Last Name:________________First Name__________________ID__________________
Discussion Section:________Discussion TA Name:_______________________________

Instructions—
Please turn off your cell phone and put it out of sight.
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 expulsion.**

Exam Grading Policy—
The exam is worth a total of 116 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.

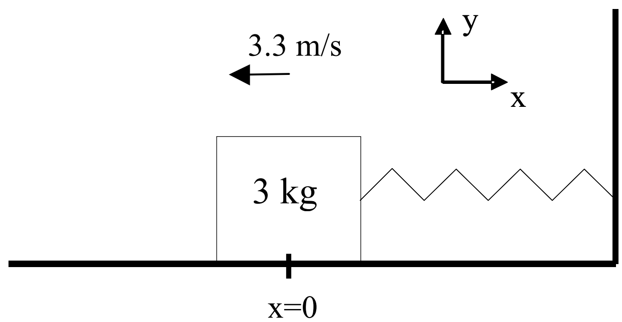
TF: *true-false questions, each worth 2 points.*
No partial credit.

(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.*

The following five questions pertain to the same situation

A 3 kg mass attached to a spring sits at rest at its equilibrium position, as shown. At time t = 0 the mass is set in motion *to the left* with an initial velocity of 3.3 m/s. The angular frequency of this harmonic oscillator is ω = 4.2 rad/s.



1. How long does it take for the mass to complete one full cycle of its motion?

a. 0.5 s
b. 1 s
c. 1.5 s

T = 2\pi x omega = 2\pi/4.2 = 1.49 s.

2. Which equation best describes the *velocity* of the mass as a function of time, v(t)?

a. v(t) = - 3.3 cos(4.2 t)
b. v(t) = 4.2 cos(3.3 t)
c. v(t) = 4.2 sin(3.3 t)
d. v(t) = - 3.3 sin(4.2 t)
e. v(t) = - 4.2 cos(3.3 t)

Since omega = 4.2, only a or d is correct. 3.3 m/s is the max speed, which is realized at t = 0 (i.e., initially), so the function must be cosine.

3. What is the force constant *k* of the spring?

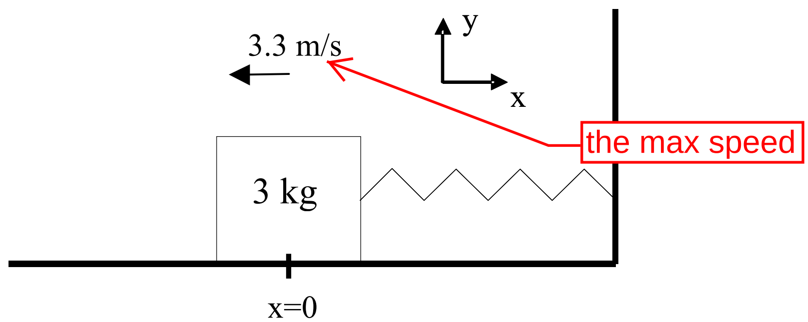
a. 28 N/m
b. 53 N/m
c. 84 N/m

omega^2 = k/m, and m = 3, so k = m omega^2 = 52.9 N/m.

from the formula sheet

The next two questions pertain to the previous page.

A 3 kg mass attached to a spring sits at rest at its equilibrium position, as shown. At time t = 0 the mass is set in motion *to the left* with an initial velocity of 3.3 m/s. The angular frequency of this harmonic oscillator is ω = 4.2 rad/s.



4. What is the maximum distance, x_{max}, that the mass gets displaced from its equilibrium position during one cycle of its motion?

a. 0.218 m
b. 0.366 m
c. 0.524 m
d. 0.786 m
e. 0.956 m

```
We know v max  in terms of the amplitude A is
v max = omega A.  Hence,
 A = 3.3/4.2 = 0.7857 m
```

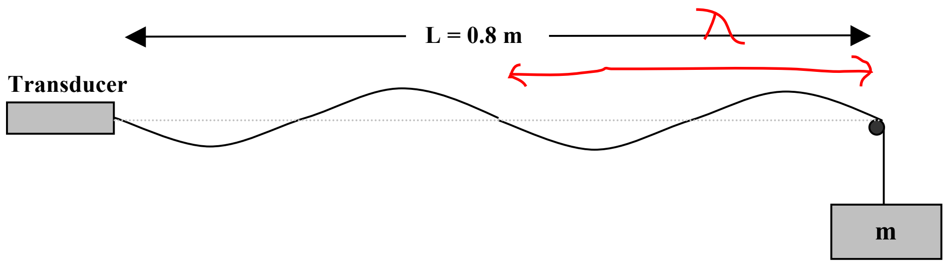
5. What is the total energy of the system?

a. 16.3 J
b. 25.8 J
c. 42.6 J
d. 55.9 J
e. 72.1 J

```
This must be equal to the initial energy
(1/2) mv^2 = (1/2) 3 x 3.3^2 = 16.335 J
```

The next three questions pertain to the same situation.

A string is stretched between a transducer and a support. It is held in tension by a mass hanging off one end. The length of the string L = 0.8 m and its mass density μ = 0.2 kg/m. The transducer excites a standing wave on the string as shown in the figure.



6. Is this wave transverse or longitudinal?

a. transverse
b. longitudinal

```
The displacement of points on the string is
perpendicular to (transversal to) the wave
propagation direction
```

7. The speed of sound on the string is determined to be v=42 m/s. What is the mass of the weight, m?

a. 9 kg
b. 18 kg
c. 24 kg
d. 36 kg
e. 44 kg

```
This is very similar to one of our quiz questions.

v = \sqrt{mg/\mu}, so

mg/\mu = v^2, that is, m = v^2\mu/g
= 42^2 x 0.2/9.8 = 36 kg.
```

8. What is the frequency of the of oscillation of the string, f?

a. 55 Hz
b. 63 Hz
c. 78 Hz
d. 92 Hz
e. 105 Hz

```
The wavelength lambda = L/2 = 0.4 m from the figure.
We know the wave speed is v = f x lambda, so
     f = v/lambda = 42/0.4 = 105 Hz.
```

9. A grandfather clock keeps time by counting the cycles of a pendulum, whose period is 2 sec. How long must the pendulum be?

a. 0.26 m
b. 0.44 m
c. 0.63 m
d. 0.87 m
e. 1 m

```
T = 2\pi \sqrt{L/g}, so

L = g T^2/4\pi^2 = 9.8 x 2^2/4\pi^2
   = 0.9929 m
```

The next two questions pertain to the same situation.

You are trying to study but your roommate is blasting his stereo so loud you cannot think. You are standing a distance 3 m away and measure the intensity of the sound to be $I = 3.98\ W/m^2$.

10. What is the loudness of the sound?

a. 105 dB
b. 112 dB
c. 119 dB
d. 126 dB
e. 131 dB

```
By the definition of loudness

\b = 10 log(I/I_0)
   = 10 log(3.98/10^{-12})
   = 125.9988... = 126 dB
```

log here is log_{10}

The formula sheet gives this number.

You can start with I = P/4\pi r^2 on the formula sheet, but the key is that I is proportional to 1/D^2, where D is the distance to the source.

11. You cannot study if the intensity is greater than $0.8\ W/m^2$. What is the minimum distance to which you must move from the stereo? (Assume there are no obstacles you can hide behind and you have no ear plugs.)

a. 3.86 m
b. 4.02 m
c. 6.69 m
d. 12.8 m
e. 25.4 m

```
At 3 m I_3 = 3.95 W/m^2.  Let us write I_D = I_1/D^2.
Then,
     3.95 = I_1/9,
     0.8 = I_1/D^2.
Therefore, D^2 = I_1/0.8 = 3.95 x 9/0.8 = 44.44,
so D = 6.67 m (the given solution is slightly wrong.)
```

The next two questions pertain to the same situation.

You are standing at a street corner listening to a fire engine, which is approaching you at a speed of 60 mph (26.8 m/s). The fire engine sounds its siren with a frequency f = 460 Hz. The speed of sound in air is 343 m/s.

12. At what frequency do you hear the siren?

a. 436 Hz
b. 460 Hz
c. 499 Hz
d. 514 Hz
e. 554 Hz

For the given formula of the Doppler effect,
v_o = 0, v_s = +26.8 m/s.

f_o = 460 x 343/(343-26.8) = 498.9 Hz.

13. The ambulance passes you and is now traveling away from you at the same speed. What is frequency you hear now?

a. 405 Hz
b. 427 Hz
c. 448 Hz
d. 460 Hz
e. 477 Hz

For the given formula of the Doppler effect,
v_o = 0, v_s = -26.8 m/s.

f_o = 460 x 343/(343+26.8) = 426.7 Hz.

14. A patient is being given an intraveneous drip. The vertical distance from the top of the fluid to the patient's arm is 1.5m. The fluid in the bag has density of 1000 kg/m^3 and is at atmospheric pressure (10^5 Pa). What is the pressure of the fluid at the patient's arm?

a. 100000 N/m^2
b. 106940 N/m^2
c. 114700 N/m^2

The pressure at the depth d

P(d) = P at the top + rho g d, where d is the `depth', 1.5 m for our problem. P at the top = 10^5 Pa, so
P(1.5) = 10^5 + 1000 x 1.5 x 9.8
= 114700 Pa.

15. A laboratory building is being constructed under water. The building has mass 50,000 kg and volume 300 m^3. What is the force acting on the building? The upward direction is assumed positive. The density of water is 1000 kg/m^3. (Hint: include only the buoyant force and the gravity force into your calculation.)

a. -2.45×10^6 N
b. -4.9×10^5 N
c. 4.9×10^5 N
d. 2.45×10^6 N
e. 2.94×10^6 N

```
Gravitational force = -50,000g
Buoyant force = 300 x 1000 g = +300,000g,
so
F = 250 x 1000 x 9.8 = +2450000 N
```

16. A rubber duck floats in water (the water density is 1000 kg/m^3). One fifth of the volume of the rubber duck is below the surface of the water. What is the density of the rubber duck?

a. 200 kg/m^3
b. 300 kg/m^3
c. 400 kg/m^3

```
Intuitively, the answer should be 1/5 of the
water density.

The balance between the gravity and buoyancy is
\rho Vg =  1000(V/5)g,
so \rho = 1000/5 = 200 kg/m^3.
```

17. A faucet runs water. The cross-section of the opening in the faucet has area 1 cm^2. 10cm below the faucet the cross-section of the stream of water has thinned to 0.4 cm^2. What is the speed at which the water exits the faucet?

This is not very easy.

a. 29 cm/s
b. 42 cm/s
c. 61 cm/s
d. 83 cm/s
e. 101 cm/s

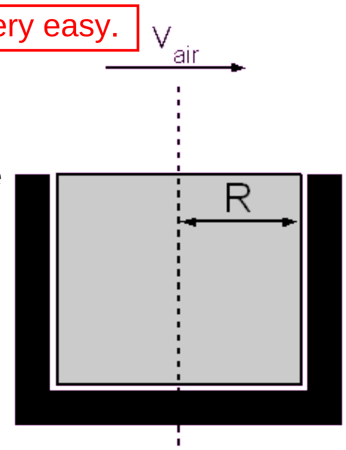
```
A_h v_h = A_l v_l (h means `high', l: low)
We wish to know v_h.  We get
     v_l = (A_h/A_l)v_h = 2.5 v_h
(1/2) rho v_h^2 + rho g h = (1/2) r
or
     v_l^2 - v_h^2 = 2gh

Therefore, (2.5^2 - 1)v_h^2 = 2gh, or
v_h^2 = 2 x 9.8 x 0.1/5.25 = 0.3733.
or v_h = 0.611 m/s
```

This h is the height difference, 10 cm in our case.

The next two questions concern the same situation.

A cylindrically shaped peg sits in a cup, as shown in the figure. You are asked to remove the peg without touching it. Remembering physics 101, you blow air across the top of the peg. The radius R of the peg is 0.02 m, and its mass is 0.01 kg. The density of air is $1.29 kg/m^3$.

This is not very easy.



18. What is the minimum speed v_{air} required to lift the peg?

a. 7 m/s
b. 9 m/s
c. 11 m/s

```
The needed force to lift the peg is
0.01x9.8 = 0.098 N.  If the pressure
difference is dP, A x dP = 0.098 is
the condition we wish to realize,
where A is the area of the top
surface of the peg:
   A= \pi R^2 = 1.257x10^{-3} m^2.
Thus, dP = 77.98 Pa.

Bernoulli says dP = (1/2)rho v^2, where rho = 1.29,
so v^2 = 2 dP/rho = 120.9.  That is, v = 10.99 m/s.
```

19. If R were increased, while the density of the peg remained unchanged, what would happen to the required value of v_{air}?

a. It would be smaller
b. It would be the same
c. It would be bigger

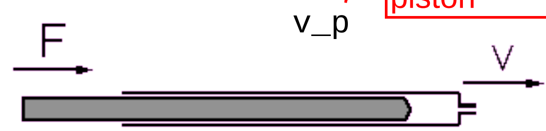
```
If R is increased, then the mass of the peg is
also increased; both the lifting force and the
mass are proportional to R^2, so the same v is
needed.
```

The next two questions concern the same situation.

20. You are pushing water out of a syringe (the density of water is ρ=1000 kg/m^3). The radius of the piston is 0.005 m, the radius of the needle is 0.001 m. The water exits the opening at 10 m/s. What force F are you applying to the piston of the syringe?

the speed of the piston

a. F = 1.1 N
b. F = 1.4 N
c. F = 2.6 N
d. F = 3.3 N
e. F = 3.9 N



continuity

Av = const. 0.005^2 v_p = 0.001^2 V, so v_L = V/25.

(1/2)rho v_p^2 + P = (1/2)rho V^2.
v_p^2 is very tiny, so we may ignore its square. Thus, the pressure difference P is P = (1/2) 1000 10^2 = 50,000 Pa.

Therefore, F = P A = 50,000 x \pi 0.005^2 = 3.926 N.

cross section of the piston

21. Suppose the syringe were filled with alcohol instead of water. Alcohol has lower density than water. If the force on the piston were still the same, would the alcohol come out faster or slower than the water does?

a. faster
b. slower
c. unchanged

P is the same, so
P = (1/2) rho v^2. Therefore,
a smaller density rho implies larger v.

The next two questions concern the same situation.

22. A ball of mass 12 kg is dropped onto a vertical, massless spring with spring constant k = 2000 N/m. The ball sticks to the spring and compresses the spring by as much as 0.2 m. What was the speed of the ball at the moment when it hit the top of the spring? Assume no energy was lost in the collision. (Hint: the gravitational potential energy of the ball changes as the spring is compressed).

a. 0.757 m/s
b. 0.957 m/s
c. 1.257 m/s
d. 1.657 m/s
e. 1.957 m/s

```
The kinetic energy just before touching: (1/2) 12 V^2.
The potential energy at the lowest point (relative to
the touching point) is
     U = -mgh + (1/2) k h^2
       = - 12 x 0.2 g + (1/2)2000 x 0.2^2 = 16.48 J
Therefore, V^2 = 16.48/6 = 2.747, or V = 1.657 m/s.
```

23. After the first compression, the mass oscillates up and down. What is the frequency of this oscillation?

a. 1.75 Hz
b. 2.05 Hz
c. 2.40 Hz
d. 2.85 Hz
e. 3.15 Hz

```
omega = \sqrt{k/m} = 12.91 , so
f = 12.91/2\pi = 2.054 Hz.
```

24. A spring has spring constant *k*. If it is cut in half, how does the spring constant of each piece compares to that of the original spring? (Hint: think about Hooke's law).

a. It would be bigger
b. It would be the same
c. It would be smaller

```
F = kx.  Consider the whole spring as
a series connection of two halves.  Then, they
are still subjected to the same force, but the
`displacement' should be halved (to get x as a
whole).  Therefore, k is doubled.
```

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