Review of the whole semester

Each of the following slides shows some of the major themes we talked about, followed by a multiple choice question

Atomic Structure of Matter

I. How many molecules of CO_2 are contained in 880 g of "dry ice"? Choose the best answer!

a) 880,000

b) 880 mols

c) 20 mols

d) $1.2 \cdot 10^{25}$ molecules

✔ e) Both c) and d) are correct

Deformation of Solids

II. A vertical Al rod (supported at its top) elongates twice as much after hanging a weight on its bottom as a steel rod of the same size and shape (and with the same weight). If I clamp down both rods on one end, in a horizontal orientation, which one will droop more at the other end? (Without any weight attached!)

a) The Al rod
b) The steel rod
c) Both will droop the same
✔ d) Depends on the relative density of steel and aluminum

Higher density => larger weight => more droopiness
Less elongation => more stiffness => less droopiness

Density

III. What weighs less at an altitude of 4800 m (16,000 ft) than at sea level (0 m)?

✔ a) 1 liter of air

b) 1 kg of air

c) 1 liter of water

d) 1 cm^3 of gold

Air is less dense on top of the mountain, so the same volume weighs less. The water and the gold will weigh **more** because they displace less mass of air on top of the mountain and therefore the buoyant force counteracting their weight is less

Pressure

IV. Does a normal air-filled balloon shrink if you take it along on a diving expedition? Why?

a) Yes, because the high water pressure squeezes air out of the balloon

✔ b) Yes, because water pressure increases as you dive deeper, and for a gas (like the air in the balloon) the product of pressure and volume is constant

c) Yes, because the pressure inside the balloon decreases as you dive

d) No, the pressure inside the balloon will resist the external pressure

Remember $\Delta p = g\rho(-\Delta h)$
and $PV = NRT$ (T in Kelvin)

Temperature

V. What to I change in a piece of metal if I increase its temperature from 27 ^{0}C to 127 ^{0}C?

a) Nothing - it's just hotter

b) I make all of the atoms move in one direction

✔ c) I increase the average random kinetic energy of the atoms inside the metal by roughly a factor of 4/3

d) I increase the average random kinetic energy of the atoms inside the metal by roughly a factor of 5

Convert temperature from ^{0}C into Kelvin!

Heat transport

VI. Which of the following is not a form of heat transport?

a) Electromagnetic radiation
b) Heat conduction
✔ c) Vigorous rubbing together
d) Convection

Rubbing **converts** mechanical energy into heat, doesn't transfer it

Newton's Law of cooling

VI. A piece of metal cools from 75^{o} C to 50^{o} C in a room at 25^{o} C, within 15 minutes. How long will it take to reach exactly 25^{o} C (room temperature)?

a) Less than 15 minutes
b) Another 15 minutes
c) Roughly 30 minutes
✔ d) Theoretically, forever!

The heat flow is from the metal to the surrounding air is proportional to the temperature difference at each moment. As the temperature difference becomes smaller and smaller, the heat flow becomes slower and slower, and the temperature change per unit time becomes less and less.

Heat Capacity, Phase Change

VII. What takes the most amount of heat?

✔ a) To heat up a liter (1 kg) of water from 10 to 20 ^{0}C

b) To melt 1 g of water ice

c) To heat 1 g of ice-cold water up to boiling temperature

d) To evaporate 1 g of water

a) 10,000 calories (notice the amount of water; all other options are 1000x less material
b) 80 calories
c) 100 calories
d) 540 calories

First Law of Thermodynamics

VIII. According to the Ideal Gas Law, if I suddenly compress 1 liter of a gas to 1/2 its size, its pressure will increase…

a) …not at all.

b) …a little bit.

c) …by a factor of 2

✔ d) …by substantially **more** than a factor of 2

Because compressing a volume does work on it, its internal energy and therefore its temperature will increase, making the pressure increase even more than indicated by Boyle's Law

$$PV = NRT$$

Additional Question: Is it possible to build a machine that drives an electric generator that generates more electricity than needed to run that machine?

NO! Violates energy conservation!

2nd Law of Thermodynamics

IX. Which of the following machines is possible, at least in principle? (all wrong answers violate the 2nd law!)

a) A machine that cools your house (to 68 F) and warms your swimming pool (to 80 F) with the heat it removes from your house, without needing any additional (external) energy input

✔ b) A machine that uses the hot water of a geyser and the cold water of a nearby river to generate mechanical energy (e.g. for electricity generation)

c) A machine that cleans up your room for you, without increasing the temperature in your room.

d) A machine that converts 100% of the internal energy of a hot piece of metal into mechanical energy.

Additional Question: What is the efficiency of the machine under b) if the Geyser water is 100 ^{0}C and the river water is 0 ^{0}C ?

$$e = 1-T_{cold}/T_{hot} = 1 - 273K/373K \approx 1/4$$

Oscillation

A pendulum has a “natural” frequency of 1/2 Hz (i.e. it oscillates at that frequency if given an initial push and then left alone). Assume I want to get it to start oscillate a LOT (with large amplitude) by giving it lots of very small pushes. How much time should I wait between any 2 consecutive pushes? Enter the number in seconds.

2 s (i.e. your “push frequency” should be the same as the resonance frequency of the pendulum = 1/2 Hz)

Waves

XI. An organ emits a sound wave with 1 m wavelength (distance between points of highest air density). If sound velocity is 330 m/s, what musical note does that correspond to?

A. 220 Hz
B. 247.5 Hz
C. 264 Hz
D. 293.3 Hz
✔ E. 330 Hz

$$v_{wave} = \lambda f$$

Interference/Standing Waves

XII. On a string of length 2 m (tied down or held at both ends), we create a standing wave with one node in the middle, by shaking one end up and down slightly. Which of the following statements are correct? Enter ALL that apply!

✔ a) The shaking leads to a wave traveling down the string

✔ b) There has to be a reflected wave from the other end that can interfere with the incoming wave

✔ c) The wavelength of the incoming and the reflected wave have to be equal to the length of the string (2m)

✔ d) The frequency with which I shake the string must be equal to the wave velocity on the string divided by 2m

✔ e) The shaking must be in resonance with the frequency of the 2nd normal mode (intrinsic frequency) of the string

More interference

XIII. A sound source (say, a flute playing "A") is hidden behind a sound-absorbing wall (made of egg cartons), but there are 2 long and narrow vertical gaps in that wall, 2 m apart. If you walk around 10 m away from that wall (and parallel to it), what will you hear?

a) Nothing

b) A constant level of sound

c) A loud sound when I am in the middle between the 2 gaps, and less and less sound when I walk away from the point either direction

✔ d) A loud sound when I am in the middle between the 2 gaps, and an alternation of loud sound and silence as I walk away from that point in either direction.

Same interference pattern as light going through double slit

Optics

XIV. Which of the following statements is **closest** to the "truth" (as we know it)?

a) The workings of optical instruments (including lenses and mirrors) have nothing to do with the wave nature of light

✔ b) Reflection and refraction can be explained in terms of interference and Huygen's principle

c) The only visible effect of light being a wave is the interference pattern created by a diffraction grating (like the funny glasses)

d) All lenses focus the parallel light rays from the sun to a single point, which gets quite hot

Color

XV. Which of the following factors affects the color of light we perceive? Enter ALL that apply!

✔ a) The temperature of a light-emitting body

✔ b) The energy levels (electron orbits) of light emitting or absorbing atoms

✔ c) Wave-length dependent scattering of light

✔ d) Dispersion

✔ e) Diffraction

Quantization of Light

XVI. A (hypothetical) element has just two energy levels (electron orbits) that are 2 eV apart in energy. Can this element absorb ultra-violet light of frequency $9.6 \cdot 10^{14}$Hz (310 nm)?

(Note: $1/h = 1.51 \cdot 10^{-33}$ Hz/J = $2.4 \cdot 10^{14}$Hz/eV)

a) Yes, no problem
b) Yes, but only if 2 atoms get excited simultaneously
✔ c) No way!
d) Only if the light is really intense

Light can only be absorbed or emitted one full photon at a time. One ultra-violet photon has 4 eV energy and can not be absorbed by an atom that can only accept 2 eV. (However, it COULD be ionized if the ionization energy is less than 4 eV)

Quantum Mechanics

XVII. Which of these statements about quantum mechanics is **not** true?

a) All particles propagate like waves, with frequency proportional to their energy

b) All waves interact like particles, with energy proportional to frequency

c) Nothing in Nature can be predicted with absolute certainty (e.g. the location of a particle or the moment a nucleus will decay)

✔ d) Because of Quantum Mechanics, we cannot predict anything at all

Nuclear Physics

XVIII. Carbon-12 is the most abundant form of carbon. If I somehow add 2 more neutrons, what do I get?

a) A more energetic form of Carbon-12
b) A different element
✔ c) A different isotope of carbon, which happens to be radioactive
d) A nucleus that can alpha-decay back to carbon-12

Adding 2 neutrons changes N -> N+2, A -> A+2 but leaves Z constant => Same element (carbon), but different mass number (different isotope)

Radioactive Decay

XIX. With my ^{14}C nucleus from the previous slide, what happens if I wait 5700 years?

a) It will convert into a different isotope of carbon
b) It will beta-decay to ^{14}N
c) It will change its mass number A
✔ d) With a 50-50 chance, nothing!

Beta decay never changes the mass number A of a nucleus. IF the nucleus decays, b) describes the correct decay. However, radioactive decay is a statistical process, so d) is correct.

Fission and Fusion

XX. If you can gain energy from both fission and fusion, why not make a “perpetuum mobile” (a machine that generates energy without input) that constantly fissions a nucleus, than fuses the two parts back into one, etc.? Enter all answers that apply!

a) Great idea!

✔ b) This would violate energy conservation (the 1st Law of Thermodynamics)

c) Only fission liberates energy, fusion never does

✔ d) Only fission of very heavy nuclei or fusion of very light nuclei releases net energy, while the end products in either case would be medium-heavy nuclei

Particle Physics

XXI. Which of the following is **not** an elementary particle that has already been discovered experimentally?

a) gluon

b) Z-boson

✔ c) graviton

d) charmed quark

e) muon-neutrino