

Print your name clearly:_____

Signature:_____

“I agree to neither give nor receive aid during this quiz.”

Quiz 1 for Physics 176

Professor Greenside
Tuesday, January 25, 2010

This 15-minute quiz is closed book and no electronic devices of any kind are allowed on your table.

Problems That Require Writing

Please write the answers in this section on the supplementary blank pages so that you will have plenty of space. **Please also write your name and problem number on each page.** If your answer is not reasonably readable, you will lose credit. Also, unless stated otherwise, you need to give some insights about your assumptions and what you are doing, just putting an answer down, even if correct, will not lead to full credit.

1. (a) **(3 points)** For one point each, describe three ways that the Earth is not in thermodynamic equilibrium in addition to the fact that the temperature inside the Earth is not uniform.

(b) **(5 points)** Estimate to the nearest power of ten the ratio of “the thermal relaxation time of the Earth” to “the age of the solar system” which is about 5 billion years. The radius of the Earth is 6,400 km and the thermal diffusivity of rock and iron is about $10^{-6} \text{ m}^2/\text{s}$.
Hint: Round all numbers to the nearest power of ten as soon as possible to minimize the arithmetic.

2. **(5 points)** A molecule undergoes a random walk in which it successively travels a distance d , collides with another molecule, and then moves off in a random new direction. Show that the ensemble average of the final position $\mathbf{X}(N)$ of the molecule after N successive random steps $\Delta\mathbf{X}_i$

$$\mathbf{X}(N) = \sum_{i=1}^N \Delta\mathbf{X}_i, \quad (1)$$

is the zero vector $\mathbf{0}$, i.e., the origin of the coordinate system where the molecule started off.

3. **(5 points)** Given that

$$e^{\pm x} \approx 1 \pm x + \frac{1}{2}x^2 \pm \frac{1}{6}x^3, \quad \text{for } |x| \ll 1, \quad (2)$$

find the cubic polynomial that most accurately approximates the hyperbolic tangent function

$$\tanh(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}},$$

near $x = 0$. (Hint: At some point, use $1/(1-x) \approx 1+x+x^2+\dots$ for $|x| \ll 1$.)

True or False Questions (2 points each)

For each of the following statements, please circle **T** or **F** to indicate respectively whether the statement is true or false. No justification is needed.

1. **T / F** Water vapor with a temperature of 200°C is twice as hot as boiling water with a temperature of 100°C .
2. **T / F** The time scale for a system to approach thermal equilibrium does not depend on how big the temperature differences are within the system.
3. **T / F** In order for a macroscopic system to be in thermodynamic equilibrium, the number of atoms in that system can not change over time.
4. **T / F** An aluminum cylindrical rod has a length L that is much greater than its radius r and one end of the rod has a higher temperature than the other end. If the rod is sitting in outer space (i.e., in a vacuum), then the thermal relaxation time for the rod is r^2/κ .
5. **T / F** An aluminum cylindrical rod has a length L that is much greater than its radius r and one end of the rod has a higher temperature than the other end. If the rod is sitting in air with a constant temperature T , then the thermal relaxation time for the rod is r^2/κ .
6. **T / F** For a gas of volume V containing N identical molecules, the quantity $(V/N)^{1/3}$ is approximately equal to the mean free path of the molecules.
7. **T / F** If $a \propto b$ and $c \propto d$ then $a + c \propto b + d$.
8. **T / F** The result of executing the Mathematica code

```
x = { 1 , 2 } ;  
y = { 3 , 4 } ;  
Table[ x[[i]] - y[[i]] , {i, 1, 2} ]
```

will be the list { -2, -2 }.