Exam 4 - Review Problems

Name: ________________________________

1. In winter why does the temperature not rise more than a few degrees above freezing as long as there is snow cover?

2. Joe (70kg) rides his 5.0 kg sled at a constant velocity 30 meters down a slight incline covered in snow. If he changes his elevation by 10 meters during this ride, find the average force of friction acting on the sled.

3. Disappointed, Joe (70kg) waxes his 5.0 kg sled and rides 30.0 meters down a steeper snowy mountain that makes an angle of 25^o with the horizontal. The coefficient of friction between the sled and the incline is now 0.15.
    a. Use the concepts of work and energy to solve for the final velocity of the sled.
    b. Now use Newton's Laws to solve for the final velocity (this should match your value from a).
    c. How much snow is melted by the sled if the snow is at 0^oC?

4. A 5 kg block of ice is initially at -65 ^oC and then combined with 1 kg of steam at 110^oC. What is the final temperature of the system, what is the final mass of ice, water and steam?

$W = F\,\Delta x = \Delta E$ $\quad K = \frac{1}{2} m v^2$ $\quad U_g = mgh$ $\quad U_s = \frac{1}{2} k x^2$

$g = 9.8\ \text{m/s}^2$ $\quad K_r = \frac{1}{2} I \omega^2$ $\quad P = W/\Delta t = F v$

$T_C = T - 273.15\,^\circ C$ $\quad T_F = (9\,^\circ F/5\,^\circ C)\, T_C + 32\,^\circ F$

$K_{avg} = 3/2\, k_B T$ $\quad E_{th} = 3/2\, N k_B T$ $\quad v_{rms} = \sqrt{\frac{3k_B T}{m}}$ $\quad k_B = 1.38 \times 10^{-23}\ J/K$

$\Delta L = \alpha L_i \Delta T$ $\quad \Delta V = \beta V_i \Delta T$

$Q = Mc\Delta T$ $\quad Q = +/- M L_f$ $\quad Q = +/- M L_v$

$\vec{p} = m\vec{v}$ $\quad \vec{F}\,\Delta t = \Delta\vec{p}$ $\quad \vec{p}_i = \vec{p}_f$ $\quad \Sigma\vec{F} = m\vec{a}$

$v_x = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{\Delta t}$ $\quad a_x = \frac{\Delta v_x}{\Delta t} = \frac{v_{xf} - v_{xi}}{\Delta t}$

$x_f = x_i + v_{xi}\Delta t + \frac{1}{2} a_x (\Delta t)^2$ $\quad v_{xf} = v_{xi} + a_x \Delta t$ $\quad v_{xf}^2 = v_{xi}^2 + 2a_x (\Delta x)$

$\sin\theta = \text{opp/hyp}$ $\quad \cos\theta = \text{adj/hyp}$ $\quad \tan\theta = \text{opp/adj}$

$a^2 + b^2 = c^2$

TABLE 12.4 Specific heats of solids and liquids

Substance	c (J/kg · K)
Solids	
Lead	128
Gold	129
Copper	385
Iron	449
Aluminum	900
Water ice	2090
Mammalian body	3400
Liquids	
Mercury	140
Ethyl alcohol	2400
Water	4190

TABLE 12.3 Coefficients of linear and volume thermal expansion at 20°C

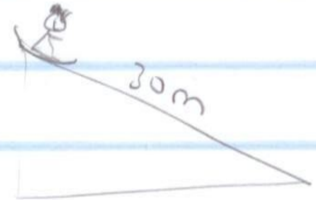
Substance	Linear α (K^{-1})	Volume β (K^{-1})
Aluminum	23×10^{-6}	69×10^{-6}
Glass	9×10^{-6}	27×10^{-6}
Iron or steel	12×10^{-6}	36×10^{-6}
Concrete	12×10^{-6}	36×10^{-6}
Ethyl alcohol		1100×10^{-6}
Water		210×10^{-6}
Air (and other gases)		3400×10^{-6}

TABLE 12.5 Melting and boiling temperatures and heats of transformation at standard atmospheric pressure

Substance	T_m (°C)	L_f (J/kg)	T_b (°C)	L_v (J/kg)
Nitrogen (N_2)	−210	0.26×10^5	−196	1.99×10^5
Ethyl alcohol	−114	1.09×10^5	78	8.79×10^5
Mercury	−39	0.11×10^5	357	2.96×10^5
Water	0	3.33×10^5	100	22.6×10^5
Lead	328	0.25×10^5	1750	8.58×10^5

1. The energy from the sun is in the form of radiation. It typically is transformed into thermal energy when it's absorbed by the ground and air. This thermal energy can either go into increasing the temperature of the objects or a phase change.

Snow at 32°F or 0°C is at the melting point of water so the energy from the sun has to melt the snow before it can raise the temperature of the snow. It takes a lot more energy to convert ice to water per kilogram than it does to increase the temperature. So the snow has to melt before it can become a nice warm day.

2. 

$K_i = K_f$ ← constant velocity

$$U_{gi} + K_i = U_{gf} + K_f + E_{th}$$

✓ work done by friction transfers energy to thermal

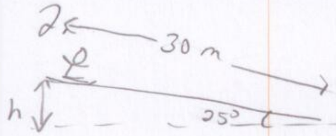
$$mgh_i + K_i = 0 + K_f + W_f \qquad K_i = K_f$$

$$mgh_i = W_f$$

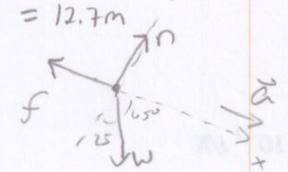
$$mgh_i = f \cdot d$$

$$75kg \; 9.8 \, m/s^2 \; 10m = f \cdot 30m$$

$$\boxed{245N = f}$$



$h = 30m \sin 25°$
$= 12.7m$



$\Sigma F_y = n - W\cos 25° = 0$

$n = mg\cos 25°$

$f = \mu n = \mu mg\cos 25°$

a. $U_{gi} + K_i = U_{gf} + K_f + E_{TH}$ ← Energy lost to heat due to the work of friction.

$mgh_i + 0 = 0 + \frac{1}{2}mv_f^2 + f\Delta x$

$\frac{2(mgh - f\Delta x)}{m} = v_f^2$

$\frac{2(mgh - \mu mg\cos 25° \Delta x)}{m} = v_f^2$

$\sqrt{2\,(9.8 \frac{m}{s^2} \cdot 12.7m - 0.15\, 9.8 \frac{m}{s^2} \cos 25°\, 30m)} = v_f$

$\boxed{12.98 \frac{m}{s} = v_f}$

||NOTE|| part b is not going to be on Exam 4 because it fits Ch 4 & 5. However it is appropriate for the final.

b. $\Sigma F_x = W\sin 25° - f = ma$ Find acceleration

$\Sigma F_y = n - W\cos 25° = 0$ Then use kinematics to find the velocity.

$mg\sin 25° - \mu mg\cos 25° = ma$

$9.8 \frac{m}{s^2} \sin 25° - 0.15\, 9.8 \frac{m}{s^2} \cos 25° = a$

$2.809 \frac{m}{s^2} = a$

$v_f^2 = v_i^2 + 2a\Delta x$

$v_f = \sqrt{2a\Delta x}$

$= \sqrt{2\,(2.809 \frac{m}{s^2})\, 30m}$

$\boxed{v_f = 12.98 \frac{m}{s}}$

$E_{TH} = f\Delta x$

$Q = mc\Delta T$

c. Thermal energy either increases the temperature or it causes a phase transition. Here the snow is at 0°C so it will melt if heat is added.

$E_{TH} = 0.15\; 75kg\; 9.8 \frac{m}{s^2} \cos 25° \cdot 30m = 2997 J$

$\frac{2997 J}{3.33 \times 10^5 J/kg} = \boxed{0.009 kg}$

4. First I will determine how much energy is lost when the steam cools from 110 to 100°C. Then I'll find energy lost when steam condenses to liquid water. Then I'll compare this to the heat gained by the ice when it's temperature is increased from −65°C to 0°C plus the heat gained by melting the ice.

Steam from 110 to 100°C $mc\Delta T = 1.0kg\ 2010\ J/kgK(100-110) = -20{,}100J$

Steam to water (condense) − $ML_v = 1.0kg\ 2.26\times10^6\ J/kg = -2{,}260{,}000J$

$-2{,}280{,}100J$

ice from −65 to 0°C $mc\Delta t = 5.0kg\ 2090\ J/kgK(0-65) = 679{,}250J$

ice to water (melt) $ML_f = 5.0kg\ 3.33\times10^5\ J/kg = 1{,}665{,}000\ J$

$2{,}344{,}250J$

When you analyze the above values you can see that it takes more heat to warm the ice (−65 to 0) and melt the ice than it does to cool the steam (110 to 100) and condense the steam. So you need more heat out of the steam to finish melting the ice. The math above leaves the steam at 100°C and the ice at 0°C so there's still a temperature difference. Let's check to see if there's enough energy available in the hot water that was steam to melt the remaining ice.

condensed steam from 100°C to 0°C $mc\Delta T = 1.0kg\ 4186\ J/kgK(0-100) = 418{,}600J$

We needed 2,344,250J − 2,280,100 = 64,150J and the hot water has 418,600J so it will easily melt all the ice. So we now know T_F is between 0°C & 100°C and all of our ice & steam have been converted to liquid water.

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$$Q_{lost} + Q_{gained} = 0$$

$$Q_{steam\ 110\to100} + -Q_{condense} + Q_{water\ 100°\to T_F} + Q_{ice\ -15\to0} + Q_{melt} + Q_{water\ 0°\to T_F} = 0$$

$$-20{,}100J + -2{,}260{,}000J + 1.0kg\ 4186(T_F - 100°C) + 679{,}250J + 1{,}665{,}000J + 5kg\ 4186(T_F - 0) = 0$$

$$-2{,}280{,}100J + 4186T_F - 418{,}600J + 2{,}344{,}250J + 20{,}930T_F = 0$$

$$-354{,}450J + 25{,}116T_F = 0$$

$$T_F = \frac{354{,}450J}{25{,}116J/K}$$

$$\boxed{T_F = 14.1°C}$$