Physics 101	Hour Exam III	December 3, 2012

Last Name:______________First Name________________Network-ID___________
Discussion Section:________Discussion TA Name:____________________________
Exam Room__________________________Seat Number___________

Instructions—Turn off your cell phone and put it away.
Calculators cannot be shared. Please keep yours on your own desk.

This is a closed book exam. You have 1.5 hours (90 minutes) to complete it.
This is a multiple choice exam. Use the bubble sheet to record your answers.

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. You may find the version of **this Exam Booklet at the top of page 2**. Mark the version circle in the **TEST FORM** box in the bottom right on the front side of your answer sheet. **DO THIS NOW!**

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. Print your UIN# in the **STUDENT NUMBER** designated spaces and mark the corresponding circles. You need not write in or mark the circles in the SECTION box.

7. Write in your course on the **COURSE LINE** and on the **SECTION** *line*, print your **DISCUSSION SECTION**. (You need not fill in the INSTRUCTOR line.)

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 14 ***numbered pages*** *which include2 Formula Sheets.*

On the test booklet:
Write your **NAME**, your **Discussion TA's NAME**, your **DISCUSSION SECTION** and your **NETWORK-ID**. Also, write your **EXAM ROOM** and **SEAT NUMBER**.

When you are finished, you must <u>hand in BOTH the exam booklet AND the answer sheet</u>. Your exam will not be graded unless both are present.

***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.**

This Exam Booklet is Version A. Mark the **A** circle in the **TEST FORM** box in the bottom right on the front side of your answer sheet. **DO THIS NOW!**

Exam Format & Instructions:

This exam is a mixture of

* Two-Answer Multiple Choice	(2 points each)
* Three-Answer Multiple Choice	(3 points each)
* Five-Answer Multiple Choice	(6 points each)

There are 24 problems for a maximum possible raw score of 108 points.

<u>Instructions for Two-Answer Multiple Choice Problems:</u>
Indicate on the answer sheet the correct answer to the question (*a* or *b*).
Each question is worth 2 points. If you mark the wrong answer, or mark more than one answer, you receive 0 points.

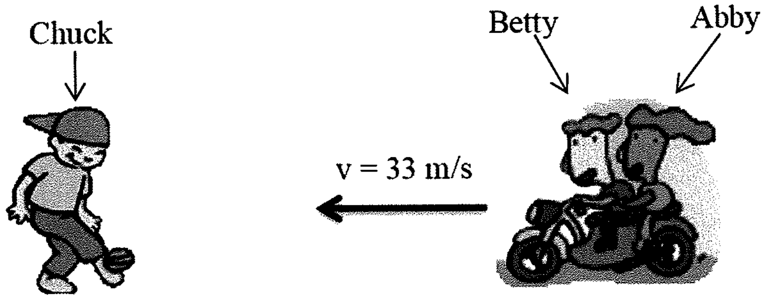
<u>Instructions for Three-Answer Multiple Choice Problems:</u>
Indicate on the answer sheet the correct answer to the question (*a, b* or *c*).
Each question is worth 3 points. If you mark the wrong answer, or mark more than one answer, you receive 0 points.

<u>Instructions for Five-Answer Multiple Choice Problems:</u>
Indicate on the answer sheet the correct answer to each question (*a, b, c, d* or *e*).
<u>Credit is awarded in the following way:</u>
- If you mark one answer and it is correct, you will receive 6 points;
- If you mark two answers, and one of them is correct, you will receive 3 points;
- If you mark three answers and one of them is correct, you will receive 2 points.
- If you mark no answer or more than three answers, you will receive 0 points.

Unless otherwise stated, ignore air resistance. Assume the acceleration of gravity is $g = 9.8\ m/s^2$ vertically downward. Assume that all fluids are ideal, and that all gases are ideal.

This description applies to the next two problems.

Take the speed of sound to be 330 m/s.
Abby and Betty are riding on a very quiet electric motorcycle at 33 m/s toward Chuck. Abby is sitting behind Betty, who is driving. A hole in Abby's helmet makes a loud whistling sound at exactly 10,000 Hz.



1. What frequency of sound does Betty hear from Abby's helmet?

A. 10,000 Hz
B. 10,330 Hz
C. 11,034 Hz

2. Chuck is standing by the road as Betty and Abby approach. What frequency does he hear from Abby's helmet?

A. 10,000 Hz
B. 10,330 Hz
C. 11,110 Hz

$$f_o = f_s \frac{V_{sound} \pm V_o}{V_{sound} - V_s} \qquad V_o = 0$$

$$= 10{,}000 \text{ Hz} \frac{330}{330 - 33}$$

$$= 11{,}111 \text{ Hz}$$

3. On the first Tuesday of each month, Urbana-Champaign emits from 3 towers a tornado warning. When measured individually, each of the 3 towers emits sound at 80 dB when measured at a distance of 100 m. These towers, although driven to make sound at the same time, are independent of each other, i.e. are incoherent. What is the sound level of the resulting, combined, sound when standing at an equal distance of 100 m from each tower?

A. 26.7 dB
B. 80.0 dB
C. 83.0 dB
D. 84.8 dB
E. 240 dB

$$\beta_2 = \beta_1 + 10 \text{ dB} \log_{10} \frac{I_2}{I_1}$$

$$= 80 \text{ dB} + 10 \text{ dB} \times \log_{10} 3$$

$$= 84.77 \text{ dB}$$

4. A 16.0 N weight hangs at the end of a 2.0 m long string. The string has a mass of 20.0 g. How long does it take a wave pulse to travel the length of the string?

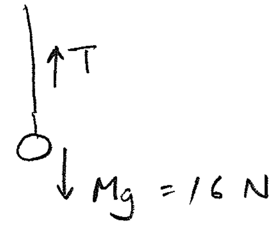
A. 0.050 s
B. 0.100 s
C. 0.125 s
D. 0.200 s
E. 0.250 s

$d = vt \Rightarrow t = d\sqrt{\frac{\mu}{T}} = d\sqrt{\frac{m/d}{Mg}}$

$v = \sqrt{\frac{T}{\mu}}$

$= 2\,m\sqrt{\frac{0.02\,kg/2m}{16\,N}}$

$= 0.05\,s$



5. Suppose I tune a violin so that two successive harmonics have frequencies 1464 Hz and 1708 Hz. Which harmonic is the 1708 Hz frequency?

A. 1
B. 2
C. 4
D. 7
E. 244

$1708\,Hz - 1464\,Hz = 244\,H$

$\frac{1708\,Hz}{244\,Hz} = 7$

6. A siren is located at the top of a tall tower and emits sound equally in all directions. At a distance of 10.0 m from the siren the sound intensity level is 120dB. What is the sound intensity level at a distance of 30m from the siren?

A. 13.3 dB
B. 40.0 dB
C. 110.5 dB
D. 117.0 dB
E. 123.0 dB

$I = \frac{P}{4\pi r^2} \Rightarrow I_2 = \frac{1}{9} I_1$

$\beta_2 - \beta_1 = 10\,dB \log_{10} \frac{I_2}{I_1}$

$\beta_2 = 120\,dB + 10\,dB \log_{10} 1/9$

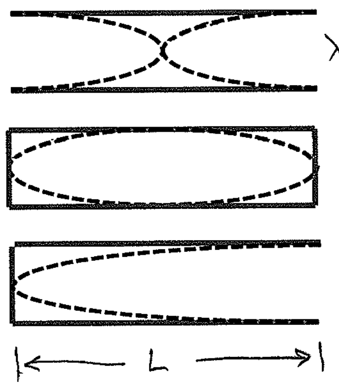
$\beta_2 = 110.46\,dB$

7. Three standing waves in tubes are drawn below. All three tubes are the same length. Which wave has the lowest frequency?

A.

B.

C.



$\lambda = 2L$ (A)

$\lambda = 2L$ (B)

$\lambda = 4L$ (C)

D. A. and B. are tied for lowest frequency.

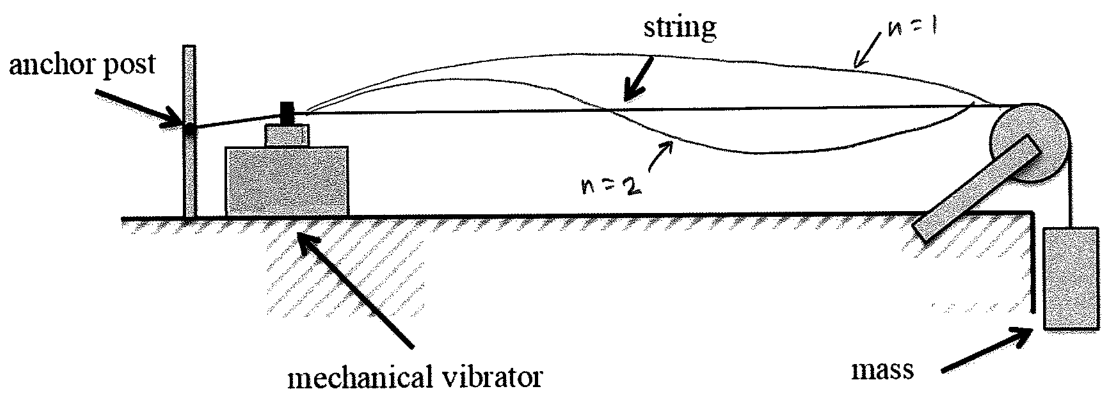
E. All three have the same frequency.

$$v = \underset{\text{big}}{\lambda}\,\overset{\text{small}}{f}$$

8. You have a string tied as shown in the figure below. You vary the frequency of the mechanical vibrator such that in the string you get a fundamental resonance (n=1) with a wavelength of 2 meters. What will be the wavelength of the second harmonic (n=2)?

$$\lambda_2 = \frac{1}{2}\lambda_1 = \frac{1}{2}2m = 1\,m$$

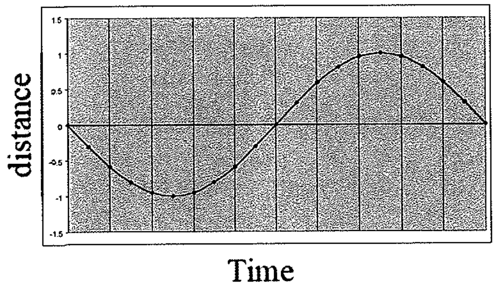
A. 1/2 meter
B. 1 meters
C. 4 meters

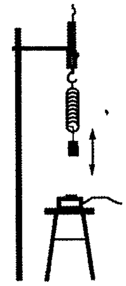


9. You have a mass, M, on a spring. You hold on to the mass, stretch it out a distance x, and then let it go. If the mass is light, it will oscillate faster than a heavier mass because:

A. The force of the spring on the mass is more than if the mass were heavier.
B. The force of the spring on the mass is less than if the mass were heavier.
C. The spring is pulling on the mass with the same force whether it is lighter or heavier, and by F=Ma, the acceleration is greater for the lighter object.

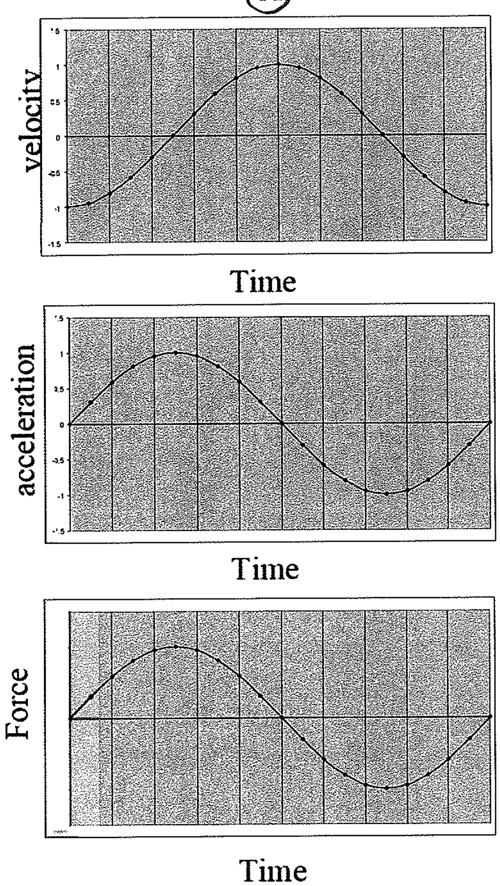
10. A mass is bobbing up and down on a spring as shown. Its distance vs. time looks like:



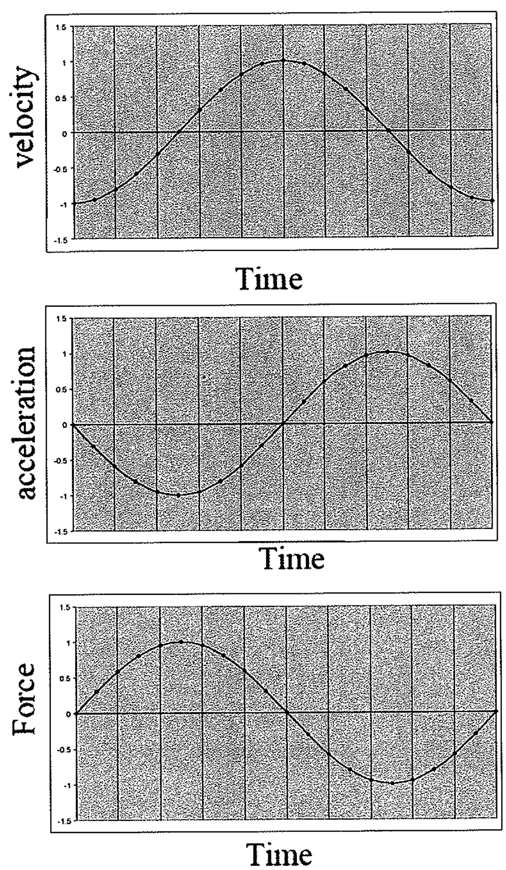


Which of the following, A, B, or C, is a correct velocity, acceleration, and Force?

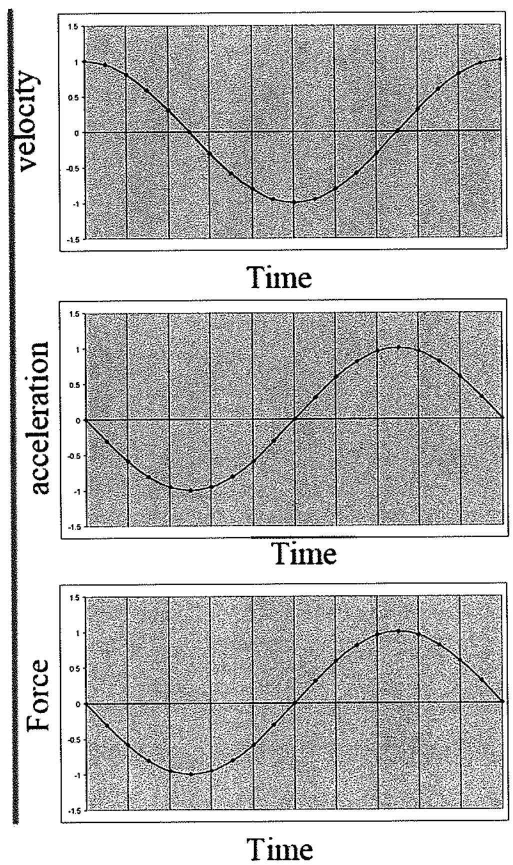
A



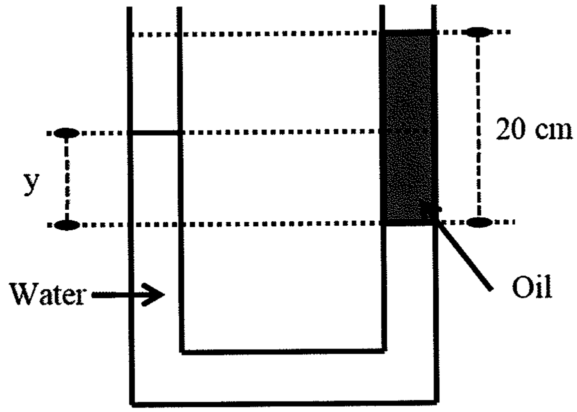
B.



C.



11. A U-shaped tube is filled with water and oil as shown in the diagram below, and its ends are open to the atmosphere. The density of water is $\rho_{H2O} = 1$ g/cm^3, and that of the oil is $\rho_{oil} = 0.7$ g/cm^3. The height of the column of oil is 20 cm. What is the distance y?



$\rho_{water} \cancel{g} y = \rho_{oil} \cancel{g} \times 20$ cm

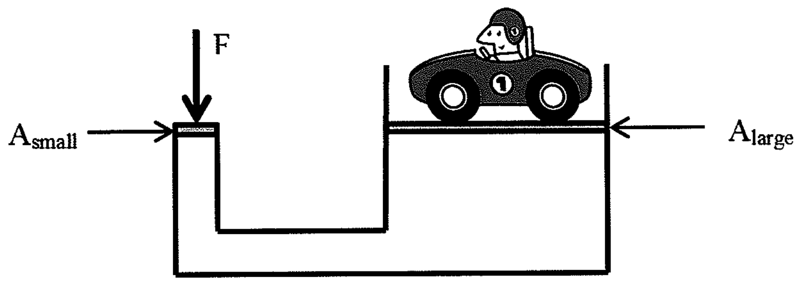
A. 12 cm
B. 14 cm
C. 16 cm
D. 18 cm
E. 20 cm

$y = 20 \text{ cm} \times \frac{\rho_{oil}}{\rho_{water}}$

$= 20 \text{ cm} \times \frac{0.7}{1}$

$= 14$ cm

The following three questions relate to the following situation:
A hydraulic jack is used to lift a car of mass m_{car} = 1590 kg, as shown in the diagram. The cross-sectional area of the small piston is A_{small} = 0.1 m^2, while that of the large piston is A_{large} = 25 m^2. The pistons have negligible weight. The density of the oil used in the lift is ρ_{oil} = 900 kg/m^3.



12. The two pistons are initially at the same height. What force F must be applied to the small piston to support the car?

A. 62 N
B. 71 N
C. 93 N

$P_1 = P_2$

$\frac{F}{A_{small}} = \frac{mg}{A_{large}} \Rightarrow F = mg\frac{A_{small}}{A_{large}} = 1590\ kg \times 9.8\ m/s^2 \times \frac{0.1}{25}$

$= 62.3\ N$

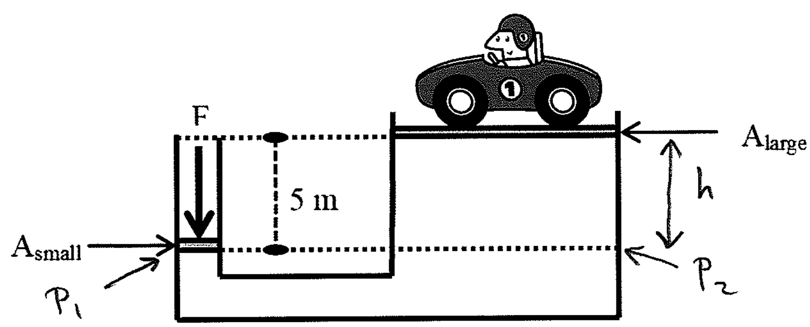
13. How far must the small piston be pushed to raise the car 0.01 m?

A. 1.0 m
B. 1.5 m
C. 2.0 m
D. 2.5 m
E. 3.0 m

$d_1 A_{small} = d_2 A_{large}$

$d_1 = d_2 \frac{A_{large}}{A_{small}} = 0.01\ m \times \frac{25}{0.1} = 2.5\ m$

14. The car and large piston have now been lifted to the configuration shown. What force F must now be applied to the small piston to maintain the height of the car and large piston?



A. 4472 N
B. 4836 N
C. 5285 N

$P_1 = P_2$

$\frac{F}{A_{small}} = \frac{mg + \rho A_{large} h g}{A_{large}}$

$F = \frac{A_{small}}{A_{large}} mg + A_{small} \rho h g$

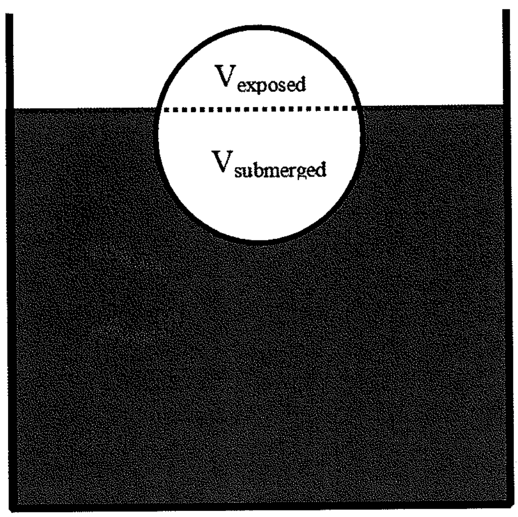
$= \frac{0.1}{25} 1590\ kg \times 9.8\ m/s^2 + 0.1\ m^2 \times 900\ kg/m^3 \times 5\ m \times 9.8\ m/s^2 = 4472\ N$

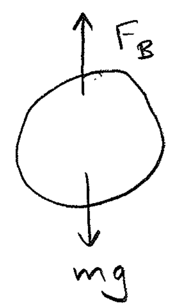
15. The maximum depth of Lake Baikal in southern Siberia, the deepest lake in the world, is 1,642 m. What is the pressure at this depth? Assume that the lake has a constant density of 1000 kg/m^3 and that the atmospheric pressure is 1 atm or 101,325 Pa.

A. 16 atm
B. 83 atm
C. 97 atm
D. 105 atm
E. 160 atm

$$P_2 = P_1 + \rho g h$$
$$= 101{,}325 \text{ Pa} + 1000 \text{ kg/m}^3 \times 9.8 \text{ m/s}^2 \times 1642 \text{ m}$$
$$= 16{,}192{,}925 \text{ Pa}$$
$$= 159.8 \text{ atm}$$

16. An object of density ρ_{obj} = 0.7 g/cm^3 is placed in a container of water (ρ_{H2O} = 1 g/cm^3) and floats to the surface as shown. What fraction of the object's volume is submerged below the surface of the water? In the diagram, we define $V_{object} = V_{exposed} + V_{submerged}$.

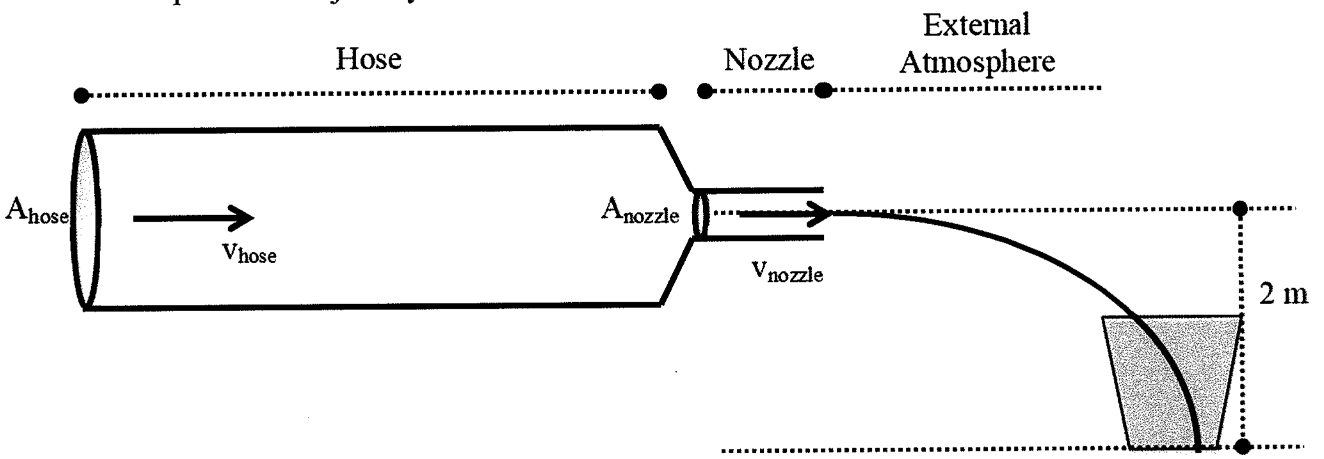




A. $V_{submerged}/V_{object} = 0.30$
B. $V_{submerged}/V_{object} = 0.40$
C. $V_{submerged}/V_{object} = 0.50$
D. $V_{submerged}/V_{object} = 0.60$
E. $V_{submerged}/V_{object} = 0.70$

$$F_B = mg$$
$$\rho_{H2O} V_{sub} \cancel{g} = \rho_{obj} V_{obj} \cancel{g}$$
$$\frac{V_{sub}}{V_{obj}} = \frac{\rho_{obj}}{\rho_{H2O}} = \frac{0.7}{1} = 0.7$$

The following three questions relate to the following situation:
You are spraying water out of a hose ($\rho_{H2O} = 1$ g/cm^3). The hose has cross sectional area of $A_{hose} = 4$ cm^2. At the end of a hose is attached a nozzle of cross sectional area $A_{nozzle} = 0.5$ cm^2. Water comes spraying out of the nozzle at a speed of $v_{nozzle} = 3$ m/s and follows the parabolic trajectory into a 1 L bucket as shown.



17. What is the speed of the water inside the hose?

A. 0.124 m/s
B. 0.227 m/s
C. 0.375 m/s

$A_1 v_1 = A_2 v_2$

$v_1 = \frac{A_2}{A_1} v_2 = \frac{0.5}{4} 3 \text{ m/s} = 0.375 \text{ m/s}$

18. How does the pressure in the hose, P_{hose}, relate to the pressure in the nozzle, P_{nozzle}?

A. $P_{hose} > P_{nozzle}$
B. $P_{hose} = P_{nozzle}$
C. $P_{hose} < P_{nozzle}$

$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$

Small v → Large P and vice versa

19. The water coming out of the hose is sprayed into a 1 L bucket (1 L = 0.001 m^3). How long does it take to fill the bucket?

A. 2.3 s
B. 6.7 s
C. 9.4 s

Flow rate $= A_{nozzle} v_{nozzle}$

$= 0.5 \text{ cm}^2 \times 3 \text{ m/s}$

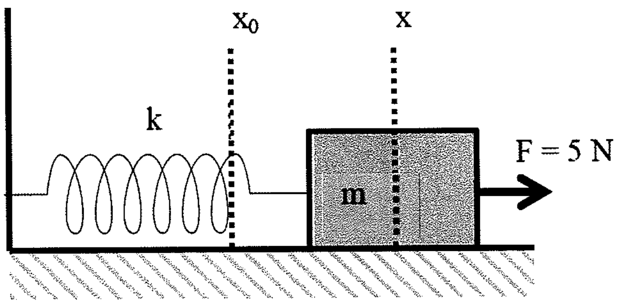
$= 0.5 \text{ cm}^3 \times 300 \text{ cm/s} = 150 \text{ cm}^3\text{/s}$

Flow rate $\times \Delta t$ = Volume

$\Delta t = \frac{\text{Volume}}{\text{Flow rate}} = \frac{1000 \text{ cm}^3}{150 \text{ cm}^3\text{/s}} = 6.67 \text{ s}$

1 L = 1000 cm^3

The following three questions relate to the following situation:
An object of mass m = 5 kg is attached to a horizontal spring with spring constant k = 0.5 N/m. The object is pulled from its equilibrium position, x_0, by a force F = 5 N. All surfaces are frictionless.



20. How far is the object displaced from its equilibrium position, i.e., x-x_0?

A. 5 m
B. 10 m
C. 15 m

$$F = -kx$$
$$|x| = \frac{F}{k} = \frac{5\ N}{0.5\ N/m} = 10\ m$$

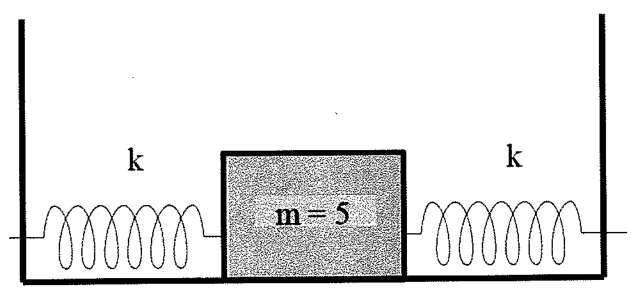
21. If we double the mass of the object, what is the new angular frequency of oscillation, ω?

A. $\omega' = \omega/2$
B. $\omega' = \omega/\sqrt{2}$
C. $\omega' = \omega$
D. $\omega' = \sqrt{2}\omega$
E. $\omega' = 2\omega$

$$\omega = \sqrt{\frac{k}{m}}$$
$$\omega' = \sqrt{\frac{k}{2m}} = \frac{1}{\sqrt{2}}\sqrt{\frac{k}{m}} = \frac{1}{\sqrt{2}}\omega$$

22. If we attach another spring of equal spring constant k = 0.5 N/m to the m = 5 kg mass as shown below, what is the angular frequency of oscillation?

A. $\omega' = \omega/2$
B. $\omega' = \omega/\sqrt{2}$
C. $\omega' = \omega$
D. $\omega' = \sqrt{2}\omega$
E. $\omega' = 2\omega$



$$\omega = \sqrt{\frac{k}{m}}$$
$$\omega' = \sqrt{\frac{2k}{m}} = \sqrt{2}\sqrt{\frac{k}{m}} = \sqrt{2}\,\omega$$

The next two questions relate to the following situation:

A grandfather clock keeps time by use of a pendulum of mass m = 1 kg oscillating back and forth with an oscillatory period of T = 1s.

23. If we double the mass attached to the pendulum, how does the new required length, L', relate to the old length, L, in order to maintain an oscillatory period of 1 s?

A. L' = L/2
B. L' = L/√2
C. L' = L
D. L' = √2 L
E. L' = 2L

$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{L}{g}} \Rightarrow L = g\left(\frac{T}{2\pi}\right)^2$

$L' = L$

24. We next construct a clock identical to the first (i.e. length L, mass m = 1 kg, etc.) on the surface of the distant Planet X, on which the gravitational acceleration is nine times greater than that on Earth, i.e. $g_X = 9g_{Earth}$, where $g_{Earth} = 9.8\ m/s^2$. How does the oscillatory period of the pendulum on Planet X, T_X, relate to that on Earth, T_{Earth}?

A. $T_X = 9\ T_{Earth}$
B. $T_X = 3\ T_{Earth}$
C. $T_X = T_{Earth}$
D. $T_X = T_{Earth}/3$
E. $T_X = T_{Earth}/9$

$T = 2\pi\sqrt{\frac{L}{g}}$

$T_x = 2\pi\sqrt{\frac{L}{g_x}} = 2\pi\sqrt{\frac{L}{9g}} = \frac{1}{3}2\pi\sqrt{\frac{L}{g}} = \frac{1}{3}T$

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

Physics 101 Formulas

Kinematics

$\mathbf{v}_{ave} = \Delta\mathbf{x}/\Delta t$ $\mathbf{a}_{ave} = \Delta\mathbf{v}/\Delta t$

$v = v_0 + at$ $x = x_0 + v_0t + {}^1/_2at^2$ $v^2 = v_0^2 + 2a\Delta x$

$g = 9.8\text{m/s}^2 = 32.2\text{ft/s}^2$ (near Earth's surface)

Dynamics

$\Sigma\mathbf{F} = m\mathbf{a}$ $F_g = Gm_1m_2 / R^2$ $F_g = mg$ (near Earth's surface)

$f_{s,max} = \mu_sF_N$ Gravitational constant, $G = 6.7 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2$

$f_k = \mu_kF_N$ $a_c = v^2 / R = \omega^2R$

Work & Energy

$W_F = FS\cos(\theta)$ $K(\text{or KE}) = {}^1/_2mv^2$ $W_{NET} = \Delta K = K_f - K_i$ $E = K + U$

$W_{nc} = \Delta E = E_f - E_i = (K_f + U_f) - (K_i + U_i)$

$W_{grav} = -mg\Delta y$ U_{grav} (or PE_{grav}) $= mgy$

Impulse & Momentum

Impulse $\mathbf{I} = \mathbf{F}_{ave}\Delta t = \Delta\mathbf{p}$ $\mathbf{F}_{ave}\Delta t = \Delta\mathbf{p} = m\mathbf{v}_f - m\mathbf{v}_i$ $\mathbf{F}_{ave} = \Delta\mathbf{p}/\Delta t$

$\Sigma\mathbf{F}_{ext}\Delta t = \Delta\mathbf{P}_{total} = \mathbf{P}_{total,final} - \mathbf{P}_{total,initial}$ (momentum conserved if $\Sigma\mathbf{F}_{ext} = 0$)

$\mathbf{X}_{cm} = (m_1\mathbf{x}_1 + m_2\mathbf{x}_2)/(m_1 + m_2)$

Rotational Kinematics

$\omega = \omega_0 + \alpha t$ $\theta = \theta_0 + \omega_0t + {}^1/_2\alpha t^2$ $\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$

$\Delta x_T = \Delta\theta R$ $v_T = \omega R$ $a_T = \alpha R$ (rolling without slipping: $\Delta x = \Delta\theta R$ $v = \omega R$ $a = \alpha R$)

Rotational Statics & Dynamics

$\tau = Fr\sin\theta$

$\Sigma\tau = 0$ and $\Sigma F = 0$ (static equilibrium)

$\Sigma\tau = I\alpha$

$I = \Sigma mr^2$ (for a collection of point particles)

$I = {}^1/_2MR^2$ (solid disk or cylinder) $I = {}^2/_5MR^2$ (solid sphere) $I = {}^2/_3MR^2$ (hollow sphere)

$I = MR^2$ (hoop or hollow cylinder) $I = {}^1/_{12}ML^2$ (uniform rod about center)

$W = \tau\theta$ (work done by a torque)

$\mathbf{L} = I\omega$ $\Sigma\tau_{ext}\Delta t = \Delta\mathbf{L}$ (angular momentum conserved if $\Sigma\tau_{ext} = 0$)

$K_{rot} = {}^1/_2I\omega^2 = L^2/2I$ $K_{total} = K_{trans} + K_{rot} = {}^1/_2mv^2 + {}^1/_2I\omega^2$

Simple Harmonic Motion

Hooke's Law: $F_s = -kx$

$W_{spring} = {}^1/_2kx_i^2 - {}^1/_2kx_f^2$ $U_{spring} = {}^1/_2kx^2$

$x(t) = A\cos(\omega t)$ or $x(t) = A\sin(\omega t)$

$v(t) = -A\omega\sin(\omega t)$ or $v(t) = A\omega\cos(\omega t)$

$a(t) = -A\omega^2\cos(\omega t)$ or $a(t) = -A\omega^2\sin(\omega t)$

$\omega^2 = k/m$ $T = 2\pi/\omega = 2\pi\sqrt{m/k}$ $f = 1/T$

$x_{max} = A$ $v_{max} = \omega A$ $a_{max} = \omega^2A$ $\omega = 2\pi f$

For a simple pendulum $\omega^2 = g/L$, $T = 2\pi\sqrt{L/g}$

Fluids

$P = F/A$, $P(d) = P(0) + \rho gd$ change in pressure with depth d
Buoyant force $F_B = \rho gV_{dis}$ = weight of displaced fluid
Flow rate $Q = v_1A_1 = v_2A_2$ continuity equation (area of circle $A = \pi r^2$)
$P_1 + {}^1/_2\rho v_1^2 + \rho gy_1 = P_2 + {}^1/_2\rho v_2^2 + \rho gy_2$ Bernoulli equation
$\rho_{water} = 1000\ kg/m^3$ $1m^3 = 1000$ liters
$\rho = M/V$ 1 atmos. = 1.01×10^5 Pa 1 Pa = 1 N/m^2

Temperature and Heat

Temperature: Celsius (T_C) to Fahrenheit (T_F) conversion: $T_C = (5/9)(T_F - 32)$
Celsius (T_C) to Kelvin (T_K) conversion: $T_K = T_C + 273$
$\Delta L = \alpha L_0\Delta T$ $\Delta V = \beta V_0\Delta T$ thermal expansion
$Q = cM\Delta T$ specific heat capacity
$Q = L_fM$ latent heat of fusion (solid to liquid) $Q = L_vM$ latent heat of vaporization
$Q = kA\Delta Tt/L$ conduction
$Q = e\sigma T^4At$ radiation ($\sigma = 5.67\times10^{-8}$ J/(s·m²·K⁴))
$P_{net} = e\sigma A(T^4 - T_0^4)$ (surface area of a sphere $A = 4\pi r^2$)

Ideal Gas & Kinetic Theory

$N_A = 6.022 \times 10^{23}$ molecules/mole Mass of carbon-12 = 12.000u
$PV = nRT = Nk_BT$ $R = 8.31$ J/(mol·K) $k_B = R/N_A = 1.38 \times 10^{-23}$ J/K
$KE_{ave} = {}^3/_2k_BT = {}^1/_2mv_{rms}^2$ $U = {}^3/_2Nk_BT$ (internal energy of a monatomic ideal gas)
$v_{rms}^2 = 3k_BT/m = 3RT/M$ (M = molar mass = kg/mole)

Thermodynamics

$\Delta U = Q + W$ (1'st law)

$U = ({}^3/_2)nRT$ (internal energy of a monatomic ideal gas for fixed n)

$C_V = ({}^3/_2)R = 12.5$ J/(mol·K) (specific heat at constant volume for a monatomic ideal gas)

$Q_H = Q_C + W$ (heat engine or refrigerator)
$e = W/Q_H = 1 - Q_C/Q_H$ $e_{max} = 1 - T_C/T_H$ (Carnot engine)
$Q_C/Q_H = T_C/T_H$ at maximum efficiency (2'nd law)
$W = -P\Delta V$ (work done by expanding gas)

Harmonic Waves

$v = \lambda / T = \lambda f$
$v^2 = F/(m/L)$ for wave on a string
$v = c = 3 \times 10^8$ m/s for electromagnetic waves (light, microwaves, etc.)
$I = P/(4\pi r^2)$ (sound intensity)

Sound Waves

Loudness: $\beta = 10 \log_{10}(I/I_0)$ (in dB), where $I_0 = 10^{-12}$ W/m²

$$f_{observer} = f_{source}\frac{v_{wave} - v_{observer}}{v_{wave} - v_{source}}$$ (Doppler effect)