Problem 1: (C)

Atomic dimensions

The "diameter" of the hydrogen atom is approximately 1 A.

Problem 2: (B)

Kinetic theory

$\frac{1}{2} m\langle v^2\rangle = (3/2)kT$

Problem 3: (B)

The proper time interval

t' is the proper time interval. The time between the events in the laboratory frame is $\gamma t'$, during this time the rocket travels a distance $v\gamma t'$.

Problem 4: (C)

Acceleration, energy conservation

The block accelerates as long as the gravitational force is greater than the elastic force. It has maximum kinetic energy when mg = kx, x = mg/k.

$E = \frac{1}{2}mv^2 = mg(h + x) - \frac{1}{2} kx^2 = mgh + m^2g^2/(2k)$.

Problem 5: (C)

Entropy

$$\Delta S = S_2 - S_1 = \int_1^2 \frac{dQ}{T} .$$

The entropy of the gas in process 3 decreases and therefore the entropy of the reservoir (4) increases, since the total entropy for a reversible process does not change.

Problem 6: (A)

Hooke's law

$\omega = (k/m)^{1/2}$. $T = 2\pi/\omega$, $T_2/T_1 = (m_2/m_1)^{1/2}$

Problem 7: (E)

RLC circuits

Look at the limiting cases. When ω becomes very small the inductor approaches a short circuit, when ω becomes very large, the capacitor approaches a short circuit. In both cases I becomes very large.

Formal solution: I = V/Z

$1/Z = 1/R + 1/(i\omega L) + i\omega C = 1/R + i(\omega C - 1/(\omega L)) = (1/R^2 + (\omega C - 1/(\omega L))^2)^{1/2}\exp(i\ \square)$

$|I| = |V|/(1/R^2 + (\omega C - 1/(\omega L))^2)^{1/2}$.

Problem 8: (A)

Photomultipliers

Problem 9: (E)

Conservation Laws

Problem 10: (D)

Alpha decay

Problem 11: (B)

LS coupling

L = 0, S =1, J = L + S = 1

Problem 12: (E)

Resistors in series and parallel:

$1/R_t = 1/R + 1/(2R) = (3/2)R$. $I = V/R_t = 3V/(2R)$.

Problem 13: (E)

Range formula

$R = (2v_0^2\cos\theta_0\sin\theta_0)/g = (v_0^2\sin 2\theta_0)/g$.

Problem 14: (B)

Motion of a charged particle in a magnetic field

$$m\frac{v^2}{R} = qvB\,, \qquad v = \frac{qBR}{m}\,, \qquad \frac{v_\alpha}{v_p} = \frac{q_\alpha m_p}{q_p m_\alpha} = \frac{1}{2}\,.$$

Problem 15: (D)

Special Relativity

$T = \gamma mc^2 - mc^2 = mc^2(1/(1-v^2/c^2)^{1/2} - 1)$. As $v \to c$, $T \to$ infinity.

Problem 16: (B)

Conductors in electrostatics

Conductors in contact have the same potential.

Problem 17: (E)

Newton's 2nd law

The magnitude of the restoring force is not proportional to m.

Problem 18: (E)

Rayleigh scattering

Problem 19: (B)

Speed of sound

The speed of sound should be proportional to the average speed of the gas molecules.

$\frac{1}{2} mv^2 = (3/2)kT$.

Problem 20: (B)

$F_{avg} = \Delta p/\Delta t$

$F_{avg} = \Delta p/\Delta t = \Delta mv/t = (20*10^{-3} * 1200 *600/60)N = 240\ N$

Problem 21: (E)

Polarization

Linearly polarized light: $\phi = n\pi$, n = 0, 1, 2, ...

Problem 22: (B)

Indistinguishable particles

There are 3 ways of putting the particles in different boxes and leaving one box empty. There are 3 ways of putting the two particles in the same box.

Problem 23: (D)

Degrees of freedom

In 2D, each point particle has two degrees of freedom.

Problem 24: (B)

Energy conservation

Problem 25: (D)

Ampere's law

Let $\lambda = I/w$. Apply Ampere's law to a strip of width dx carrying current λdx.

The magnitude of the magnetic field a perpendicular distance ρ from this strip is $B = \mu_0 \Delta\lambda dx/(2\pi\rho)$. The direction is given by the right-hand rule. Integrate to find B at P.

$$B = \int_0^w \frac{\mu_0}{2\pi(r+x)} \frac{I}{w} dx = \frac{\mu_0 I}{2\pi w} \ln(r+x)\Big|_0^w = \frac{\mu_0 I}{2\pi w} \ln\left(\frac{r+w}{r}\right)$$