Phys 220, Fall 2013

Exam 4

Version A

Name: Solution Lab Group: _________

Problems 1-3: A 2.0 kg book is resting on a table. The table top is 1.5 meters above the floor.

1. What is the potential energy of the book with respect to the table?
   - [✓ a.] 0 J
   - b. 3 J
   - c. 20 J
   - d. 29 J

$mgh = U_G$

$2.0kg\ 9.8^m/_{s^2}\ 0m = U_g = 0J$

2. The book is nudged off the table. What is the kinetic energy of the book just before it hits the floor?
   - a. 0 J
   - b. 3 J
   - c. 20 J
   - [✓ d.] 29 J

$U_{Gi} = K_F$

$mgh = K_F$

$2.0kg\ 9.8^m/_{s^2}\ 1.5m = K_F = 29.4J$

3. What is the speed of the book just before it hits the floor?
   - a. 0 m/s
   - b. 1.7 m/s
   - c. 4.4 m/s
   - [✓ d.] 5.4 m/s

$mgh = \frac{1}{2}mv^2$

$gh = \frac{1}{2}v^2$

$\sqrt{2gh} = v$

$\sqrt{2\ 9.8^m/_{s^2}\ 1.5m} = 5.4^m/_s$

4. How much work is done by gravity on the book if it is lifted off of the floor and put on a shelf 2.0 m above the floor?
   - a. 0 J
   - b. 29 J
   - c. - 29 J
   - d. 39 J
   - [✓ e.] - 39 J

$W = F \cdot d$

$= -mg \cdot 2.0m$

$= -2.0kg\ 9.8^m/_{s^2}\ 2.0m$

$= -39.2J$

5. A boy throws his sister's doll off a cliff high above the ravine below. The doll is thrown at an angle of 60 degrees and reaches a maximum height of 25 meters above the ravine before landing in the bottom. What is the doll's speed just before it hits the bottom of the ravine? (ignore air resistance)
   - a. 11 m/s
   - b. 16 m/s
   - [✓ c.] 22 m/s
   - d. 49 m/s

$U_{Gi} = K_F$

$\cancel{m}gh = \frac{1}{2}\cancel{m}v^2$

$\sqrt{2gh} = v$

$\sqrt{2\ 9.8^m/_{s^2}\ 25m} = 22.1^m/_s$

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

7. What makes a bigger explosion
    a. Pure oxygen
    b. Pure hydrogen
    [✓ c.] Hydrogen and oxygen
    d. b and c
    e. a, b and c

8. In perfectly inelastic collisions
    [✓ a.] only momentum is conserved.
    b. only mechanical energy is conserved.
    c. both momentum and mechanical energy are conserved.

9. When you lose 15 lbs, how did the largest fraction of the weight leave your body?
    a. Water (sweat, urine)
    b. Solid waste
    c. Energy
    d. Respiration – water vapor
    [✓ e.] Respiration – carbon dioxide

10. A nail sits out in the elements and rusts. Rusting is oxidation of iron where iron and oxygen combine to form iron oxide (rust). After rusting, the nail
    a. Weighs the same
    b. Weighs less than before
    [✓ c.] Weighs more than before

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

12. Convert 200 °F to Celsius
    [✓ a.] 93 °C
    b. 149 °C
    c. 182 °C
    d. 392 °C

$$T_F = \frac{9}{5} T_C + 32°F$$

$$\frac{5}{9}(T_F - 32°F) = T_C$$

$$\frac{5}{9}(200°F - 32°F) = 93°C$$

13. Is 600 °F colder, warmer or equal to 600 K?

    [✓ a.] colder
    b. warmer
    c. equal

$$T_C = 5/9(T_F - 32°F)$$
$$= 316°C$$
$$T = T_C + 273 = 589\ K$$

14. When the temperature of an ideal gas is increased, which of the following also increases? (1) The thermal energy of the gas; (2) the average kinetic energy of the gas; (3) the average potential energy of the gas; (4) the speed of the molecules in the gas.

    a. 1, 2, and 3
    b. 1 and 2
    c. 3 and 4
    [✓ d.] 1, 2 and 4
    e. All of 1–4

15. A helium balloon contains one mole of Helium (6.647 x 10^{-27}kg). You take it outside on a very cold day, -15°C. What is the thermal energy of the gas in the balloon? $-15°C + 273 = 258\ K$

    a. 3.1 x 10^{-22} J
    b. 5.3 x 10^{-21} J
    c. 186 J
    [✓ d.] 3200 J

$$E_{TH} = 3/2\ N k_B T$$
$$= 3/2\ 6.022\times10^{23}\ \text{molecules}\ 1.38\times10^{23}\ J/K\ \ 258K$$
$$= 3216\ J$$

16. What is the rms speed of a helium molecule (6.647 x 10^{-27}kg) at -15°C?

    a. 306 m/s
    b. 1350 m/s
    [✓ c.] 1270 m/s
    d. 3200 m/s

$$V_{rms} = \sqrt{\frac{2k_BT}{m}} = \sqrt{\frac{3\ 1.38\times10^{-23}\ J/K\ 258K}{6.647\times10^{-27}\ kg}}$$
$$= 1268\ m/s$$

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

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

$$\alpha_{AL} = 23\times10^{-6}\ K^{-1}$$
$$\alpha_{Fe} = 12\times10^{-6}\ K^{-1}$$

Alumnum expands more than iron when heated.

18. A glass of ice water has been sitting on a table for an hour and still has a little bit of ice in it. What is the temperature of the water?

    a. < 0 °C
    [✓ b.] 0 °C
    c. 100 °C
    d. > 0 °C
    e. b or d.

19. The reason suction cups stick to a wall is because
    a. The molecules of the suction cup and the wall form a weak bond.
    b. There is a vacuum formed behind the cup when you press it that sucks it to the wall.
    [✓ c.] There is a force outside the suction cup pushing it against the wall.

↑ air molecules

20. You purchase a coffee on a blustery winters' day. The barista puts a nice snug lid on the coffee made out of thin plastic with two little holes in the top, one to sip from and one for air. Which form of heat transfer does this lid insulate against?
    a. Conduction
    b. Convection
    c. Radiation
    [✓ d.] Evaporation
    e. It is a poor insulator.

21. Which of the following changes would allow your refrigerator to use less energy to run? (1) Increasing the temperature inside the refrigerator; (2) increasing the temperature of the kitchen; (3) decreasing the temperature inside the refrigerator; (4) decreasing the temperature of the kitchen.
    a. All of the above
    b. 1 only
    [✓ c.] 1 and 4
    d. 2 and 3

Smaller ΔT is easier to maintain.

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

22. Joe (70kg) rides his 5.0 kg sled at a constant velocity 40 meters down a slight incline covered in snow. If he changes his elevation by 15 meters during this ride,
    a. Find the average force of friction acting on the sled.
    b. How much snow is melted by the sled if it is at 0 °C?

23. A 5.00 kg block of ice is at -65 °C. It is put in thermal contact with 1.00 kg of water at 50.0°C. What is the final temperature of the system? What is the final mass of ice? 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

24. A 2,000 kg Mercury Monterey and a 2,300 kg Chrysler Imperial collide head on during a demolition derby. The Monterey was initially moving at 3 m/s and the Imperial at 10 m/s. The two cars lock bumpers after the collision. How much energy was converted to thermal energy?

Version B

22. Mass Joe + Sled = 75 kg

$U_{Gi} + K_i = \cancel{U_{Gf}}^{\to 0} + K_f + E_{TH}$

$K_i = K_f$ since constant velocity

$U_{Gi} = \cancel{K_f - K_i} + E_{TH}$

$mgh_i = E_{TH}$

$75\text{kg}\ 9.8\text{m/s}^2\ 20\text{m} = E_{TH}$

a. $= 14{,}700\text{J}$

Work done by friction transfeered the energy to Thermal

$E_{TH} = W_f = f \cdot d$

$14{,}700\text{J} = f \cdot 50\text{m}$

$\boxed{294\text{N} = f}$

b. $E_{TH} = Q = mL_F$

$14{,}700\text{J} = m\ 333{,}000\text{J/kg}$

$\frac{14{,}700\text{J}}{333{,}000\text{J/kg}} = \boxed{0.044\text{kg}}$

Version A

$75\text{kg}\ 9.8\text{m/s}^2\ 15\text{m} = E_{TH}$

$= 11{,}025$

$11{,}025\text{J} = f \cdot 40\text{m}$

$\boxed{276\text{N} = f}$

$11{,}025\text{J} = m\ 333{,}000\frac{\text{J}}{\text{kg}}$

$\frac{11{,}025\text{J}}{333{,}000\frac{\text{J}}{\text{kg}}} = m$

$\boxed{= 0.033\text{kg}}$

Version 3

23. 5.00kg ice @ $-65°C$

1.00kg water @ $60.0°C$

Heat Gained

ice $-65°C \rightarrow 0°C$ $\quad mc\Delta T = 5.00\text{kg}\ 2090\ \text{J/kg°C}\ (0°C - {}^{-}65°C)$

$= 679.250\text{J}$

Heat Lost

water $60°C \rightarrow 0°C$ $\quad mc\Delta T = 1.00\text{kg}\ 4186 \frac{\text{J}}{\text{kg°C}} (0°C - 60°C)$

$= -251,160\text{J}$

Freeze water $\quad {}^{-}mL = {}^{-}1.00\text{kg}\ 333,000 \frac{\text{J}}{\text{kg}}$

$= {}^{-}333,000\text{J}$

So I can see there is not enough energy lost by cooling water and then freezing it to bring the ice to 0°C. That means The ice cools the water, freezes it <u>and</u> cools it below 0°C.

heat lost + heat gained = 0

$$\underbrace{\text{Water } 60°C \rightarrow 0°C + \text{freeze water}}_{} + \text{new ice to } T_F + \text{ice } {}^{-}65°C \rightarrow T_F = 0$$

$$-251,160\text{J} + -333,000\text{J} + mC_i\Delta T + mC_i\Delta T = 0$$

$$-584,160\text{J} + 1.00\text{kg}\ 2090\frac{\text{J}}{\text{kg°C}}(T_F - 0°C) + 5.00\text{kg}\ 2090\frac{\text{J}}{\text{kg°C}}(T_F - {}^{-}65°C) = 0$$

$$-584,160\text{J} + 2090\frac{\text{J}}{°C}T_F + 10,450\frac{\text{J}}{°C}T_F + 679,250\text{J} = 0$$

$$12,540\frac{\text{J}}{°C}T_F + 95,050\text{J} = 0$$

$$T_F = \frac{{}^{-}95,090\text{J}}{12,540\ \text{J/°C}}$$

$$\boxed{= {}^{-}7.6°C}$$

$$\boxed{6.0\text{kg ice}}$$

[0kg water]

Version A

23. 5.00 kg ice @ -65°C
1.00 kg water @ 50.0°C

Heat Gained

ice $-65°C \to 0°C$ $\quad mc\Delta T = 5.00\text{kg}\ 2090\frac{J}{kg\cdot°C}(0°C - -65°C)$
$= 679,250\ J$

Heat Lost

water $50°C \to 0°C$ $\quad mc\Delta T$
$= 1.00\text{kg}\ 4186\frac{J}{kg\cdot°C}(0°C - 50°C)$
$= -209,300J$

Water to ice $\quad -mL$
$= -1.00\text{kg}\ 333,000\frac{J}{kg}$
$= -333,000J$

Cooling water and turning it to ice gives off 542,300J of energy but it would take 679,250J to warm the 5.0 kg chunk of ice to 0°C. So the ice does not warm all the way to 0°C. instead it only gets to some T_F below 0°C. That means the 1.0kg of water that froze also cools below 0°C to T_F.

heat lost + heat gained = 0

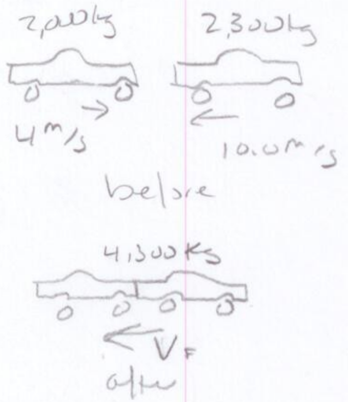
water 50°C → 0°C + freeze water + new ice 0°C → T_F + ice -65°C → T_F = 0

$-209,300\,J + -333,000\,J + mc_i(T_F - 0°C) + mc_i(T_F - -65°C) = 0$

$-542,300\,J + 1.0\text{kg}\ 2090\frac{J}{kg\cdot°C}T_F + 5.0\text{kg}\ 2090\frac{J}{kg\cdot°C}T_F + 679,250\,J = 0$

$12,540\frac{J}{°C}T_F + 136,950\,J = 0$ $\quad \boxed{T_F = -10.92°C}\ \boxed{6.0\text{kg ice}}$

24.



Collision:

$$m_1V_{1i} + m_2V_{2i} = m_1V_{1F} + m_2V_{2F}$$

$$m_1V_{1i} + m_2V_{2i} = (m_1+m_2)V_F$$

$$2000kg\ 4\,m/s + 2300kg(-10.0\,m/s) = 4300kg\ V_F$$

$$-3.5\,m/s = V_F$$

Energy

Version B

$$K_{1i} + K_{2i} = K_{1F} + K_{2F} + E_{TH}$$

$$\tfrac{1}{2}m_1V_{1i}^2 + \tfrac{1}{2}m_2V_{2i}^2 = \tfrac{1}{2}(m_1+m_2)V_F^2 + E_{TH}$$

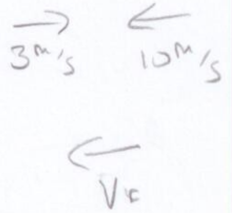
$$\tfrac{1}{2}\,2000kg\,(4\,m/s)^2 + \tfrac{1}{2}\,2300kg\,(-10\,m/s)^2 = \tfrac{1}{2}\,4300kg\,(3.488\,m/s)^2 + E_{TH}$$

$$16000\,J + 115{,}000\,J = 26{,}162\,J + E_{TH}$$

$$104{,}837\,J = E_{TH}$$

$$\boxed{105{,}000\,J = E_{TH}}$$

Version A



Collision:

$$2000kg\ 3\,m/s + 2300kg(-10.\,m/s) = 4300kg\ V_F$$

$$-3.95\,m/s = V_F$$

Energy:

$$K_{1i} + K_{2i} = K_{1F} + K_{2F} + E_{TH}$$

$$\tfrac{1}{2}m_1V_{1i}^2 + \tfrac{1}{2}m_2V_{2i}^2 = \tfrac{1}{2}(m_1+m_2)V_F^2 + E_{TH}$$

$$\tfrac{1}{2}\,2000kg(3\,m/s)^2 + \tfrac{1}{2}\,2300(10\,m/s)^2 = \tfrac{1}{2}\,4300kg\,(3.95\,m/s)^2 + E_{TH}$$

$$9000\,J + 115{,}000\,J = 33{,}605\,J + E_{TH}$$

$$90{,}395\,J = E_{TH}$$

$$\boxed{90{,}000\,J = E_{TH}}$$

Phys 220, Fall 2013
Exam 4
Version B

Name: Solution Lab Group: ________

Problems 1-3: A 1.7 kg book is resting on a table. The table top is 1.2 meters above the floor.

1. What is the potential energy of the book with respect to the table?
   - [✓ a.] 0 J
   - b. 3 J
   - c. 20 J
   - d. 29 J

$mgh = U_G$

$2.0\,kg\ 9.8\,m/s^2\ 0\,m = 0\,J$

2. The book is nudged off the table. What is the kinetic energy of the book just before it hits the floor?
   - a. 0 J
   - b. 3 J
   - [✓ c.] 20 J
   - d. 29 J

$U_{Gi} = K_F$

$mgh_i = K_F$

$1.7\,kg\ 9.8\,m/s^2\ 1.2\,m = 20.0\,J$

3. What is the speed of the book just before it hits the floor?
   - a. 0 m/s
   - b. ~~2.4 m/s~~ 2.1
   - c. ~~3.3 m/s~~ 3.4
   - [✓ d.] ~~4.4 m/s~~ 4.8

$U_{Gi} = K_F$

$\cancel{m}gh = \frac{1}{2}\cancel{m}v^2$

$\sqrt{2gh} = v$

$\sqrt{2 \cdot 9.8\,m/s^2\ 1.2\,m} = 4.8\,m/s$

4. How much work is done by gravity on the book if it is lifted off of the floor and put on a shelf 2.0 m above the floor?
   - a. 0 J
   - b. 20 J
   - c. - 20 J
   - d. 33 J
   - [✓ e.] - 33 J

$W = F \cdot d$

$= -mg\ d$

$= -1.7\,kg\ 9.8\,m/s^2\ 2.0\,m$

$= {}^-33\,J$

5. A boy throws his sister's doll off a cliff high above the ravine below. The doll is thrown at an angle of 55 degrees and reaches a maximum height of 30 meters above the ravine before landing in the bottom. What is the doll's speed just before it hits the bottom of the ravine? (ignore air resistance)
   - a. 12 m/s
   - b. 17 m/s
   - [✓ c.] 24 m/s
   - d. 30 m/s

$U_{Gi} = K_F$

$\cancel{m}gh = \frac{1}{2}\cancel{m}v^2$

$\sqrt{2gh} = v$

$\sqrt{2\ 9.8\,m/s^2\ 30\,m} = 24.2\,m/s$

6. What is in the bubbles of boiling water?
    - a. Air
    - b. Hydrogen Gas and Oxygen Gas
    - [✓ c.] Water vapor
    - d. Empty Space

7. What makes a bigger explosion
    - a. Pure oxygen
    - b. Pure hydrogen
    - [✓ c.] Hydrogen and oxygen
    - d. a, b and c
    - e. b and c

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. When you lose 15 lbs, how did the largest fraction of the weight leave your body?
    - a. Energy
    - b. Water (sweat, urine)
    - c. Solid waste
    - [✓ d.] Respiration – carbon dioxide
    - e. Respiration – water vapor

10. A nail sits out in the elements and rusts. Rusting is oxidation of iron where iron and oxygen combine to form iron oxide (rust). After rusting, the nail
    - [✓ a.] Weighs more than before
    - b. Weighs the same
    - c. Weighs less than before

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 200 °F to Celsius
    - [✓ a.] 93 °C
    - b. 149 °C
    - c. 182 °C
    - d. 392 °C

$$T_F = 9/5\, T_c + 32°F$$

$$5/9\,(T_F - 32°F) = T_c$$

$$5/9\,(200°F - 32°F) = T_c = 93.3°C$$

13. Is 650 °F colder, warmer or equal to 650 K?
   - [✓ a.] colder
   - b. warmer
   - c. equal

$$T_C = 5/9\,(T_F - 32°F)$$
$$= 5/9\,(650°F - 32°F)$$
$$= 343°C$$
$$T = T_C + 273 = 616\ K$$

14. When the temperature of an ideal gas is increased, which of the following also increases? (1) The thermal energy of the gas; (2) the average kinetic energy of the gas; (3) the average potential energy of the gas; (4) the speed of the molecules in the gas.
   - a. 1 and 2
   - b. 3 and 4
   - c. 1, 2, and 3
   - [✓ d.] 1, 2 and 4
   - e. All of 1–4

15. A helium balloon contains one mole of Helium (6.647×10^{-27}kg). You take it outside on a very cold day, -18°C. What is the thermal energy of the gas in the balloon? $-18+273 = 255\ K$
   - a. 3.1×10^{-22} J
   - b. 5.3×10^{-21} J
   - c. 186 J
   - [✓ d.] 3200 J

$$E_{TH} = \frac{3}{2} N k_B T$$
$$= \frac{3}{2}\ 6.022\times10^{23}\ \text{molecules}\ 1.38\times10^{-23}\ J/K\ 255\ K$$
$$= 3179\ J$$

16. What is the rms speed of a helium molecule (6.647×10^{-27}kg) at -18°C?
   - a. 306 m/s
   - b. 1350 m/s
   - [✓ c.] 1260 m/s
   - d. 3200 m/s

$$V_{rms} = \sqrt{\frac{3 k_B T}{m}}$$
$$= \sqrt{\frac{3\ 1.38\times10^{-23}\ J/K\ \ 255\ K}{6.647\times10^{-27}\ kg}} = 1260\ m/s$$

17. An aluminum 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.

$\alpha_{AL} = 23\times10^{-6}\ K^{-1}$

$\alpha_{Fe} = 12\times10^{-6}\ K^{-1}$

Aluminum expands more than iron when heated.

18. A glass of ice water has been sitting on a table for an hour and still has a little bit of ice in it. What is the temperature of the water?
   - a. > 0 °C
   - b. 100 °C
   - c. < 0 °C
   - [✓ d.] 0 °C
   - e. b or d.

19. The reason suction cups stick to a wall is because

    a. The molecules of the suction cup and the wall form a weak bond.
    [✓ b.] There is a force outside the suction cup pushing it against the wall.
    air molecules
    c. There is a vacuum formed behind the cup when you press it that sucks it to the wall.

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    a. Convection
    [✓ b.] Evaporation
    c. Conduction
    d. Radiation
    e. It is a poor insulator.

21. Which of the following changes would allow your refrigerator to use less energy to run? (1) Increasing the temperature inside the refrigerator; (2) increasing the temperature of the kitchen; (3) decreasing the temperature inside the refrigerator; (4) decreasing the temperature of the kitchen.

    a. 1 only
    [✓ b.] 1 and 4
    c. 2 and 3
    d. All of the above

    Smaller ΔT is easier to maintain.

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

12 22. Joe (70kg) rides his 5.0 kg sled at a constant velocity 50 meters down a slight incline covered in snow. If he changes his elevation by 20 meters during this ride,

    a. Find the average force of friction acting on the sled.
    b. How much snow is melted by the sled if it is at 0 °C?

15 23. A 5.00 kg block of ice is at -65 °C. It is put in thermal contact with 1.00 kg of water at 60.0°C. What is the final temperature of the system? What is the final mass of ice? 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

10 24. A 2,000 kg Mercury Monterey and a 2,300 kg Chrysler Imperial collide head on during a demolition derby. The Monterey was initially moving at 4 m/s and the Imperial at 10 m/s. The two cars lock bumpers after the collision. How much energy was converted to thermal energy?