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Applied Physics II Final Exam Winter 2006-2007

Multiple Choice (5 Points Each):

1. Pure nitrogen gas is contained in a sealed tank containing a movable piston. The initial volume, pressure and temperature are 0.020 m^3, 200 kPa, and 300K. If the volume is decreased to 0.010 m^3 and the pressure increased to to 400 kPa, what is the final temperature?

(a) 300 K
b. 600 K
c. 150 K
d. 100 K
e. None of the above.

$$\frac{P_1 V_1}{P_2 V_2} = \frac{n R T_1}{n R T_2}$$

$$T_2 = \frac{P_2 V_2 T_1}{P_1 V_1} = 300\,K$$

2. A 10 kg block of ice is at -10.0 ^{0}C. How much energy is required to turn it into 10 kg of water at 0.0 ^{0}C? (latent heat of fusion of water L_f = 3330 J / kg , latent heat of vaporization of water $L_v = 2.26 \times 10^6$ J / kg, specific heat c_{ice} = 2090 J / kg ^{0}C, specific heat c_{water} = 4186 J / kg ^{0}C, specific heat c_{steam} = 2010 J / kg ^{0}C)

a.) 33300 J
(b.) 242300 J
c.) 418600 J
d.) 484600 J
e.) None of the above.

$$Q = m_i c_i \Delta T + m_i L_f$$
$$= 10\,kg\left(2090\frac{J}{kg\,^\circ C}\right)(0^\circ C - -10^\circ C) + 10\,kg\,(3330\,J)$$
$$= 242\,300\,J$$

4. A 20 kg block with a specific is moving at 30 m/s when it comes in contact with a horizontal surface with friction and slows to a stop. Assuming that all the energy goes into warming the block and the specific heat of the block is 200 J / kg K, how much does the temperature of the block rise?

a.) 4.50 ^{0}C
(b.) 2.25 ^{0}C
c.) 1.00 ^{0}C
d.) 6.00 ^{0}C
e.) None of the above.

$$E_i = E_f$$
$$\frac{1}{2} m v^2 = m c \Delta T$$
$$\Delta T = \frac{v^2}{2c} = \frac{(30\,m/s)^2}{2\left(200\frac{J}{kg\,k}\right)} = 2.25^\circ C$$

5. A 1.0 mole sample of an idea gas is kept at a constant temperature of 0.0 ^{0}C during an isothermal expansion from 3.0 L to 10.0 L. How much work is done *by* the gas during the expansion ?

a.) -7.5×10^4 J
b.) $+8.5 \times 10^3$ J
c.) $+2.7 \times 10^3$ J
d.) +400 J
e.) None of the above.

$$W = nRT \ln\left(\frac{V_f}{V_i}\right)$$
$$= 1\,\text{mole}\left(8.31 \frac{J}{mol}\right)(273K) \ln\left(\frac{10\ell}{3\ell}\right)$$
$$= 2.7 \times 10^3 J$$

5. A sidewalk is comprised of square slabs of concrete ($\alpha = 12 \times 10^{-6}$ $^0C^{-1}$) with a length of 0.60 meter square when the temperature is 32.0 ^{0}F. How much of a space should be placed between each slab so that there is no buckling when the temperature reaches 100 ^{0}F?

a.) 0.27 mm
b.) 1.60 cm
c.) 0.25 mm
d.) 0.98 mm
e.) None of the above.

$$\Delta \ell = \alpha \ell \Delta T$$
$$= (12 \times 10^{-6}\,^oC^{-1})(0.6m)(37.8^oC - 0^oC)$$
$$= 2.72 \times 10^{-4} m = .27mm$$

$T_c = \frac{5}{9}(T_F - 32) = 37.8\,^oC$

$T_c = 0^oC$

6. You wish to make a simple pendulum with a period of 2.0 seconds with a bob of a mass of 20 kg and a length of string. How long should the string be?

a.) 1.00 m
b.) 9.00 m
c.) 6.00 m
d.) 4.00 m
e.) None of the above.

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$
$$\ell = \left(\frac{T}{2\pi}\right)^2 g = \left(\frac{2s}{2\pi}\right)^2 9.8\,m/s^2 = 0.99\,m$$

7. A tuning fork is held over a 2.0 meter long tube closed at one end. When the tuning fork is vibrating the first mode of resonance is produced. What is the length of the standing wave produced?

a.) 2.0 m
b.) 4.0 m
c.) 1.0 m
d.) 8.0 m
e.) None of the above.

$\frac{1}{4}\lambda = \ell$

$\lambda = 4\ell = 4(2m) = 8m$

8. What is the frequency of the tuning fork used in question 7?

a.) 171.5 Hz
b.) 85.75 Hz
c.) 343 Hz
d.) 42.88 Hz
e.) None of the above.

$v = \frac{\lambda}{T} = \lambda f$

$f = \frac{v}{\lambda} = \frac{343 m/s}{8 m} = 42.88 Hz$

9. Resonance can be described as:

a.) A small amplitude driving force producing large amplitude waves.
b.) A large amplitude driving force producing small amplitude waves.
c.) A large amplitude driving force producing large amplitude waves.
d.) Waves moving at the speed of sound.
e.) None of the above.

10. During one cycle, an engine extracts 4000 J of energy from a hot reservoir and transfers 2000 J of energy to a cold reservoir. Find the thermal efficiency of the engine and the amount of work the engine does in one cycle.

a.) 50 % and 6000 J
b.) 25 % and 6000 J
c.) 50 % and 2000 J
d.) 25 % and 2000 J
e.) None of the above.

$e = 1 - \frac{Q_c}{Q_H} = 1 - \frac{2000J}{4000J} = .5$

$\%e = 50\%$

$W = Q_H - Q_c = 4000J - 2000J = 2000J$

11. A child's toy consists of a piece of plastic attached to a spring. The spring is compressed against the floor a distance of 2.0 cm, and the toy is released. If the mass of the toy is 0.200 kg and rises to a maximum height of 1.00 meter, estimate the spring force constant of the spring.

a.) 9800 N/m
b.) 4900 N/m
c.) 19600 N/m
d.) 100 N/m
e.) None of the above.

$$E_i = E_f$$
$$mgh = \frac{1}{2} k x^2$$
$$k = \frac{2mgh}{x^2} = \frac{2(0.2\,kg)(9.8\,m/s^2)(1\,m)}{(0.02\,m)^2}$$
$$= 9800\,\frac{N}{m}$$

12. A motor produces a sound with a sound level of 70.0 dB. What is the intensity of the sound?

a.) 5.00×10^{-6} W/m².
b.) 1.00×10^{-5} W/m².
c.) 7.00×10^{-6} W/m².
d.) 1.38×10^{-2} W/m².
e.) None of the above.

$$\beta = 10\,dB \log\left(\frac{I}{I_0}\right)$$
$$I = I_0\, 10^{\beta/10\,dB} = 1 \times 10^{-12} \frac{W}{m^2}\, 10^{\frac{70\,dB}{10\,dB}} =$$
$$= 1 \times 10^{-5} \frac{W}{m^2}$$

13. A hiker sees lightning in the sky and and hears the thunder two seconds later. He believes that there must be a storm nearby. If he assumes that the lightning and thunder were created simultaneously, how far away does he approximate the storm is? (1 mile = 1609 m)

a.) 686 miles
b.) 0.43 miles
c.) 171.5 miles
d.) 0.11 miles
e.) None of the above.

$$v = \frac{\Delta x}{t}$$
$$\Delta x = vt = 343\,m/s\,(2s) = 686\,m\left(\frac{1\,mi}{1609\,m}\right) = 0.43\,mi$$

14. A 10 kg mass is attached to a spring with a spring force constant 100 N/m. The mass is lifted 2 cm and released from rest. What is the period of the motion?

a.) 3.16 s
b.) 1.98 s
c.) 9.78 s
d.) 19.85 s
e.) None of the above.

$$T = 2\pi\sqrt{\frac{m}{k}}$$
$$= 2\pi\sqrt{\frac{10\,kg}{100\,N/m}} = 1.98\,s$$

15. A pendulum with a length of 1.00 meters is released from rest from an initial angle of 15 degrees. After 1000 seconds, its amplitude has been reduced by friction to 5.5 degrees. What is the value of b/2m ?

a.) $1.00 \times 10^{-3}\ s^{-1}$.
b.) $2.00 \times 10^{-3}\ s^{-1}$.
c.) $4.00 \times 10^{-3}\ s^{-1}$.
d.) $5.00 \times 10^{-3}\ s^{-1}$.
e.) None of the above.

$$\theta = \theta_{max}\, e^{-bt/2m}$$

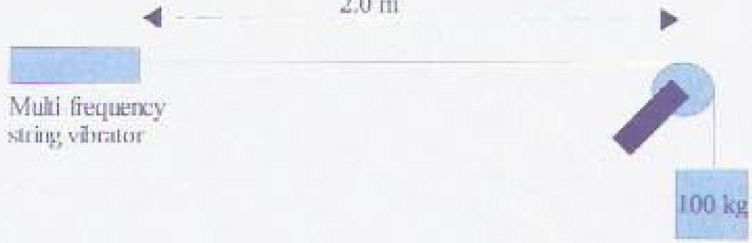
$$\frac{\theta}{\theta_{max}} = e^{-bt/2m}$$

$$\ln\left(\frac{\theta}{\theta_{max}}\right) = -\frac{bt}{2m}$$

$$-\frac{\ln\left(\frac{\theta}{\theta_{max}}\right)}{t} = \frac{b}{2m}$$

$$= \frac{-\ln\left(\frac{5.5^{\circ}}{15^{\circ}}\right)}{1000s} = 1 \times 10^{-3}\ s^{-1}$$

Problem One (15 Points):



One end of a string with a mass per length of 0.006 kg/m is attached to a multi-frequency string vibrator. The other end is looped over a pulley that is located 2.0 meters away and a 20 kg mass is attached. The multi-frequency string vibrator is tuned to produce the first four modes of standing waves.

a.) What is the speed of the waves through the string?
b.) Draw the first three modes of the standing waves.
c.) Label the wavelength of the first three standing waves.
d.) Label the frequency of the first three standing waves.
e.) The multi-frequency vibrator produces standing waves of the 60th mode. What is the wavelength of that mode?
f.) The multi-frequency vibrator produces standing waves of the 60th mode. What is the frequency of that mode?
g.) The 60th mode produces sound waves. What is the frequency of the sound wave?
h.) What is the speed of the sound waves?
i.) What is the wavelength of the sound waves produced?

a) $v = \sqrt{\frac{F_T}{\mu}} = \sqrt{\frac{mg}{\mu}} = \sqrt{\frac{100\,kg\,(9.8\,m/s^2)}{0.006\,kg/m}} = 404\ m/s$

b)

c) $\lambda_1 = 2\ell = 4m$

$\lambda_2 = \ell = 2m$

$\lambda_3 = \frac{2}{3}\ell = 1.3m$

d) $f_1 = \frac{v}{\lambda_1} = 101\ Hz$

$f_2 = \frac{v}{\lambda_2} = 202\ Hz$

$f_3 = \frac{v}{\lambda_3} = 303\ Hz$

e) $\lambda_n = \frac{2}{n}\ell = \frac{2}{60}(2m) = 0.07m$

f) $f_n = \frac{v}{\lambda_n} = \frac{404\ m/s}{0.07\ m} = 6060\ Hz$

g) 6060 Hz

h) 343 m/s

i) $v = \frac{\lambda}{T} = \lambda f$

$\lambda = \frac{v}{f} = \frac{343\ m/s}{6060\ Hz} = 0.057m$

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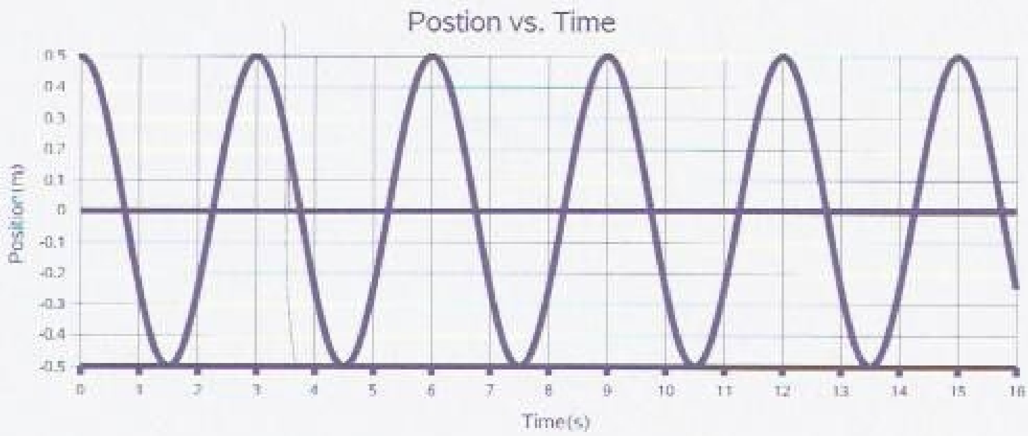
Problem Two (10 Points):



A 20 kg mass is attached to a spring and placed on a frictionless table. The mass is pulled out to x = +A and released. The mass oscillates between +A and -A. A plot of position of the mass versus time is shown above.

a.) What is the amplitude of the motion of the mass? 0,5m

b.) What is the period of the motion of the mass? 3 s

c.) What is the frequency of the motion of the mass? $f = \frac{1}{T} = 0{,}33\ Hz$

d.) What is the angular frequency of the motion of the mass? $\omega = \frac{2\pi}{T} = 2{,}09\ s^{-1}$

e.) What is the maximum velocity of the motion of the mass? $v = A\omega = 1{,}05\ m/s$

f.) What is the maximum acceleration of the motion of the mass? $a = A\omega^2 = 2{,}19\ m/s^2$

g.) Write three specific equations for this motion of **THIS** mass, one for position versus time, one for velocity versus time, and one for acceleration versus time.

$x(t) = 0{,}5m \cos(2{,}09 s^{-1} t)$

$v(t) = -1{,}05\ m/s \sin(2{,}09 s^{-1} t)$

$a(t) = -2{,}19\ m/s^2 \cos(2.09 s^{-1} t)$

h.) What is the position of the mass at t = 3.5 seconds (Do not read from the plot) 0,26m

$x(3{,}5s) = 0{,}5m \cos(2{,}09 s^{-1} (3{,}5s)) = 0{,}26m$

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Problem Three (5 Points):

A student "A" holds a 1000 Hz tuning fork and runs towards a wall where another student "B" at a speed of 3.0 m/s. The sound from the tuning fork, reflects off the wall and reaches student "A".

a.) What is the frequency of the sound heard by student "B"? 1008.8 Hz

b.) What is the beat frequency heard by student "A" ? 8.82 Hz

$$f = f_0 \left(\frac{v \pm v_o}{v \mp v_s} \right)$$ Top Sign Approaching

a) $f = f_0 \left(\frac{v}{v - v_s} \right) = 1000\,Hz \left(\frac{343\,m/s}{343\,m/s - 3\,m/s} \right) = 1008.8\,Hz$

b) $f = f_0 \left(\frac{v + v_o}{v} \right) = 1008.8\,Hz \left(\frac{343\,m/s + 3\,m/s}{343\,m/s} \right) = 1017.6\,Hz$

$f_{beat} = 1017.6\,Hz - 1008.8\,Hz = 8.82\,Hz$

Extra Credit (5 Points):

Using conservation of energy, prove that the maximum velocity of the mass in Problem Two is:

$$v_{max} = A\omega$$

$$E_i = E_f$$

$$\frac{1}{2}kA^2 = \frac{1}{2}kx^2 + \frac{1}{2}mv^2$$

$$\frac{1}{2}kA^2 = 0 + \frac{1}{2}mv_{max}^2$$

$$v_{max} = \sqrt{\frac{kA^2}{m}} = \sqrt{\frac{k}{m}}A = A\omega$$

$$x = A\cos(\omega t + \phi)$$

$$v = -A\omega\sin(\omega t + \phi)$$

$$a = -A\omega^2\cos(\omega t + \phi)$$

$$ma = -kx$$

$$m(-A\omega^2\cos(\omega t + \phi)) = -k(A\cos(\omega t + \phi))$$

$$m\omega^2 = k$$

$$\omega = \sqrt{\frac{k}{m}}$$