PT1, solutions

Problem 1:
(B) There is no change in the kinetic energy, all the potential energy is dissipated by friction.

Problem 2:
(B) Energy = Power*Δt.
10^4W*10^{-15}s = 10^{-11}J = 6.25*10^7eV
#of photons = 6.25*10^7eV/(hf) = 6.25*10^7eV*λ/(hc)
= 6.25*10^7eV*600nm/1240eV-nm = 3*10^7

Problem 3:
(A) Dipole selection rules

Problem 4:
(E) As $\omega \rightarrow 0$ the capacitor opens the circuit and no current is flowing through the resistor. $V_{out} = 0$
As $\omega \rightarrow \infty$ the impedance of the capacitor goes to zero, and $I = V_{in}/R$ is flowing through the resistor. $V_{ou}t = V_{in}$

Problem 5:
(C) $B = (N/L)\mu_0 I$.

Problem 6:
(A) Vector Calculus

Problem 7:
(E) The Stefan-Boltzmann law: The total energy radiated per unit area per unit time is proportional to T^4.

Problem 8:
(E) $E_F = kT_F = ½mv^2$. v = (1.38*10^{-23} J/K *8*10^4 K*2/9.1*10^{-31} kg)$^{1/2}$ = 1.6*10^6 m/s.

Problem 9:
(D) Velocity addition:
A particle moves in K with velocity **u** = d**r**/dt. K' moves with respect to K with velocity **v**. The particle's velocity in K', **u**' = d**r**'/dt', is given by
$u'_{||} = (u_{||} - v)/(1 - \mathbf{v}\cdot\mathbf{u}/c^2)$
$u'_{\perp} = u_{\perp}/(\gamma(1 - \mathbf{v}\cdot\mathbf{u}/c^2))$
where parallel and perpendicular refer to the direction of the relative velocity **v**.
Here $u_{\perp}$ is zero, $u_{||}$ = u is positive, v is negative. u' = (0.3c + 0.6c)/(1 + 0.18) = 0.76 c.

Problem 10:
(E)

Problem 11:
(B) We only have centripetal acceleration. The horizontal force of the road on the tires must cancel the air resistance force and provide the centripetal acceleration

Problem 12:
(B) Hydrogenic atoms: The reduced mass is $m_e/2$.

Problem 13:
(E) The net electrostatic force on the charge Q at the center is zero since the force on Q due to each negative charge is balanced by the force due to the negative charge at the diagonally opposite corner of the cube.

Problem 14:
(A) Energy and momentum conservation: The ball recoils with speed v/3. $E \propto v^2$.

Problem 15:
(E) Method of images. The force on q is the same as that due to q and the two image charges. (-q at -0.5a and -2q at -1.5a) $F_x = -k2q^2/a^2 - kq^2/a^2 - k2q^2/(4a^2) = (7/2)\, kq^2/a^2$.

Problem 16:
(E) RC is the time constant for the circuit.
$Q/C + RdQ/dt = 0$ $dQ/dt = -Q/(RC)$, $Q = Q_0\exp(-t/)RC))$,
$E = Q^2/C = E_0\exp(-2t/(RC))$, $½ = \exp(-2t_{1/2}/RC)$, $t_{1/2} = \ln(2)RC/2$.

Problem 17:
(C) $P(l = 5) = |<Y_{51}|\Psi>|^2 + |<Y_{5-1}|\Psi>|^2 = 9/38 + 4/38 = 13/38$.

Problem 18:
(D) Energy and momentum conservation:
$Mc^2 = 2\gamma mc^2$. $\gamma = (1 - 9/25)^{-1/2} = 5/4$, $M = 5m/2 = 10$ kg.

Problem 19:
(C) The orbiting electron is equivalent to a circular current loop, whose magnetic dipole moment is given by M = IA where I is the equivalent current and A is the area of the loop. Therefore, $M = (q/T)\times(\pi r^2) = q\, f\, \pi r^2$ where q is the electronic charge, T is the orbital period, r is the orbital radius and f is the frequency of revolution of the electron. Thus $M = 1.6\times10^{-19}\times6.6\times10^{15}\times\pi\times(5.28\times10^{-10})^2$. This yields a value nearly 10^{-23}

Problem 20:
(B) Double slit interference: $d \sin\theta = m \lambda \rightarrow$ interference maxima
$\sin\theta \sim \theta = m \lambda/d$. Doubling the frequency means reducing the wavelength by a factor of 2 and therefore reducing θ and the separation of the fringes by a factor of 2.

Problem 21:
(E) Motion in a central potential: Energy and angular momentum are conserved, torque = 0.

Problem 22:
(B) We have 1 kg of water. The water loses 100 J/s of thermal energy to the environment, when its temperature is near 100 ^{o}C. The water must lose 4.2 kJ/(kg^{o}C) to cool by 1 ^{o}C, which takes approximately 40 s.

Problem 23:
(A) No acceleration implies no net force.

Problem 24:
(C) Lens I or lens IV

Problem 25:
(B)