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**General Physics I, Final 1**
PHYS10000AA, AB, AC, Class year 109
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SN:____________________, Name:________________________

**ABSOLUTELY NO CHEATING!**

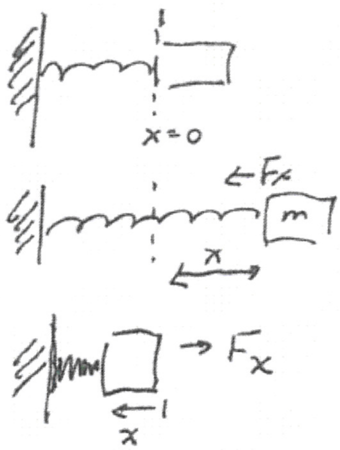
*Note: This is a close-book examine. You can use pencil or any pen in answering the problems. Dictionary and Calculators are NOT allowed.*

**<u>Problems (5 Problems, total 100%)</u>**

1. **<u>Thermal energy, molar heat and first law (30%):</u>** (a, 5%) A heating element is rated as "150W". What amount of energy will this heating element provide each minute? (b, 15%) A 150W heater is placed in 1 Kg of methanol and turned on for exactly 1 minute. The temperature increased by 3.54°C. Assuming that all the heat is absorbed by the methanol, calculate the molar heat capacity for liquid $CH_3OH$. (c, 10%) A 1/4hp (0.25 horse power) motor uses 187W of electric energy while delivering 35J of work each second. How much heat must be dissipated in the form of friction (heat)?

2. **<u>Simple harmonic Oscillation (20%):</u>** A vertically suspended spring of negligible mass and force constant $\boldsymbol{k}$ is stretched by an amount $\boldsymbol{l}$ when a body of mass $\boldsymbol{m}$ is hung on it. The body is pulled by hand an additional distance $\boldsymbol{y}$ downward and then released. (a, 10%) Show that the motion of the body is governed by the equation a=-ky/m, so that the body executes harmonic motion about it equilibrium position, and (b, 10%) show that the period of this motion is the same as that of a simple pendulums of length $\boldsymbol{l}$.

3. **<u>Simple Harmonic system (20%):</u>** Refer to the figure to the right for a very simple mass-spring system. The attached mass is $\boldsymbol{m}$, and the spring has a spring constant $\boldsymbol{k}$. (a, 5%) Start from Newton's law, if you pull the mass with displacement $\boldsymbol{x}$, and release it; it will start to oscillate. What is its acceleration $\boldsymbol{a}$? (b, 5%) Write down the differential equation that describes the oscillation. (c, 5%) Demonstrate, without solving it, that $x(\mathrm{t}) = Cos\,(\varpi \mathrm{t} + \phi)$ is one of the possible solutions of the equation. (d, 5%) Solve the period of the oscillation.




4. **<u>Escape Speed (15%)</u>:** Estimate the size of a rocky sphere with a density of 3.0 g/cm$^3$ from the surface of which you could just barely throw away a golf ball and have it never return. (Assume your best throw is 40 m/s).

5. **<u>Doppler effect (15%):</u>** If a sound wave has a speed $v$ and frequency $f$. What is the detected frequency when the source is moving at speed $v_s$ towards the detector and the detector is stationary? Derive this.

1. (a) 150W means $150\,\text{joule}/\text{sec}$, Therefore for one minute. it will provides $150\,\text{j}/\text{sec} \times 60\,\text{sec} = 9000$ joule

(b)

$$\Delta Q = 9000\,\text{j} = n\int_{T_1}^{T_2} C_p\, dT. = n\, C_p\, \Delta T$$

$$\therefore\ 9000\,\text{j} = \frac{1000\,g}{32\,g/\text{mole}} \cdot C_p \cdot 3.54\,K$$

$$\rightarrow C_p = 81.35\ \text{j}/K.\text{mole}$$

Note : the molecular weight for methanol $CH_3OH$
$= 12 + 3 + 16 + 1$
$= 32$

(c) $W = 35\,J$

Internal energy changes is $\Delta E_{int} = 187\,J$

$\therefore\ Q = \Delta E_{in} - W = 187\,J - 35\,J = 152\,J$

This much heat (152J) will be disscipated due to friction in the motor.

2. (a) The initial equilibrium is from the weight of the object
$mg = kl$

now the object is pulled by an addition force a distance $y$

The force $F = mg - k(l+y) = -ky = ma$

↑ the harmonic oscillation by pulling it $y$ downward

$\therefore\ f = ma = -ky$

$\rightarrow a = -\frac{ky}{m}$

(b) Since $mg = kl$, $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{kl}{g}\frac{1}{k}} = 2\pi\sqrt{\frac{l}{g}}$

The period is the same as a simple pendulum.

3. (a) $F = -kx = ma_x \quad \therefore a_x = -\frac{k}{m}x$

(b) $a_x = \frac{dV_x}{dt} = \frac{d}{dt}\left(\frac{dx}{dt}\right) = \frac{d^2x}{dt^2} = -\frac{k}{m}x$

$\rightarrow \underbrace{\frac{d^2x(t)}{dt^2} + \frac{k}{m}x(t) = 0}$ 2nd order differential equation to describe the Oscillation of m attached to a Spring of force constant k.

(c) To see if $x(t) = A\cos(\omega t + \phi)$ is one of the solutions to differential equation in (b). We simply have to plug in the $x(t)$ into the equation

$$\frac{d^2x(t)}{dt^2} = \frac{d}{dt}\left[\frac{d(x(t))}{dt}\right] = \frac{d}{dt}\left[\frac{d}{dt}(A\cos(\omega t + \phi))\right]$$

$$= \frac{d}{dt}\left[-A\omega\sin(\omega t + \phi)\right]$$

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

$$= -\omega^2 x(t)$$

Compare this with (b)

$\rightarrow \frac{d^2x(t)}{dt^2} + \omega^2 x(t) = 0 \rightarrow$ that is $\omega^2 = \frac{k}{m} \rightarrow \omega = \sqrt{\frac{k}{m}}$

Therefore it can be a Solution of the differential equation.

(d) Let the period of the Oscillation be T

then $x(t) = x(t+T)$

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

$$\therefore \omega(t+T) + \phi - (\omega t + \phi) = 2\pi$$

$$\therefore \omega T = 2\pi, \text{ or } \underline{T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}}}$$

4. Let the rocky splere have mass M. $\rho = 3.0\ g/cm^3$
from the surface if you want to throw a golf ball and it never return (i.e. it escape the sphere), you use your best to throw, $v = 40\ m/s$
from conservation of energy

$$\frac{1}{2} m v_0^2 = \frac{GMm}{R}$$

$M$ = mass of the sphere
$= \rho \frac{4}{3} \pi R^3$

$R$ = the radius of the splere

then

$$\frac{1}{2} m v_0^2 = \frac{G \rho \frac{4}{3} \pi R^3 m}{R}$$

$V_0$ = highest speed you can throw

$G$ = Gravitational constant

$$\rightarrow R = v_0 \sqrt{\frac{3}{8\pi G \rho}}$$

5.


When the source moves toward the detector with a speed $V_s$, the wavefront moves @ speed $v$
and the wavefront moves a distance $vT$ in one period of time, $T$ $(W_1)$. The source moves $V_s T$ distance for time $T$. $(W_2)$
The distance between these two $W_1$ and $W_2$ is the wavelength $\lambda'$ detected

$$\lambda' = vT - V_s T$$

$$\therefore f' = \frac{v}{\lambda'} = \frac{v}{vT - V_s T} = \frac{v}{\frac{v}{f} - \frac{V_s}{f}} = f \frac{v}{v - V_s}$$