Solutions for class #12 from Yosumism website

Problem 13:

Thermodynamics⇒}Heat

Given $P = 100$W and $V = 1L = 1m^3 = 1kg$ for water, one can chunk out the specific heat equation for heat, $Q = mc\Delta T = Pt \Rightarrow 4200(1°) = 100t \Rightarrow t \approx 40s$, as in choice (B).

YOUR NOTES:

Problem 14:

Thermodynamics⇒}Heat

The final temperature is $50°C$. The heat exchanged from the hot block to the cool block is $Q = mc\Delta T = 5kcal$, as in choice (D).

YOUR NOTES:

Problem 15:

Thermodynamics⇒}Phase Diagram

Recall that for an ideal gas $U = C_v\Delta T$ and $PV = nRT$. Don't forget the first law of thermodynamics, $Q = W + U$.

For $A \rightarrow B$, $U = 0$, since the temperature is constant. Thus, $Q = W = RT_H \ln V_2/V_1$.

For $B \rightarrow C$, $W = P_2(V_1 - V_2) = R(T_c - T_h)$. $U = C_v(T_c - T_h)$, and thus $Q = W + U = C_v(T_c - T_h) - R(T_h - T_c)$.

For $C \rightarrow A$, $W = 0$, $U = C_v(T_h - T_c)$, thus $Q = U = C_v(T_h - T_c)$.

Add up all the Q's from above, cancel the C_v term, to get $Q_{tot} = RT_h \ln(V_2/V_1) - R(T_h - T_c)$, as in choice (E).s

YOUR NOTES:

Problem 16:

Thermodynamics⇒}Mean Free Path

Air is obviously less dense than the atomic radius 10^{-10}, thus choices (C), (D), and (E) are out. Air is not dilute enough that the distance between particles is actually within human visible range, as in (A)! Thus, the answer must be (B). (Note how this problem exemplifies the usefulness of common sense.)

YOUR NOTES:

Problem 73:

Thermodynamics⇒}Adiabatic Work

One should recall the expression for work done by an ideal gas in an adiabatic process. But, if not, one can easily derive it from the condition given in the problem, viz., $PV^\gamma = C \Rightarrow P = C/V^\gamma$.

Recall that the definition of work is $W = \int P dV = \int_{V_1}^{V_2} C dV/V^\gamma = -\frac{1}{\gamma-1}C/V^{\gamma-1}\Big|_{V_1}^{V_2}$, which when one plugs in the endpoint limits, becomes choice (C).

YOUR NOTES:

Problem 54:

Optics $\Rightarrow$ }Field Trajectory

The problem gives equi-amplitude, thus the field becomes $\vec{E} = E e^{i(kz-\omega t)}\hat{x} + E e^{i(kz-\omega t+\pi)}\hat{y}$.
Taking the real part, (applying Euler's Theorem, to wit: $e^{i\theta} = \cos\theta + i\sin\theta$) one has
$\vec{E} = E\cos(kz-\omega t)\hat{x} + E\cos(kz-\omega t+\pi)\hat{y}$. Apply the trig identity
$\cos(\alpha \pm \beta) = \cos\alpha\cos\beta \mp \sin\alpha\sin\beta$ to make the field argument equi-phase,
$\vec{E} = E\cos(kz-\omega t)\hat{x} - E\cos(kz-\omega t)\hat{y}$.

Looking down from the z-axis, one has $z = 0 \Rightarrow \vec{E} = E\cos(\omega t)\hat{x} - E\cos(\omega t)\hat{y}$.

Make a table of a few values of t and E,

wt   (cos(wt), -cos(wt))

0   (1, -1)

?/6   ½ (?3, -?3)

?/4   ½ (?2, -?2)

and one deduces that the points plot out a diagonal line at $135°$ to the x-axis, as in choice (B).

YOUR NOTES:

Problem 55:

Optics⇒}Polarizations

After the wave has been de-coupled into separate directions, the intensity adds separately. That is, the intensity of the wave split by the x-polarizer is $I_1 = |E_1|^2$, while that of the wave split by the y-polarizer is $I_2 = |E_2|^2$. Add the two intensities to get choice (A).

YOUR NOTES:

Problem 56:
Optics⇒}Total Internal Reflections

Total internal reflection is when one has a beam of light having *all* of the incident wave reflected. Going through a bit of formalism in electromagnetism one can derive Snell's Law for Total Internal Reflection,

$$n_{inside}\sin\theta = n_{outside},
$$

where $n_{inside} = 1.33$, and one assumes that the surface has $n_{outside} = 1$ for air.

One must solve the equation $\theta = \sin^{-1}(1/1.33)$. One can immediately throw out choices (A) and (E). From the unit circle, one recalls that $\sin(30^{deg}) = 1/2$ and $\sin(60^{deg}) = 1.7/2 = 0.85$. Since $1/1.33 \approx 0.7$, one deduces that the angle must be choice (C).

YOUR NOTES:

Problem 57:
Optics⇒}Diffractions

The single slit diffraction formula is $d\sin\theta = \lambda m$, where one has integer m for maxima and half-integers for minima. (Opposite to single-slit interference.)

Given $m=1, \theta=4E-3rad$, $\lambda=400E-9m$, and making the approximation $\sin\theta \approx \theta$ for small angles, one has the following equation for d,

$d \approx \frac{\lambda m}{\theta} = \frac{4E-7}{4E-3} = 1E-4$, as in choice (C).

YOUR NOTES:

Problem 27:
Lab Methods$\Rightarrow$}Log Graphs

Log graphs are good for exponential-related phenomenon. Thus (A), (C), and (E) are appropriate, thus eliminated. The stopping potential has a linear relation to the frequency, and thus choice (B) is eliminated. The remaining choice is (D).

YOUR NOTES:

Problem 28:

Lab Methods$\Rightarrow$}Oscilloscope

A superposition of two oscillations has the form $\sin\omega_1 t + \sin\omega_2 t = 2\cos\left(\frac{\omega_1-\omega_2}{2}\right)\sin\left(\frac{\omega_1+\omega_2}{2}\right)$. This implies that the cosine term is the amplitude of the combined wave.

Similarly, one can see one the lower frequency as the contribution towards the bigger envelope-like wave and the higher-frequency as the zig-zag-gish motion along the envelope.

One oscillation must have a high frequency and the other has a relatively lower frequency. Only choices (D), (A), and (B) show this trait. The high frequency oscillation should have a smaller amplitude than the lower frequency oscillation. Only choices (A) and (D) show this trait. Finally, the amplitude of the lower frequency wave forms the envelope, and the amplitude from that is only about 1 cm; on a 2V scale, this is about 2V---which is closest to choice (D).

YOUR NOTES:

Problem 29:

Advanced Methods $\Rightarrow$ }Dimensional Analysis

The current author is fortunate enough to have taken a String Theory course as an undergraduate, and thus know by heart that the Planck length is $\sqrt{G\hbar/c^3}$. However, the problem can also be solved via dimensional analysis

(A) $G\hbar c$ has units of $(m^3/(kg\,s^2))(kg\,m/s^2\,m\,s)(m/s) = m^5/(s^3)$, which doesn't have the units of m.

(B) $(m^3/(kg\,s^2))(kg\,m/s^2\,m\,s)^2(m/s)^3 = m^{10}kg/s^7$, which doesn't have the units of m.

(C) $(m^3/(kg\,s^2))^2(kg\,m/s^2\,m\,s)(m/s) = m^9/(kg\,s)$, which doesn't have the units of m.

(D) $(m^3/(kg\,s^2))^{1/2}(kg\,m/s^2\,m\,s)^2(m/s) = \sqrt{kg}\,m^{4.5}/s^3$, which doesn't have the units of m.

(E) This is the last one. Take it!

YOUR NOTES: