Phys 220, Fall 2014
Exam 4

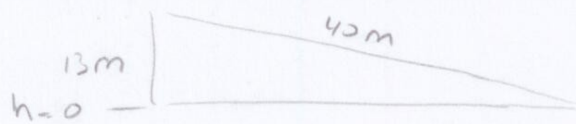
Name: Solution

1. A ball is thrown up with an initial velocity of 7.67 m/s. Use the conservation of energy to find the maximum height that it reaches.
   a. 0.8 m
   b. 1.0 m
   c. 1.25 m
   d. 3.0 m

$$mgh_{init} + \tfrac{1}{2}mv_i^2 = mgh_f + \tfrac{1}{2}mv_f^2$$
$$0 + \tfrac{1}{2}\cancel{m}v_i^2 = \cancel{m}gh_f + 0$$
$$\frac{\tfrac{1}{2}v_i^2}{g} = h_f = \frac{\tfrac{1}{2}(7.67\,m/s)^2}{9.8\,m/s^2} = 3.0\,m$$

Joe (70kg) rides his 5.0 kg sled 40.0 meters down a slight incline covered in snow. If he changes his elevation by 13 meters during this ride,

2. What is Joe's potential energy at the top of the hill with respect to the bottom of the hill?
   a. 29,400 J
   b. 9,555 J
   c. 7,350 J
   d. 0 J



$$mgh = 75kg\ 9.8\,m/s^2\ 13m = 9,555J$$

3. Determine Joe's final speed if we ignore friction on the slope.
   a. 14 m/s
   b. 13 m/s
   c. 16 m/s
   d. Not enough information

$$9,555J = \tfrac{1}{2}mv^2 = \tfrac{1}{2}\,75kg\,v^2$$
$$v = 15.96\,m/s$$

4. If we include friction, it turns out that Joe travels at a constant speed down this slope. Find the amount of snow melted by the sled from traveling the 40.0 meters at constant speed.
   a. 0.088 kg
   b. 0.029 kg
   c. 0.022 kg
   d. 0.013 kg

$$9,555J = mL = m\ 3.33\times10^5\,J/kg$$
$$0.0287kg = m$$

A 20 kg box is pushed with an applied force of 30 N on a horizontal surface over a distance of 5 meters?

5. How much work is done by gravity on the box?
   a. 0 J
   b. 150 J
   c. -150 J
   d. 980 J
   e. –980J

$$W = F \cdot \Delta x$$

There is no Δx in the y direction.

6. How much work is done by the applied force on the box?
   a. 0 J
   b. 150 J
   c. -150 J
   d. 980 J
   e. –980J

$W = F \cdot \Delta x$
$= 30N \cdot 5m$
$= 150J$

7. What is in the bubbles of boiling water?
   a. Air
   b. Hydrogen Gas and Oxygen Gas
   c. Water vapor
   d. Empty Space

8. In perfectly elastic collisions
   a. only momentum is conserved.
   b. only mechanical energy is conserved.
   c. both momentum and mechanical energy are conserved.

9. In perfectly inelastic collisions
   a. only momentum is conserved.
   b. only kinetic energy is conserved.
   c. both momentum and kinetic energy are conserved.

10. Consider a giant oak tree. Where does the largest fraction of the dry mass of the tree come from?
   a. Water
   b. Minerals in the soil
   c. Sun
   d. Oxygen
   e. Carbon

11. What causes the atmosphere to be denser at lower altitudes?
   a. There is more pressure
   b. The air is hotter
   c. There are more molecules
   d. gravity

12. Convert 300 °F to Celsius and Kelvin
   a. 135 °C, 408 K
   b. 149 °C, -124 K
   c. 149 °C, 422 K
   d. 242 °C, 515 K
   e. 572 °C, 299 K

$T_F = 9/5\, T_C + 32°F$

$\frac{5}{9}(T_F - 32°F) = T_C$

$5/9(300°F - 32°F) = T_C$
$= 148.9°C$

$T = T_C + 273$
$= 421.9\ K$

13. Is -200 °C colder, warmer or equal to -200 °F?

   a. colder
   b. warmer
   c. equal

$T_F = \frac{9}{5} T_C + 32\,°F$

$= \frac{9}{5}\,(-200\,°C) + 32\,°F = -328\,°F$

14. Two samples of ideal gas, sample 1 and sample 2, have the **same thermal energy**. Sample 1 has **twice as many atoms** as sample 2. What can we say about the temperatures of the two samples?

   a. $T_1 > T_2$
   b. $T_1 = T_2$
   c. $T_1 < T_2$

S_1: $\boxed{2N_2}$ $\quad$ S_2: $\boxed{N_2}$

$E_{TH_1} = E_{TH_2}$

$E_{TH} = N \frac{3}{2} k_B T$

$2N_2 \frac{3}{2} k_B T_1 = N_2 \frac{3}{2} k_B T_2$

$T_2 = 2T_1$

15. A balloon contains one mole of air which is mostly nitrogen (2.325×10^{-26} kg). You take it outside on a very hot day, 38°C. What is the thermal energy of the gas in the balloon?

   a. 3.1×10^{-22} J
   b. 6.5×10^{-21} J
   c. 3200 J
   d. 3900 J

$E_{TH} = N \frac{3}{2} k_B T$

$= 6.022 \times 10^{23} \cdot \frac{3}{2} \cdot 1.38 \times 10^{-23} \frac{J}{K} \cdot 311\,K$

$= 3877\,J$

16. What is the rms speed of a nitrogen molecule (2.325×10^{-26} kg) at 38°C? (Nitrogen is diatomic)

   a. 530 m/s
   b. 1100 m/s
   c. 2750 m/s
   d. 3900 m/s

$V_{rms} = \sqrt{\frac{3 k_B T}{m}} = \sqrt{\frac{3 \cdot 1.38 \times 10^{-23} \frac{J}{K} \cdot 311\,K}{2 \cdot 2.325 \times 10^{-26}\,kg}}$

$= 526\,m/s$

$9 \times 10^{-6}\,k^{-1}$ $\quad$ $12 \times 10^{-6}\,k^{-1}$

17. A glass ring is tight around a solid iron rod. If we wish to loosen the ring to remove it from the rod, we should

   a. Decrease the temperature of the ring and rod
   b. Increase the temperature of the ring and rod
   c. Neither will work.

The rod will expand/shrink more than the glass ring if heated or cooled.

18. A concrete block is 3 m long, 0.5 meters high and 0.75 m wide during the hottest part of the day when it's 43°C. What is the change in length of the block when it is -7°C.

   a. 0.0003 m
   b. 0.00045 m
   c. 0.0020 m
   d. 0.0018 m
   e. 0.012 m

$\Delta L = \alpha L \Delta T$

$= 12 \times 10^{-6}\,k^{-1} \cdot 3\,m\,(-7°C - 43°C)$

$= 0.0018\,m$

19. A tea kettle is sitting over open flame (250°C) and the water has been boiling for 10 minutes. The steam coming out of the kettle is

   a. 0 °C
   b. < 100 °C
   c. 100 °C
   d. > 100 °C
   e. Not enough information

Heat goes into changing phase (water to steam)
Until the water is all converted, the temp will not rise above 100°C

20. In the demonstration where the pop can had a little bit of boiling water inside and was dipped upside down in cold water the can collapsed. Why was the can crushed?
    a. The warm air molecules inside quickly rushed out when they came in contact with the cold water.
    b. The hot and cold molecules react when they come in contact.
    c. The steam inside the can quickly condensed to water when it came in contact with the cold water causing the outside air molecules to crush the can.
    d. The steam inside the can quickly condensed to water when it came in contact with the cold water causing a vacuum that sucked the can in.

21. Describe the behavior of a substance that has a temperature of -20K? Explain why?

0K is absolute zero At that point all molecular motion ceaces. Temperature is the kinetic energy of molecules, when they stop moving, they have no kinetic energy. It's not possible to have negative kinetic energy.

For the following problems, ***show all work for credit.***

1. Two rams are running at each other and butt heads. The first ram has a mass of 50 kg and is traveling at 6 m/s and the other ram has a mass of 60 kg and is traveling at 7 m/s. The 50 kg ram bounces backwards at 2 m/s after the collision. On the last exam you found that the 60 kg ram kept going in the same direction at 0.33 m/s.
    a. State whether this was a perfectly elastic, elastic or perfectly inelastic collision.
    b. How much energy was converted to thermal energy during this collision?

2. A container holds 5.00 kg of steam at 150°C which is put in thermal contact with 1.00 kg of water at 0.00°C. What is the final temperature of the system? What is the final mass of steam? What is the final mass of water?
c_{water} = 4186 J/kg°C, c_{ice} =2090 J/kg°C, c_{steam} = 2010 J/kg°C, L_f =3.33 x 10^5J/Kg, L_v = 2.26 x 10^6J/kg

1. a. elastic They did not stick together (perfectly inelastic) and energy was converted to to other forms.

b. $\frac{1}{2}mv_{1i}^2 + \frac{1}{2}mv_{2i}^2 = \frac{1}{2}mv_{1f}^2 + \frac{1}{2}m_{2f}^2 + E_{TH}$

$\frac{1}{2}50kg(6\,m/s)^2 + \frac{1}{2}60kg(-7\,m/s)^2 = \frac{1}{2}50kg(-2\,m/s)^2 + \frac{1}{2}60kg(-0.33\,m/s)^2 + E_{TH}$

$900J + 1470J = 100J + 3.267J + E_{TH}$

$2370J - 103.267J = E_{TH}$

$\boxed{= 2270J}$

2. m_s 5.00kg @ 150°C

m_w 1.00kg @ 0.00°C

Steam to 100°C $Q = mc\Delta T = 5.00\text{kg}\ 2010 \frac{J}{kg \cdot °C} (100°C - 150°C) = -502{,}500\ J$

Steam to water $Q = mL = -5.00\text{kg}\ 2.26 \times 10^6 \frac{J}{kg} = -11{,}300{,}000\ J$

water to 100°C $Q = mc\Delta T = 1.00\text{kg}\ 4186 \frac{J}{kg \cdot °C} (100° - 0°C) = 418{,}600\ J$

water to steam $Q = mL = 1.00\text{kg}\ 2.26 \times 10^6\ J/kg = 2{,}260{,}000\ J$

From the above analysis I see that there's more energy released by the steam cooling to 100°C than is needed to warm the water to 100°C. That means the extra energy released is able to convert some of the water to steam.

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

Steam 150→100°C + Water 0°→100°C + m_7 water to steam = 0

$-502{,}500\ J + 418{,}600\ J + m L_v = 0$

$-83{,}900 + m\ 2.26 \times 10^6\ J/kg = 0$

$m = 0.037$ kg

So we have 5 kg Steam + 0.037kg = $\boxed{5.037\text{kg} = m_s}$

1kg water − 0.037 kg = $\boxed{0.963\ \text{kg} = m_w}$

Water and steam coexist at $\boxed{100°C = T_F}$

at atmospheric pressure.