NAME: ___________________________  KEY  Pledge: ____________________________  

Please answer all questions concisely. With the exception of the numerical problems, most questions can be answered in two or three sentences at most (phrase your answers carefully!). Show all work on the numerical problems so that partial credit can be given. You are welcome to use your calculator. Please remember to sign the honor pledge. Total possible points = 100.

1) (10 pts) Define, identify or state the following (explain in words any equation you use):

a) latent heat of fusion
- the heat necessary to bring about the fusion/melting phase transformation. This heat does not change temperature of the material.

b) heat pump
- a device used to transfer heat from a low temp. region to a high temp. region. Example: air conditioner or refrigerator. Heat in + work = heat out

c) harmonic oscillator
- any object undergoing oscillation according to a linear restoring force, or a force that is linearly proportional to displacement. Example: spring with \( F = -kx \) (Hooke’s law)

d) torque
- torque is a vector quantity that causes an angular acceleration according to \( \tau = I \alpha \) where \( \tau \) = net torque and \( \alpha \) = angular acceleration, \( I \) = moment of inertia

e) specific heat
- the amount of heat needed to raise 1 gram of a substance one degree Celsius. Each material has its own peculiar specific heat.

2) (10 pts) In order to stop a 1000 kg automobile moving at 25 m/s, a force of 5000 N is applied against the vehicle. Over what distance must this force be applied?

\[
\text{Work} = \text{force} \times \text{distance} = \Delta KE = \frac{1}{2}mv^2 - 0
\]

\[
\frac{1}{2} (1000 \text{kg}) (25 \text{m/s})^2 = (5000 \text{N}) \cdot x
\]

Solve for \( x = 62.5 \text{ m} \)
3) (10 pts) Suppose you lift your 1 kg physics textbook from the floor of your room to a height of 2 m.
   a) How much mechanical work is done to lift the book?
      \[ W = F \cdot d = m \cdot g \cdot h = (1 \text{ kg}) (9.8 \text{ m/s}^2)(2 \text{ m}) = 19.6 \text{ J} \]
      (Assume no acceleration)
   b) How much work is done in holding the book while you walk 3.5 m across the room?
      None (displacement \& force means no work!)
   c) If you drop the book to the floor from a height of 2 m, how much kinetic energy will the book have
      just before hitting the floor? What happens to this kinetic energy?
      \[ KE = 19.6 \text{ J} \] Converts to sound + heat energy

4) (10 pts) A pendulum of 3 kg is pulled back so that the mass is raised 25 cm. The mass is then
   released. What will be the pendulum's maximum speed? Where does this occur? (Neglect air friction.)
   \[ \text{Max speed at bottom of swing. Conservation of mech. energy:} \]
   \[ \frac{1}{2}mv^2 = 2gh \]
   \[ v = \sqrt{2gh} = \sqrt{2 \cdot 9.8 \text{ m/s}^2 \cdot 0.25 \text{ m}} = 2.2 \text{ m/s} \]

5) (10 pts) a) On a warm summer day you climb into your car and notice that the metal seat belt buckle
   is too "hot" to touch, and yet the cloth part of the belt is not very "hot". Why is this? Explain briefly.
   Both buckle + cloth are at same temperature. However, metal buckle is a good conductor, so it conducts heat to your skin.
   b) When you stand in the sunshine on a sunny day, by what heat transfer mechanism does the sun heat
   your body?
      Radiation
   c) Give two reasons that damp skin will cool itself when the wind blows.
      1. damp skin dries by evaporation - taking latent heat of vaporization from your skin. Wind replaces this air with dry air, speeding up vaporization.
      2. wind blows away layer of air near your skin warmed by your body - thus lowering ambient temperature, so body cools faster. (Wind chill)
6) (10 pts) A heat engine operates between heat reservoirs at 700 K and 250 K. In each cycle of operation, the engine takes in 500 kJ of heat from the hot reservoir. What is the minimum amount of heat that it must reject to the cold reservoir?

\[ Q_\text{H} = 500 \text{kJ} \]

Minimum heat loss to cold reservoir occurs for Carnot efficiency \( e_c \)

\[ e_c = 1 - \frac{T_c}{T_H} = 1 - \frac{250}{700} = 0.64 \text{ or } 64\% = \text{max possible efficiency} \]

\[ 64\% = 0.64 = 1 - \frac{Q_c}{Q_\text{H}} \text{ or } \frac{Q_c}{Q_\text{H}} = 0.36 \]

\[ Q_c = 0.36(500 \text{kJ}) = 180 \text{kJ} \]

7) (10 pts) A cooling fan is turned off when it is running at 850 revolutions/min. It turns 1500 revolutions before it comes to a stop. Assume the fan decelerates uniformly. How long does it take the fan to come to a complete stop?

\[ \text{Rotational kinematics: } V^2 = V_0^2 + 2\alpha x \Rightarrow w^2 = w_0^2 + 2\alpha \Delta \theta \]

\[ w_0 = 2\pi \left(\frac{850 \text{rev}}{\min}\right) \]

\[ w = 0\Delta \theta = 1500 \text{rev} \Rightarrow 2\pi \cdot 1500 \text{ rad} \]

\[ \text{Find } \alpha \frac{w^2 - w_0^2}{2\Delta \theta} = \alpha = \frac{-\left(2\pi \cdot 850 \text{ rad/min}\right)^2}{2 \cdot 3000 \text{ rad}} = \frac{-1513 \text{ rad/min}^2}{-1513 \text{ rad/min}^2} \]

\[ w = w_0 + \alpha t \text{ so } t = \frac{w - w_0}{\alpha} = \frac{0 - 2\pi \cdot 850 \text{ rad/min}}{-1513 \text{ rad/min}^2} = 3.5 \text{ min} \text{ or } 210 \text{ sec} \]

8) (10 pts) Three children are trying to balance on a seesaw which consists of a fulcrum and a very light board 3.6 m long. Two children are already at either end. Where should girl C place herself so as to balance the seesaw?

To balance: net torque must = 0

Assume clockwise rotation = positive

\[ \tau = \text{force } \times \text{lever arm} \]

\[ -50 \text{ kg} \cdot g \cdot (1.8 \text{ m}) + (35 \text{ kg})(g)(1.8 \text{ m}) + (25 \text{ kg})g \cdot x = \text{total net torque} = 0 \text{ for balance} \]

So \(-50g(1.8) + 35g \cdot 1.8m + 25g \cdot x = 0\)

\( -90 + 63 + 25x = 0 \text{ Solve for } x = 1.1 \text{ m} \)

So \([1.1 \text{ meter}] \text{ to right of fulcrum} \)
9) (10 pts) How much energy does a freezer have to remove from 1.5 kg of water at 20°C to make ice at 0°C? The specific heat of water is 4186 Joules/kg°C, and the latent heat of fusion for water is \(3.33 \times 10^5\) J/kg.

\[
\text{Need to remove heat to cool from } 20^\circ C \rightarrow 0^\circ C \\
\text{Need to remove heat to freeze (latent heat of fusion!)} \\
20 \rightarrow 0^\circ C \quad (1.5 \text{ kg})(20^\circ C \cdot (4186 \text{ J/kg°C}) = 125,580 \text{ J} \\
\text{Freezing: } (3.33 \times 10^5 \text{ J/kg})(1.5 \text{ kg}) = 499,500 \text{ J} \\
\text{Total } = (6.3 \times 10^5 \text{ J})
\]

10) (10 pts) Suppose you are rotating a ball on a string in a circle. If you allow the string to wrap around your finger, does the rotational velocity of the ball change or stay the same as the string shortens? Explain.

\[
\text{KE} = \frac{1}{2} m v^2 \quad \text{but} \quad v = \omega r \quad \text{for rotational motion} \\
\text{So } KE = \frac{1}{2} m w^2 r^2 = \frac{1}{2} mr^2 \omega^2 = \frac{1}{2} I \omega^2 \\
\text{KE will remain constant (why? no work being done)} \\
\text{So as } r \text{ decreases, } w \text{ must increase to keep } KE = \text{constant!} \\
\text{Also } L = I \omega \text{ is constant as } I v, \omega \text{ must increase!}
\]

Useful information and equations:

\[
\begin{align*}
F &= ma \\
W &= Fd \\
a &= \frac{v^2}{r} \\
k &= 9.0 \times 10^9 \text{ Nm}^2/\text{C}^2 \\
c &= 1.6 \times 10^{-19} \text{ C} \\
d &= v_0 t + \frac{1}{2} a t^2 \\
v(t) &= v_0 + at \\
P &= \frac{W}{t} \\
G &= 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2 \\
v &= \omega r \\
^\circ C &= \text{Kelvin} - 273^\circ \\
\frac{1}{2} kx^2 &= \frac{1}{2} m v^2 \\
Q &= mc\Delta T \\
Q &= mL_f \\
L &= I\omega \\
\tau &= Ia
\end{align*}
\]