Examination 3

Name: ____________________________

Section: __________________________

Physics 201
Fall 2012
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Time: 1.5 hours

Show all of your work.

Part I: Dimension, Multiple Choice Questions and Easy Work Out Questions

1. What are the units of the following quantities?

(10pts)

- Sound intensity $I$ = $[\text{W/m}^2]$
- Mass per unit length $\mu$ = $[\text{kg/m}]$
- Specific heat capacity $c$ = $[\text{J/kg K}]$
- Coefficient of linear expansion $\alpha$ = $[\text{K}^{-1}]$
- Emissivity $e$ = $[\text{dimensionless}]$
- Coefficient of volume expansion $\beta$ = $[\text{K}^{-1}]$
- Heat of vaporization $L_v$ = $[\text{J/kg}]$
- Heat current $H$ = $[\text{W or J/s}]$
- Thermal conductivity $k$ = $[\text{W/m K}]$
- Stefan-Boltzmann constant $\sigma$ = $[\text{W/m}^2 \text{K}^4]$
2. A hiker sees a lightning flash: 15 s later he hears the sound of the thunder. Recalling from his study of physics that the speed of sound in air is approximately $\frac{1}{3}$ km/s, he estimates that the distance to where the lightning flash occurred is approximately.

(a.) 5 km.
(b.) 10 km.
(c.) 15 km.
(d.) 45 km.

3. Two pulses of exactly the same size and shape are traveling toward each other along a stretch rope. They differ only in that one is upright while the other is inverted. Superposition tells us that when the pulses meet each other, they will cancel each other exactly at the instant and the rope will show no evidence of a pulse. What happens afterwards?

(a.) Each pulse continues as though it had never met the other one.
(b.) The rope remains straight since the pulses have cancelled each other.
(c.) the pulses rebound from each other, each going back in the direction from which it came.
4. Suppose at a concert a singer’s voice is radio broadcast all the way around the world before reaching the radio you hold to your ear. This takes $\frac{1}{8}$ second. If you’re close, you hear her voice in air before you hear it from the radio. But, if you are far enough away, both signals will reach you at the same time.

How many meters distant must you be for this to occur? [Show your work.]

\[ s = v \cdot t = \left( \frac{1}{8} \text{s} \right) \frac{344 \text{ m}}{\text{s}} = 43 \text{ m} \]

5. A conical shock wave is generated by a supersonic aircraft as shown.

(5 pts) Estimate the speed of the aircraft in m/s. (Hint: compare the velocity of sound (shockwave) with the speed of the aircraft.)

\[ v_{plane} = 2 \times \text{speed of sound} \times \text{sound speed} = 344 \text{ m/s} \]

\[ 2 \times 344 = 688 \frac{\text{m}}{\text{s}} \]
6. A sphere radiates energy at a rate of 1.00 J/s when its temperature is 100°C. At what rate will it radiate energy if its temperature is increased to 200°C? (Neglect any heat transferred back into the sphere.)

(a) 1.27 J/s
(b) 200 J/s
(c) 2.59 J/s
(d) 16.0 J/s

\[ H = A \varepsilon e \propto T^4 \]

\[ H = A \varepsilon (5.67 \times 10^{-8}) (373,15 K)^4 \]

\[ A \varepsilon = 9.0 \times 10^{-6} \]

\[ H = 9.0 \times 10^{-4} (5.67 \times 373,15 K)^4 = 2,573 \text{ J/s} \]

7. Suppose in a restaurant your coffee is served about 5 or 10 minutes before you are ready for it. In order that it to be as hot as possible when you drink it, should you pour in the room-temperature cream right away or when you are ready to drink the coffee? (Give your reasoning and list the physical law on which it is based.)

Poor cream in right away, this lowers the emissivity from \( \varepsilon \approx 1 \) (black) to much lower and therefore radiation loss are much less far the almost white surface.
8. You're a consultant for a cookware manufacturer who wishes to make a pan that will have two features:

1. Absorb thermal energy from a flame as quickly as possible.
2. Have a cooking surface that stays as hot as possible when heated.

You should recommend a pan with the

a. Outer and cooking surface black.

b. Outer and cooking surface shiny.

c. Outer surface shiny and cooking surface black.

d. Outer surface black and cooking surface shiny.

9. When you double your distance from a point source of sound, how much does the sound intensity level drop?

\[
\begin{align*}
I_1 &= \frac{P_1}{4\pi r_1^2} \\
I_2 &= \frac{P_2}{4\pi r_2^2}
\end{align*}
\]

\[
\frac{I_1}{I_2} = \frac{r_2^2}{r_1^2} = 4
\]

\[
\frac{I_1}{I_2} = \frac{4r_2^2}{r_1^2} = 4
\]

\[
4 I_2 = I_1, \quad I_2 = \frac{1}{4} I_1
\]

drops by 4
10. (a) **Audible wavelengths.** The range of audible frequencies from about 20 Hz to 20,000 Hz. What is the range of the wavelengths of audible sound in air?

\[ v = f \cdot \lambda \]

For \( f = 20,000 \text{ Hz} \)

\[ \lambda = \frac{v}{f} = \frac{344 \text{ m/s}}{20 \times 10^3} = 1.7 \text{ cm} \]

\( f = 20 \) \( \lambda = \frac{344}{20} = 17 \text{ m} \)

(b) **Visible light.** The range of visible light extends from 400 nm to 700 nm. What is the range of visible frequencies of light?

\[ v = 3 \times 10^8 \text{ m/s} \]

For 700 nm

\[ f = \frac{v}{\lambda} = \frac{3 \times 10^8 \text{ m/s}}{700 \times 10^{-9} \text{ m}} = 4.3 \times 10^{14} \text{ Hz} \]

For 400 nm

\[ f = \frac{3 \times 10^8}{4 \times 10^{-9} \text{ m}} = 7.5 \times 10^{14} \text{ Hz} \]
Part II: Problems

11. **Treatment for a stroke.** One suggested treatment for a person who has suffered a stroke is to immerse the patient in an ice-water bath at 0°C to lower the body temperature, which prevents damage to the brain. In one set of tests, patients were cooled until their internal temperature reached 32.0°C. To treat a 70.0 kg patient, what is the minimum amount of ice (at 0°C) that you need in the bath so that its temperature remains at 0°C? The specific heat capacity of the human body is 3480 J/(kg · °C), and recall that normal body temperature is 37.0°C.

\[
\text{Normal body temperature is } 38.6 \, ^\circ \text{F} = 37 \, ^\circ \text{C} \\
\text{so for the person } \Delta T = -5 \, ^\circ \text{C} \\
\text{The ice water stays at } 0 \, ^\circ \text{C}. \text{ A mass of ice melts}
\]

\[
Q_{\text{ice}} = m \cdot L_f \\
4 = 334 \times 10^3 \, \text{J/kg}
\]

\[
Q_{\text{water}} = m \cdot C \cdot \Delta T = 70 \, \text{kg} \cdot 3480 \, \text{J/kg} \cdot ^\circ \text{C} \cdot -5 \, ^\circ \text{C}
\]

\[
= -1.22 \times 10^6 \, \text{J}
\]

The amount which goes into ice \(1.22 \times 10^6 \, \text{J}\)

\[
m_{\text{ice}} \cdot L_f = 1.22 \times 10^6 \, \text{J}
\]

\[
m_{\text{ice}} = \frac{1.22 \times 10^6 \, \text{J}}{334 \times 10^3 \, \text{J/kg}} = 3.7 \, \text{kg}
\]
12. **Hot air in a physics lecture.** A typical student listening attentively to a physics lecture has a heat output of 100 W. How much heat energy does a class of 90 physics students release into a lecture hall over the course of a 50 minute lecture?

\[
50 \text{ min} \times 60 \text{ s} \times 90 \text{ students} \times \frac{100 \text{ J}}{5} = 2.7 \times 10^7 \text{ J}
\]
13. An aluminum cube 0.100 m on a side is heated from 10.0°C to 50.0°C. What is the change in its density? Use \( \rho \) for aluminum.

\[
\rho = 7.2 \times 10^{-5} \, \text{g/cm}^3
\]

\[
\rho = 2.7 \times 10^3 \, \text{kg/m}^3
\]

At 50°C the volume is \( V \) and density is \( \rho \), mass is constant \( m = \frac{m}{V_0} \),

\[
\rho_0 - \rho = \left( \frac{m}{V_0} \right) \left( \frac{1}{V} - \frac{1}{V_0} \right) = \frac{m}{V_0} \frac{V - V_0}{V_0 V} = \frac{m}{V_0} \frac{V - V_0}{V_0^2}
\]

\[
\frac{m}{V_0} = \rho_0
\]

\[
\Delta \rho = \rho_0 - \rho = \rho_0 \frac{\Delta V}{V_0} = \rho_0 \beta \Delta T
\]

\[
= (2.7 \times 10^3 \, \text{kg/m}^3) (7.2 \times 10^{-5} \, \text{C}^{-1})
\]

\[
(40 \, \text{C}) = 7.8 \frac{\text{kg}}{\text{m}^3}
\]

The density decreases by 7.8 kg/m³.