EXAM 2 PHYS 103 Key Spring 2013 **A**

NAME: ______________________________ SECTION__________

As a student at NJIT I ______________________, will conduct myself in a professional manner and will comply with the provisions of the NJIT Academic Honor Code. I also understand that I must subscribe to the following pledge on major work submitted for credit as described in the NJIT Academic Honor Code: On my honor, I pledge that I have not violated the provisions of the NJIT Academic Honor Code.

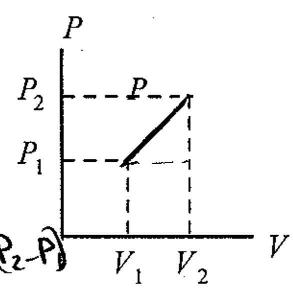
Answer each question on the Scantron card using #2 pencil. Also circle your answers on the question papers. SHOW HOW YOU GOT YOUR ANSWERS ON THE EXAM SHEETS. Use the back if necessary.

1. During an isobaric process which one of the following does not change?

   Constant P

   a. volume
   b. temperature
   c. internal energy
   (d) pressure
   e. density

2. What is the work done on the gas as it expands from pressure P_1 and volume V_1 to pressure P_2 and volume V_2 along the indicated straight line?



   (a) $(P_1 + P_2)(V_1 - V_2)/2$
   b. $(P_1 + P_2)(V_1 - V_2)$
   c. $(P_1 + P_2)(V_1 - V_2)/4$
   d. $(P_1 - P_2)(V_1 + V_2)$
   e. $(P_1 + P_2)(V_1 - 2V_2)/2$

   $W = -P\Delta V$

   $P\Delta V \Rightarrow$ area under curve $= (V_2 - V_1)P_1 + \frac{1}{2}(V_2 - V_1)(P_2 - P_1) = \frac{1}{2}(V_2 - V_1)(P_1 + P_2)$

   $W = -\frac{1}{2}(V_2 - V_1)(P_1 + P_2)$

3. A cylinder containing an ideal gas has a volume of 2.0 m^3 and a pressure of 1.0×10^5 Pa at a temperature of 300 K. The cylinder is placed against a metal block that is maintained at 900 K and the gas expands as the pressure remains constant until the temperature of the gas reaches 900 K. The change in internal energy of the gas is $+6.0 \times 10^5$ J. How much heat did the gas absorb?

   a. 0
   b. 4.0×10^5 J
   c. 6.0×10^5 J
   (d) 10×10^5 J
   e. 2.0×10^5 J

   $P_1V_1 = nRT_1$ $P_2V_2 = nRT_2$

   $V_1 = \frac{nRT_1}{P}$ $V_2 = \frac{nRT_2}{P}$

   $\Delta V = V_2 - V_1 = \frac{nR}{P}(T_2 - T_1)$

   $W = -P\Delta V = -P\left(\frac{nR}{P}(T_2 - T_1)\right) = -nR(T_2 - T_1) = -\frac{P_1V_1}{T_1}(T_2 - T_1) = -\frac{(1.0\times10^5 \text{ Pa})(2 \text{ m}^3)}{300}(600 \text{ K})$

   $W = -4\times10^5$

   $\Delta U = Q + W$

   $Q = \Delta U - W$

   $Q = \Delta U - (W) = 6\times10^5 + 4\times10^5 = 10\times10^5$ J

   $Q = 10\times10^5$ J

4. If a heat engine has an efficiency of 30% and its power output is 600 W, what is the rate of heat input from the combustion phase?

   a. 1 800 W
   b. 2 400 W
   (c) 2 000 W
   d. 3 000 W
   d. 5 000 W

   $Q_{out} = e\, Q_{in}$

   $P_{out} = e\, P_{in}$

   $P_{in} = 600/0.3 = 2000$

5. A gasoline engine with an efficiency of 30.0% operates between a high temperature T_1 and a low temperature T_2 = 320 K. If this engine operates with Carnot efficiency, what is the high-side temperature T_1?

a. 1 070 K
b. 868 K
c. 614 K
(d) 457 K
e. 757 K

$e = 1 - T_L/T_H$

$0.30 = 1 - T_L/T_H$

$T_L/T_H = 0.7 \quad T_H = \frac{T_L}{0.7} = \frac{320}{0.7}$

$= 457\ K$

6. A 0.20-kg object is attached to a spring with spring constant k = 10 N/m and moves with simple harmonic motion over a horizontal frictionless surface. At the instant that it is displaced from equilibrium by –0.050 m, what is its acceleration?

a. 1 000 m/s^2
b. –40 m/s^2
c. 0.1 m/s^2
(d) 2.5 m/s^2
e. 1.5 m/s^2

$F = -kx$

$ma = -kx$

$a = -k/m\,x = \left(-\frac{10\ N/m}{0.2}\right)(-0.050\ m) = 2.5\ m/s$

7. A tiny spring, with a spring constant of 1.20 N/m, will be stretched to what displacement by a 0.005 0-N force?

(a) 4.2 mm
b. 6.0 mm
c. 7.2 mm
d. 9.4 mm
e. 3.4 mm

$F = -kx$

$x = |F/k| = \frac{0.005\ N}{1.2} = 0.0042\ m \Rightarrow 4.2\ mm$

8. A 0.20-kg object is oscillating on a spring with a spring constant of k = 15 N/m. What is the potential energy of the system when the object displacement is 0.040 m, exactly half the maximum amplitude?

a. zero
b. 0.006 0 J
(c) 0.012 J
d. 2.5 J
e. 1.5 J

$U = \frac{1}{2}kx^2 = \frac{1}{2}(15)(0.04)^2 = 0.012\ J$

9. A mass of 0.40 kg, hanging from a spring with a spring constant of 80 N/m, is set into an up-and-down simple harmonic motion. What is the speed of the mass when moving through a point at 0.05 m displacement? The starting displacement of the mass is 0.10 m from its equilibrium position.

a. zero
b. 1.4 m/s
c. 1.7 m/s
(d) 1.2 m/s
e. 0.5 m/s

$V = \omega\sqrt{A^2 - x^2} \qquad \omega = \sqrt{k/m}$

$= \sqrt{\frac{80}{0.4}}\sqrt{0.1^2 - 0.05^2} = 1.22\ m/s$

10. Suppose a 0.30-kg mass on a spring-loaded gun that has been compressed 0.10 m has elastic potential energy of 1.0 J. How high above the spring's equilibrium point can the gun fire the mass if the gun is fired straight up?

a. 0.10 m
b. 0.34 m
(c.) 0.24 m
d. 10 m
d. 5 m

$E_i = E_f$ no friction

$mgh_1 + \frac{1}{2}kx_1^2 + \frac{1}{2}mv_1^2 = mgh_2 + \frac{1}{2}kx_2^2 + \frac{1}{2}mv_2^2$

$\frac{1}{2}kx_1^2 = mgh_2$

$1.0J = mgh_2$ $h_2 = \frac{1.0J}{mg} = \frac{1.0}{(0.3)(9.8)} = 0.34m$

11. The position of a 0.64-kg mass undergoing simple harmonic motion is given by $x = (0.160 \text{ m}) \cos(\pi t/16)$. What is the maximum net force on the mass as it oscillates?

(a.) 3.9×10^{-3} N
b. 9.9×10^{-3} N
c. 1.3×10^{-3} N
d. 6.3 N
e. 5.6 N

$F_{max} = ma_{max}$ $a_{max} = \omega^2 A$

$= 0.64(\pi/16)^2 \, 0.16 = 0.0039$

$= 3.9 \times 10^{-3} N$

$= 3.9 mN$

12. By what factor should the length of a simple pendulum be changed if the period of vibration were to be tripled?

a. 1/9
b. 0.33
c. 3.0
(d.) 9.0
e. 5.0

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

$T_1 = 2\pi\sqrt{L_1/g}$

$T_2 = 2\pi\sqrt{L_2/g}$

$T_2/T_1 = \sqrt{L_2/L_1}$

$T_2 = T_1\sqrt{L_2/L_1}$

increase L by 9 → increase T by 3

13. Bats can detect small objects such as insects that are of a size approximately that of one wavelength. If bats emit a chirp at a frequency of 60 kHz, and the speed of sound waves in air is 330 m/s, what is the smallest size insect they can detect?

a. 1.5 mm
b. 3.5 mm
(c.) 5.5 mm
d. 7.5 mm
e. 8.5 mm

$V = \lambda f$

$\lambda = V/f = \frac{330 m/s}{60{,}000} = 5.5 \times 10^{-3} m$

$= 5.5mm$

14. A wave is traveling in a string at 60 m/s. When the tension is then increased 20%, what will be the resulting wave speed?

a. also 60 m/s
(b.) 66 m/s
c. 72 m/s
d. 55 m/s
e. 35 m/s

$V_1 = \sqrt{T_1/\mu}$ $V_2 = \sqrt{T_2/\mu}$ $T_2/T_1 = 1.20$

$\frac{V_2}{V_1} = \sqrt{T_2/T_1}$

$V_2 = V_1\sqrt{T_2/T_1} = 60\,m/s\sqrt{1.20}$

$= 66\ m/s$

15. The lower A on a piano has a frequency of 27.5 Hz. If the tension in the 2.0-m-long string is 304 N and one-half wavelength occupies the string, what is the mass of the string?

a. 100 g
b. 25 g
c. 37 g
(d.) 50 g
d. 41 g

$f_n = \frac{n}{2L}\sqrt{T/\mu}$

L = 2.0 m
n = 1 T = 304
f = 27.5 Hz

$f_n^2 = \frac{n^2}{4L^2}T/\mu$

$\mu = \frac{n^2 T}{4L^2 f^2}$ $\mu = M/L$ $M = \frac{n^2 L T}{4L^2 f^2} = \frac{n^2 T}{4L f^2}$

$M = \frac{304}{4(2)\,27.5^2}$ → 50 g

16. A sound wave in air has a frequency of 500 Hz and a wavelength of 0.68 m. What is the approximate air temperature?

a. –16°C
b. 0°C
(c.) 15°C
d. 27°C
e. 31°C

$V = \lambda f = 0.68 * 500$
$= 340\ m/s$

$V(T) = 331\,m/s\sqrt{\frac{T}{273}}$

$340\,m/s = 331\,m/s\sqrt{\frac{T}{273}}$

$\left(\frac{340}{331}\right) = \sqrt{\frac{T}{273}}$

$T = \left(\frac{340}{331}\right)^2 273 = 288\ K$

$288 - 273 = 15°C$

Bonus Question (1 pt)

A taunt clothes line has length L and mass M. A transverse pulse is produced by plucking one end of the clothes line. If the pulse makes n round trips (to far end and back) along the line in T_1 seconds. (a) write down an expression for the speed of the pulse in terms of n, L and T and (b) find the tension T (or F) in terms of the same variables.

$$V = \frac{\Delta x}{\Delta t} = \frac{2Ln}{T_1}$$

$$V = \sqrt{T/\mu}$$

$$T = V^2\mu = \left(\frac{2Ln}{T_1}\right)^2 \frac{M}{L}$$

$$= \frac{4L^2n^2}{T_1^2}\frac{M}{L}$$

$$F = T = \frac{4Ln^2 M}{T_1^2}$$

T_1 is time in seconds for round trip

T is tension

Equation Sheet

$T(^0C) = \frac{5}{9}[T(^0F) - 32]$; $T(^0F) = \frac{9}{5}T(^0C) + 32$; $T(K) = [T(^0C) + 273]$ $\rho = \frac{m}{V}$; $A_{circle} = \pi r^2$

1 m = 100 cm $V_{cube} = a^3$ $V_{sphere} = \frac{4}{3}\pi R^3$ $V_{cyl} = \pi r^2 L$ 1m = 100 cm 1 kg = 1000 g

Heat: $Q = mc(T - T_0)$, $Q = mL_F$, L - latent heat heat lost = heat gained

$c_{water} = 4186\frac{J}{kg \cdot {}^0C}$; $L_F = 3.35x10^5\frac{J}{kg}$; $c_{ice} = 2100\frac{J}{kg \cdot {}^0C}$

$Q = kA\frac{T_1 - T_2}{L}t$ $Q = kA\frac{T_1 - T_2}{\sum R_i}t$ $R = L/k$ $\frac{Q}{t} = e\sigma A(T^4 - T_0^4)$ $\sigma = 5.67x10^{-8}\ W/m^2K^4$

Thermodynamics: $\Delta U = \Delta Q + W$ $W = P\Delta V$ $Q_h = W + Q_c$ $e = \frac{W}{Q_h}$ $e = 1 - \frac{T_c}{T_h}$

$COP = \frac{Q_c}{W}$ $COP = \frac{T_c}{T_h - T_c}$

Harmonic Motion

$x = A\cos(\omega t)$ $v = -\omega A\sin(\omega t)$ $\omega = 2\pi f$ $\omega = \frac{2\pi}{T}$ $F = -kx$ period: $T_{spring} = 2\pi\sqrt{\frac{m}{k}}$;

$T_{pend} = 2\pi\sqrt{\frac{L}{g}}$ $\omega = \sqrt{\frac{k}{m}}$ $f = \frac{1}{T}$ $v_{max} = A\omega$ $E = ½ mv^2 + ½ kx^2$; $Us = ½ kx^2$;

$E = ½ kA^2$; $v = \omega (A^2 - x^2)^{1/2}$

$E = ½ m(v_m)^2$ waves: $v = \lambda \cdot f$ linear mass $\mu = \frac{m}{L}$ $v = \sqrt{\frac{F}{\mu}}$

standing waves on string : n = 1, 2, 3., $f = \frac{v}{2L}n$ $\lambda = \frac{2L}{n}$

Sound:

$v = \left(331\ \frac{m}{s}\right)\sqrt{\frac{T}{273\ K}}$ $v = \sqrt{\frac{Y}{\rho}}$ $v = \sqrt{\frac{B}{\rho}}$ $\beta = 10 \log\left(\frac{I}{I_o}\right)$