 \times 10^{23}$  
   $PV = Nk_BT$, so

b. $1.2 \times 10^{23}$  
   $N = \frac{PV}{k_BT} = 1.01 \times 10^5 \times 0.01/1.38 \times 10^{-23} \times 293$
   \[ = 1.01 \times 10^{26}/404.3 = 2.5 \times 10^{23} \]

c. $2.5 \times 10^{23}$

(25 problems)
The next two questions refer to the following situation:

A string is stretched between two supports that are 2.2 m apart. A standing wave is observed with two nodes as shown in the figure.

![Standing wave diagram]

16. The frequency of the oscillation is observed to be $f = 500$ Hz. What is the speed of the wave?
   a. 733 m/s
   b. 502 m/s
   c. 1110 m/s
   d. 214 m/s
   e. 662 m/s

   $\lambda = 2.2 \times (2/3) = 1.46$ m
   Therefore, $v = 500$ \( \lambda \) = 733 m/s

17. This standing wave is oscillating in the fundamental mode.
   a. True
   b. False

18. A bimetallic strip (see diagram) is made with aluminum $\alpha=16 \times 10^{-6}$/K on the left, and iron $\alpha = 12 \times 10^{-6}$/K on the right. At room temperature, the lengths of metal are equal. If you heat the strips up, what will it look like?

   ![Bimetallic strip diagram]

   The left strip responds more to temperature changes.
   a. 
   b. 
   c.
19. After a grueling work out, you drink a liter (1 kg) of cold water (1° C). How many Calories does it take for your body to raise the water up to body temperature of 37° C?

a. 3.6 Cal
b. 36 Cal

c. 360 Cal

20. How much ice (at 0° C) do you need to add to 0.5 liters of water at 25° C to cool it down to 10° C? The latent heat $L$ for ice melting is 80 cal/gram and the specific heat $c$ for water is 1 cal/gram C).

a. 51 gram
b. 83 gram
c. 101 gram
d. 122 gram
e. 150 gram

21. In the picture (drawing not to scale), the brass and aluminum bars are attached to immovable walls. The linear thermal expansion coefficients for brass and aluminum are $\alpha_{\text{Brass}} = 19 \times 10^{-6} \text{ C}^{-1}$ and $\alpha_{\text{Aluminum}} = 23 \times 10^{-6} \text{ C}^{-1}$. At 26.7 degrees Celsius the air gap between the rods is 1.3 x 10^{-3} m. At what temperature, $T$ (in degrees Celsius), will the gap be closed?

a. 18 C
b. 22 C
c. 32 C
d. 41 C
e. 48 C

This is exactly D13-3
The following two questions pertain to the same situation.

22. At an air show, an airplane is flying by you at 200 m/s. If you hear the frequency of the sound from the airplane is 310 Hz when it is flying away from you, what frequency will you hear as the airplane flies toward you? (Assume that the speed of sound is \( v = 340 \) m/s).
   a. 129 Hz
   b. 240 Hz
   c. 570 Hz
   d. 800 Hz
   e. 1196 Hz

   Let \( f_s \) be the source frequency.
   \[
   310 = f_s \times \frac{340}{340+200}.
   \]
   Therefore, \( f/310 = 540/140, \) so \( f = 1195.7 \) Hz.

   \( v_s < 0, \) because the airplane is flying in the opposite direction of the sound wave being observed.

23. The sound of the engine of the airplane is 95 dB when it is 500 meters away from you. How loud is the engine to you when it is 5,000 meters away from you?
   a. 75 dB
   b. 85 dB
   c. 95 dB
   d. 105 dB
   e. 115 dB

   Let \( I_1 \) be the intensity of the sound at 500 m and \( I_2 \) that at 5000 m. By definition
   \[
   10 \log_{10}(I_1/I_0) = 95 \text{ dB}
   \]
   \( I = P/(4\pi r^2) \) implies \( I_1 \times 500^2 = I_2 \times 5000^2 \), that is, \( I_2 = I_1/100 \). Therefore, the loudness \( b \) at 5000 m is
   \[
   b = 10 \log_{10}(I_2/I_0)
   = 10 \log_{10}[(I_2/I_1)(I_1/I_0)]
   = 10 \log_{10}(I_2/I_0) + 10 \log_{10}(I_1/I_0) + 10 \log_{10}(1/100)
   = 95 - 10 \log_{10}(100) = 75 \text{ dB}
   \]
24. In Lab 7 (Investigation of Periodic Motion), you added the potential energy (P.E.) and kinetic energy (K.E.) of a mass undergoing periodic motion attached to a spring. You found that the sum was constant. The relative phase of the individual graphs of PE and KE vs. time is:

a. 0° (in phase)
b. 90°
c. 180° (out of phase)

When K is max, U is min, and vice versa, so they are out of phase.

25. In the Standing Waves experiment, you found the relationship between frequency (f) and length (l) of various pipes. True or False: We found the frequency is directly proportional to the length.

a. True  
   \[ v = \text{constant} \]
   \[ f = \frac{\lambda}{L}, \text{ and } \lambda \text{ is proportional to } L \]

b. False  
   \[ f \text{ is proportional to } \frac{1}{L}, \text{ roughly speaking.} \]