30 November 2003

Instructions: Please answer each question. In questions that require written answers use complete sentences. For any problems requiring a calculation show your work and include the units used. Put a box around any final answers.

Part I. Short questions.

1. (5 pts) Why is water a popular choice as a heat storing material in solar heating systems?
   - It has a high specific heat capacity so more heat is stored for a given ΔT.

2. (5 pts) When lightning strikes some distance away you see the flash of the lightning before you hear the thunder. Why is there a time lag between the two?
   - Speed of light is much greater than the speed of sound so the flash reaches you earlier than the clap of thunder.

3. (5 pts) Diamond’s index of refraction is 2.42. What is the speed that light travels in diamond?
   \[ n = \frac{c}{v} \text{ so } v = \frac{c}{n} = \frac{3 \times 10^8 \text{ m/s}}{2.42} = \boxed{1.24 \times 10^7 \text{ m/s}}\]

4. (5 pts) Convert a temperature of 20 °C into Fahrenheit.
   \[ T_F = 1.8T_C + 32 = 1.8(20) + 32 = \boxed{68^\circ F}\]

5. (5 pts) More than half the heat generated in a coal fired power plant is not converted into electricity. What physical law explains why the conversion can’t be 100% efficient?
   - 2nd Law of Thermodynamics
6. (5 pts) How are transverse and longitudinal waves different?

With transverse waves, particles travel perpendicular to the wave motion, while longitudinal waves have particles moving parallel to the wave motion.

7. (5 pts) A “concert A” musical note has a frequency of 440 Hz. What is the wavelength of this note as it travels through air?

\[ \lambda = \frac{v}{f} \]

\[ \lambda = \frac{344 \text{ m/s}}{440 \text{ Hz}} = 0.782 \text{ m} \]

8. (5 pts) Diffuse scattering of light from a surface means incoming light, even if in parallel rays, is scattered in many directions. Does this violate the “angle of incidence equals angle of reflection” law? Explain.

No – rough surfaces cause diffuse scattering. Angle in ≠ angle out, but the normal changes direction.

9. (5 pts) How much heat would it take to raise 500 grams of water at 20 °C to a temperature of 100 °C?

\[ H = mc \Delta T \]

\[ H = 500 \text{ g} \cdot 1 \text{ cal} \cdot (100^\circ \text{C} - 20^\circ \text{C}) \]

\[ = 40,000 \text{ cal} \]

10. (5 pts) If we hear a particular note played on a violin and the same note played on an organ, we can tell what instrument played the note. What provides the audio information that lets us tell the difference between these instruments?

The different over-tones (higher freq) present provide the clue.
Part II. Longer Questions. Again, show your work and/or use complete sentences.

11. (10 pts) A sample of gas is contained in a cylinder with a movable piston. Heat is added to the gas which causes temperature of the gas to double while the pressure of the gas does not change.

A) Compared to the original volume occupied by the gas, what is the new volume?

\[
\frac{P_2}{P_1} = \frac{V_1}{V_2}, \quad \frac{T_2}{T_1}\]

\[\text{if } \frac{P_2}{P_1} = \text{ then } \frac{T_2}{T_1} = 2\]

\[\frac{V_2}{V_1} = 2\]

\[\text{to keep } P \text{ constant.}\]

B) In terms of the kinetic theory of gases, what happened to the average kinetic energy of the gas molecules in the situation described above?

\[\text{The temp is proportional to the average kinetic energy, so the average } E_k \text{ doubles as well.}\]

12. (15 pts) Waves on a lake have a wavelength of 1.5 m, an amplitude of 0.35 m, and a period of 0.80 s.

A) What is the frequency of these waves?

\[v = \lambda f \quad \text{so} \quad f = \frac{v}{\lambda}\]

\[f = \frac{1}{T} = \frac{1}{0.80} = 1.25 \text{ Hz}\]

B) What is the wave speed?

\[v = \lambda f = (1.5 \text{ m})(1.25 \text{ Hz}) = 1.88 \text{ m/s}\]

C) If the amplitude of the water waves doubled, would it change your answer to part A) or B)?

Explain. \(N_o\) - amplitude does not enter into the calculation.
13. (15 pts) For each of the lens and mirror situations shown, carefully draw in the appropriate rays to locate the image. Label the image location and whether the image is real or virtual.

A) Mirror

![Mirror Diagram]

B) Lens

![Lens Diagram]

14. (10 pts) When you load a slide projector, slides are put in upside down.

A) Is the image on the screen a real or virtual image? How do you know?

B) Why are the slides put in upside down?
9 May 2002

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Possibly useful stuff: $g = 10 \text{ m/s}^2$. The speed of light $3.00 \times 10^8 \text{ m/s}$.

$1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$  $h = 4.14 \times 10^{-15} \text{ eV} \cdot \text{s} = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$  

$v_0$ (or $f_0$ if you prefer) $= 3.3 \times 10^{15} \text{ Hz}$ ($v_0$ is the Balmer series constant)

Videotape question:

1. (10 pts) In one introductory segment in a videotape (from the series we’ve seen several clips from), Dr. David Goodstein presents his understanding of what a theory is. He says evolution is so well established that it is no longer a theory. He concludes his discussion by saying “Evolution is a fact.” Is his understanding consistent with our class discussion and text? Give reasons for your answer.

No - he calls it a fact, but it is a paradigm.

Part I. Short questions.

1. (5 pts) Why does Fischer, in God Did It, But How? warn against trying to make a sharp distinction between the natural and the supernatural? - often the distinction is ambiguous, God is supernatural, the supernatural is beyond the natural, - it is difficult to make a clear distinction between the two, - the Bible does not draw sharp distinctions.

2. (5pts) A light particle (photon) has an energy of 4.0 eV. What is the frequency of this light?

$E = hf$, so $f = \frac{E}{h} = \frac{4.0 \text{ eV}}{4.14 \times 10^{-15} \text{ eV} \cdot \text{s}} = 9.66 \times 10^{14} \text{ Hz}$
3. (5 pts) In God Did It, But How? Fischer argues that the Bible does not necessarily in contradiction with scientific evidence for a very old age for the creation. On what basis does Fischer make this argument? The Hebrew word "yom", which is translated as "day", does not necessarily mean 24 hrs. It can mean an undefined time span. Gen 1's context is not clear as to the meaning used.

4. (5 pts) Rutherford’s experiment gave clear evidence that the plum pudding model was wrong. What was this evidence? The occasionally back scattered alpha particle could not be explained by the plum pudding model. The scattering rate as a function of angle is consistent with most of the electron being concentrated in the center.

5. (5 pts) What was de Broglie’s contribution to our understanding of the atom?

He predicted that objects with mass have a wavelength given by \( \lambda = \frac{h}{p} \). The orbits of electrons allowed in Bohr's model have integer number of wavelengths.

6. (5 pts) An electron in hydrogen drops from the \( m = 4 \) state to \( n = 3 \). What is the frequency of the light that is emitted?

\[
\lambda = \frac{h}{p} = \frac{1.6 \times 10^{-19}}{3.3 \times 10^{-15}} = 4.85 \times 10^{-4} \text{ m}
\]

OR From diagram on last page \( \lambda = \frac{1}{h} (-0.85eV - (-1.5eV)) = 1.6 \times 10^{-4} \text{ m}

7. (5 pts) If 1 gram of matter (0.001 kg) could be converted entirely into energy, how much energy would that be?

\[
E = mc^2 = (0.001 \text{ kg}) (3 \times 10^8 \text{ m/s})^2 = 9 \times 10^{13} \text{ J}
\]

8. (5 pts) What did Boyle do in terms of providing evidence for the existence of atoms?

His experiments relating pressure and volume of a gas held at constant temperature were explained by considering the gas to be made of atoms bouncing around inside the container.
9. (5 pts) A proton is traveling at a speed that results in its mass being three times its rest mass. How fast is the proton traveling? 

\[ m = \gamma m_0 \]
\[ \gamma = 3 \]

\[ \frac{3}{\sqrt{1 - \frac{v^2}{c^2}}} \Rightarrow \quad 9 = \frac{1}{1 - \frac{v^2}{c^2}} \quad \Rightarrow \quad \frac{1}{q} = \frac{1}{1 - \frac{v^2}{c^2}} \]

\[ \frac{v^2}{c^2} = \frac{1}{9} \Rightarrow \frac{v^2}{c^2} = \frac{8}{9} \]

\[ v = \sqrt{\frac{8}{9}} c = 0.943 c = \boxed{2.83 \times 10^8 \text{ m/s}} \]

10. (5 pts) Why can't an object with mass be accelerated from rest until its speed equals the speed of light in vacuum? If \( v = c \), the energy would be infinite. 

\[- \text{Or} - \frac{\Delta P}{\Delta t} = \gamma m_0 \frac{v}{c^2} \text{ which would also mean an infinite force would be needed to get } v = c.\]

**Part II. Longer Questions. Again, show your work and/or use complete sentences.**

11. (10 pts) The figure below is out of the final chapter of God Did It, But How? Explain it.

![Diagram of world view with Christianity, Scientism, and Biblicism]  

The 2 sources of information, Nature and the Bible, are most directly interpreted by the systemized study of science (for nature) and Biblical Theology (for the Bible).

At the level of world view, Scientism wrongly considers only Science to be a source of knowledge, rejecting any other source, such as the Bible. Biblicism considers only Biblical Theology and rejects science. Christianity is a worldview that understands both areas of knowledge are valid.
12. (10 pts) The early version of the planetary model of the atom had some drawbacks. 

a) What were the drawbacks and what did Bohr assume to address these drawbacks?

- Orbiting electrons have centrifugal acceleration, and theory says accelerated charges emit electromagnetic radiation. So orbiting electrons would spiral into the nucleus, meaning the atom would not be stable.
- Any orbit, so any energy, is allowed. Since this is the case, spectra could not be explained.

Bohr assumed the orbits were stable and only those satisfying \(mv = nh\) were allowed.

b) People took Bohr's idea(s) seriously since his model of the hydrogen atom did a very good job of explaining the Balmer series. What is the Balmer series and how did Bohr's model explain it? The Balmer series is the set of lines in the hydrogen spectrum, which have wavelengths (or frequencies) that can be found from the Balmer formula: \(E = \frac{1}{n^2} \left( \frac{1}{2^2} - \frac{1}{n^2} \right)\). Bohr's allowed orbits mean that when an electron changes from one orbit to another, light is given off with energy \(E = h\nu = E_m - E_n\). With some rearrangement, this formula is the same as Balmer's.

13. (10 pts) An electron (mass 9.11 x 10^{-31} \text{ kg}) is traveling at a speed of 4.00 x 10^{6} \text{ m/s}. 

[Note: this speed is low enough that you do not need relativity theory to solve this problem]

a) What is the wavelength of this electron?

\[
\begin{align*}
\hat{p} &= \frac{h}{\lambda} \\
\lambda &= \frac{h}{\hat{p}} = \frac{h}{mv} = \frac{6.6 \times 10^{-34} \text{ J} \cdot \text{s}}{9.11 \times 10^{-31} \text{ kg} \cdot 4 \times 10^{6} \text{ m/s}} \\
&= \frac{6.6 \times 10^{-34} \text{ J} \cdot \text{s}}{1.8 \times 10^{-10} \text{ m}}
\end{align*}
\]

b) What is the energy of a light particle (photon) having the same wavelength as the electron?

\[
E = hf = \frac{hc}{\lambda}
\]

\[
E = \frac{6.6 \times 10^{-34} \text{ J} \cdot \text{s} \cdot 3 \times 10^8 \text{ m/s}}{1.8 \times 10^{-10} \text{ m}} = \frac{1.09 \times 10^{-15} \text{ J}}{6.900 \text{ eV}}
\]
14. (10 pts) Make up your own question on material covered by this test that you were not asked about in any of the previous questions. Answer your question. The points you receive will be based both on the correctness of the answer you give and the "challenge level" of the question you pose.

Can't make a key for this.