HOMEWORK 5 SOLUTIONS

Chapter 27.

MC.1 A & B.

All observers measure light to travel at the same speed c.

MC.3 A & D.

'D' is just the principle of relativity (laws of physics same in all inertial reference frames).
'A' is a special case of the principle of relativity for the particular law that the speed of light is 3 x 10^8 m/s.

27.3. Set Up: The observer on Pluto measures the proper time Δt_0 since the light blinks on and off at the same point in her frame. $\Delta t_0 = 80.0\ \mu\text{s}$ and $u = 0.964c$.

Solve: $\Delta t = \dfrac{\Delta t_0}{\sqrt{1 - u^2/c^2}} = \dfrac{80.0 \times 10^{-6}\text{ s}}{\sqrt{1 - (0.964)^2}} = 3.01 \times 10^{-4}\text{ s} = 0.301\text{ ms}$

Reflect: The pilot measures a much longer time for the duration of the pulse than is measured by an observer at rest with respect to the signal light.

27.11. Set Up: When the meterstick is at rest with respect to you, you measure its length to be 1.000 m, and that is its proper length, l_0. $l = 0.3048$ m.

Solve: $l = l_0\sqrt{1 - u^2/c^2}$ gives $u = c\sqrt{1 - (l/l_0)^2} = c\sqrt{1 - (0.3048/1.00)^2} = 0.9524c = 2.86 \times 10^8\text{ m/s}$.

Chapter 28

C.13 Force of gravity is about 10^{38} times weaker than electromagnetic force between electrons and protons. So we can ignore gravity.

MC.1 A & C

We are told that the light is causing electron to be emitted. So the light exceeds the frequency required. The more photons (the greater the intensity) the more electrons are emitted (A).
The max speed of an electron depends on the frequency of the photon that ejected it. But frequency has not changed (just intensity). So the max speed of electrons emitted is unchanged (C).

MC.5 C

$$E = h\nu = h\frac{c}{\lambda} \qquad\qquad E' = h\frac{c}{\lambda'} = h\frac{c}{2\lambda} = \tfrac{1}{2}E$$

MC.9 A.

$E_n = \dfrac{C}{n^2}$, where C is a constant and n is the principal quantum number.

$$E_3 = \frac{C}{3^2} = \frac{C}{9} \qquad\qquad E_1 = \frac{C}{1^1} = C$$

Solving the first equation for C, get $C = 9E_3$. So $E_1 = 9E_3$.

28.1. Set Up: $c = f\lambda$ relates frequency and wavelength and $E = hf$ relates energy and frequency for a photon. $c = 3.00 \times 10^8\ \text{m/s}$. $1\ \text{eV} = 1.60 \times 10^{-16}\ \text{J}$.

Solve: (a) $f = \dfrac{c}{\lambda} = \dfrac{3.00 \times 10^8\ \text{m/s}}{505 \times 10^{-9}\ \text{m}} = 5.94 \times 10^{14}\ \text{Hz}$

(b) $E = hf = (6.626 \times 10^{-34}\ \text{J}\cdot\text{s})(5.94 \times 10^{14}\ \text{Hz}) = 3.94 \times 10^{-19}\ \text{J} = 2.46\ \text{eV}$

(c) $K = \frac{1}{2}mv^2$ so $v = \sqrt{\dfrac{2K}{m}} = \sqrt{\dfrac{2(3.94 \times 10^{-19}\ \text{J})}{9.5 \times 10^{-15}\ \text{kg}}} = 9.1\ \text{mm/s}$

28.3. Set Up: $P_{\text{av}} = \dfrac{\text{energy}}{t}$. $1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$. For a photon, $E = hf = \dfrac{hc}{\lambda}$. $h = 6.63 \times 10^{-34}\ \text{J}\cdot\text{s}$.

Solve: (a) energy $= P_{\text{av}}t = (0.600\ \text{W})(20.0 \times 10^{-3}\ \text{s}) = 1.20 \times 10^{-2}\ \text{J} = 7.5 \times 10^{16}\ \text{eV}$

(b) $E = \dfrac{hc}{\lambda} = \dfrac{(6.63 \times 10^{-34}\ \text{J}\cdot\text{s})(3.00 \times 10^8\ \text{m/s})}{652 \times 10^{-9}\ \text{m}} = 3.05 \times 10^{-19}\ \text{J} = 1.91\ \text{eV}$

(c) The number of photons is the total energy in a pulse divided by the energy of one photon:

$$\frac{1.20 \times 10^{-2}\ \text{J}}{3.05 \times 10^{-19}\ \text{J/photon}} = 3.93 \times 10^{16}\ \text{photons.}$$

Reflect: The number of photons in each pulse is very large.

28.30. Set Up: The energy of each photon is $E = hf = \dfrac{hc}{\lambda} = \dfrac{1.99 \times 10^{-25}\ \text{J}\cdot\text{m}}{\lambda}$. The power is the total energy per second and the total energy E_{tot} is the number of photons N times the energy E of each photon.

Solve: $\lambda = 10.6 \times 10^{-6}\ \text{m}$ so $E = 1.88 \times 10^{-20}\ \text{J}$. $P = \dfrac{E_{\text{tot}}}{t} = \dfrac{NE}{t}$ so

$$\frac{N}{t} = \frac{P}{E} = \frac{0.100 \times 10^3\ \text{W}}{1.88 \times 10^{-20}\ \text{J}} = 5.32 \times 10^{21}\ \text{photons/s}$$

28.52. Set Up: For a photon $E_{\text{ph}} = \dfrac{hc}{\lambda} = \dfrac{1.24 \times 10^{-6}\ \text{eV}\cdot\text{m}}{\lambda}$. For an electron $E_{\text{e}} = \dfrac{p^2}{2m} = \dfrac{h^2}{2m\lambda^2}$.

Solve: (a) $E = \dfrac{hc}{\lambda} = \dfrac{1.24 \times 10^{-6}\ \text{eV}\cdot\text{m}}{500 \times 10^{-9}\ \text{m}} = 248\ \text{eV}$

(b) $E_{\text{e}} = \dfrac{h^2}{2m\lambda^2} = \dfrac{(6.63 \times 10^{-34}\ \text{J}\cdot\text{s})^2}{2(9.11 \times 10^{-31}\ \text{kg})(5.00 \times 10^{-9}\ \text{m})^2} = 9.65 \times 10^{-21}\ \text{J} = 0.0603\ \text{eV}$

The electron has much less energy than a photon of the same wavelength.

Chapter 29

C.4 The conventional interpretation is that an “electron cloud” is a the spatial probability distribution for the electron. The denser the cloud in a region, the more likely is the electron to be found there.

29.1. Set Up: $l = 0, 1, 2, \ldots, n-1$. $m_l = 0, \pm1, \pm2, \ldots, \pm l$.
Solve: $l = 0$: $m_l = 0$. $l = 1$: $m_l = 1, 0, -1$. $l = 2$: $m_l = 2, 1, 0, -1, -2$. There is one state for $l = 0$, three for $l = 1$, and five for $l = 2$. The total number of states is $1 + 3 + 5 = 9$.

29.9. Set Up: $0 \le l \le n-1$. $|m_l| \le l$. $s = \pm\frac{1}{2}$.
Solve: $n=1, l=0, m_l=0, s=\frac{1}{2}$. $n=1, l=0, m_l=0, s=-\frac{1}{2}$. $n=2, l=0, m_l=0, s=\frac{1}{2}$. $n=2, l=0, m_l=0, s=-\frac{1}{2}$. $n=2, l=1, m_l=1, s=\frac{1}{2}$. $n=2, l=1, m_l=1, s=-\frac{1}{2}$. $n=2, l=1, m_l=0, s=\frac{1}{2}$. $n=2, l=1, m_l=0, s=-\frac{1}{2}$. $n=2, l=1, m_l=-1, s=\frac{1}{2}$. $n=2, l=1, m_l=-1, s=-\frac{1}{2}$. $n=3, l=0, m_l=0, s=\frac{1}{2}$. $n=3, l=0, m_l=0, s=-\frac{1}{2}$.

Chapter 30

MC.1 A.

Strong force only acts on nucleons.
Radius give by $r = r_o A^{1/3}$, where $r_o = 10^{-15}$ m. This is much less that 10^{-10} m.
The density of all nuclei is about the same $\rho = \frac{mass}{volume} \frac{Am_{nucleon}}{\frac{4}{3}\pi r^3} = \frac{Am_{nucleon}}{\frac{4}{3}\pi r_o^3 A} = \frac{m_{nucleon}}{\frac{4}{3}\pi r_o^3}$ = a constant.

MC.5 D.

A baryon is "heavy" particle such as a proton or a neutron.
Electrons (e^-), positrons(e^+), and photons (γ) are not baryons.

D. violate baryon number because there are 3 baryons among the reactants but only 2 baryons among the products.

MC.7 A & D.

rad is a unit of (Energy of radiation)/(mass of tissue absorbing it)
rem is a unit of RBE x (Energy of radiation)/(mass of tissue absorbing it)

We're told that the *energy* of the x-rays and the alpha particles (to which a presumably fixed mass of tissue is exposed) is the same. So the dose of x-rays and alpha particles the same value in rad (choice 'A').

To get the value of the biologically equivalent dose, we need to multiply by the RBE, which is 20 in this case. The answer will then be in rem. (Bio Equiv Dose) = RBE x Dose = 20*D* (choice 'D').

MC.13. B.

mrem = millirem is unit of RBE x (Energy of radiation)/(mass of tissue absorbing it)

When *both* hands are inserted in the radiation beam for 30 seconds, we have
(a) doubled the total amount of radiation energy absorbed by tissue
(b) doubled the total amount of tissue absorbing the radiation
(c) left the RBE unchanged.

As the bio equiv dose depends on the ratio of (a) to (b), we see that it is unchanged.
[Doubling both the numerator and denominator of a fraction leaves it unchanged.]

30.17. Set Up: The decay rate decreases by a factor of 2 in a time of one half-life.
Solve: (a) 24 d is $3T_{1/2}$ so the activity is $(375\text{ Bq})/(2^3) = 46.9\text{ Bq}$

(b) The activity is proportional to the number of radioactive nuclei, so the percent is $\dfrac{17.0\text{ Bq}}{46.9\text{ Bq}} = 36.2\%$

(c) ${}^{131}_{53}\text{I} \rightarrow {}^{0}_{-1}\text{e} + {}^{131}_{54}\text{Xe}$ The nucleus ${}^{131}_{54}\text{Xe}$ is produced.
Reflect: Both the activity and the number of radioactive nuclei present decrease by a factor of 2 in one half-life.

30.23. Set Up: 1 Gy = 1 J/kg and is the SI unit of absorbed dose. 1 rad = 0.010 Gy. Sv is the SI unit for equivalent dose. equivalent dose = RBE $\times$ absorbed dose. Rem is the equivalent dose when the absorbed dose is in rad. For x rays, RBE = 1.0. For protons, RBE = 10.
Solve: (a) 5.0 Gy, 500 rad. RBE = 1.0 so equivalent dose = absorbed dose. 5.0 Sv and 500 rem.
(b) $(70.0\text{ kg})(5.0\text{ J/kg}) = 350\text{ J}$
(c) The absorbed dose and total absorbed energy are the same but the equivalent dose is 10 times larger. So the answers are: 5.0 Gy, 500 rad, 50 Sv, 5000 rem, 350 J.
Reflect: The same energy deposited by protons as x rays is ten times greater in its biological effect.

30.27. Set Up: For x rays RBE = 1 so the equivalent dose in Sv is the same as the absorbed dose in J/kg.
Solve: One whole-body scan delivers $(75\text{ kg})(12 \times 10^{-3}\text{ J/kg}) = 0.90\text{ J}$. One chest x ray delivers

$$(5.0\text{ kg})(0.20 \times 10^{-3}\text{ J/kg}) = 1.0 \times 10^{-3}\text{ J}.$$

It takes $\dfrac{0.90\text{ J}}{1.0 \times 10^{-3}\text{ J}} = 900$ chest x rays to deliver the same total energy.

30.29. Set Up: For x rays RBE = 1 and the equivalent dose equals the absorbed dose.
Solve: (a) 175 krad = 175 krem = 1.75 kGy = 1.75 kSv. $(1.75 \times 10^3\text{ J/kg})(0.150\text{ kg}) = 2.62 \times 10^2\text{ J}$.
(b) 175 krad = 1.75 kGy; $(1.50)(175\text{ krad}) = 262\text{ krem} = 2.62\text{ kSv}$
The energy deposited would be 2.62×10^2 J, the same as in (a).
Reflect: The energy required to raise the temperature of 0.150 kg of water 1 C° is 628 J, and 2.62×10^2 J is less than this. The energy deposited corresponds to a very small amount of heating.

30.58. Set Up: The activity $|\Delta N/\Delta t| = \lambda N$. $\lambda = \dfrac{\ln 2}{T_{1/2}}$. The mass of one ${}^{103}\text{Pd}$ nucleus is $103m_p$. In a time of one half-life the number of radioactive nuclei and the activity decrease by a factor of 2.

Solve: (a) $\lambda = \dfrac{\ln 2}{T_{1/2}} = \dfrac{\ln 2}{(17\text{ days})(24\text{ h/day})(3600\text{ s/h})} = 4.7 \times 10^{-7}\text{ s}^{-1}$

$$N = \frac{0.250 \times 10^{-3}\text{ kg}}{103m_p} = 1.45 \times 10^{21}$$

$$|\Delta N/\Delta t| = (4.7 \times 10^{-7}\text{ s}^{-1})(1.45 \times 10^{21}) = 6.8 \times 10^{14}\text{ Bq}$$

(b) 68 days is $4T_{1/2}$ so the activity is $(6.8 \times 10^{14}\text{ Bq})/2^4 = 4.2 \times 10^{13}\text{ Bq}$