ASSIGNMENT-3

1.

Initial radius (typical W.D. radius), $R_i \approx 10^4$ km

final radius (that of N.S. core), $R_f \approx 10$ km

Mass of the N.S. core, $M_c = 1.4 M_\odot$

Assuming that there is no significant mass loss after the collapse, the energy generated is

$$E_{gr} = \left(-\frac{GM_c^2}{R_i}\right) - \left(-\frac{GM_c^2}{R_f}\right) = GM_c^2\left(\frac{1}{R_f} - \frac{1}{R_i}\right)$$

$$\approx \frac{GM_c^2}{R_f} \quad (\because R_f \sim 10^{-3} R_i)$$

$$\Rightarrow E_{gr} \approx \frac{6.67 \times 10^{-8} \times (1.4 \times 2 \times 10^{33})^2}{10^6} \text{ ergs}$$

$$\approx 5 \times 10^{53} \text{ ergs}$$

$$\boxed{E_{gr} \sim 10^{54} \text{ ergs}}$$

2.

Mass of the progenitor $= 10 M_\odot$

Mass of the core (from problem 1) $= 1.4 M_\odot$

$\Rightarrow$ Mass of the ejecta $= (10 - 1.4) M_\odot = 8.6 M_\odot$

Measured velocity of the ejecta $\sim 10^4$ km/s. $= 10^9$ cm/s

$\therefore$ Kinetic energy of the ejecta $\sim \frac{1}{2} \times (8.6 \times 2 \times 10^{33}) \times (10^9)^2$

$= 8.6 \times 10^{51}$ ergs

$$\boxed{KE_{ejecta} \sim 10^{52} \text{ ergs}}$$

Electromagnetic luminosity $= 2 \times 10^8 L_\odot$

Duration of EM. emission ~ 2 months $= 2 \times 30 \times 24 \times 3600$ s

$\sim 5 \times 10^6$ s

$\therefore$ Energy lost into photons $\sim 2\times10^{8} \times 4\times10^{33} \times 5\times10^{6}$ ergs

$$= 4\times10^{48} \text{ ergs}$$

$$\boxed{E_\gamma \sim 10^{49} \text{ ergs}}$$

Energy lost into neutrinos, $E_\nu = E_{gr} - KE_{ejecta} - E_\gamma$

$$\Rightarrow E_\nu \approx (10^{54} - 10^{52} - 10^{49}) \text{ ergs}$$

$$\Rightarrow \boxed{E_\nu \sim 10^{54} \text{ ergs}}$$

Clearly, almost all energy is lost into neutrinos.

3) Average energy of neutrinos $\simeq 5\text{MeV} = 5\times10^{6}\times1.6\times10^{-12}$ ergs

$$= 8\times10^{-6} \text{ ergs}$$

$$\sim 10^{-5} \text{ ergs}$$

$\therefore$ Number of neutrinos produced $\sim \dfrac{10^{54}}{10^{-5}}$

$$\Rightarrow \boxed{N_\nu \sim 10^{59}}$$

Considering that neutrinos are emitted in $\sim 10^{-2}$ s

(Collapse takes place within free fall time)

Distance from the supernova ~ 10 kpc $= 3\times10^{22}$ cm

$\therefore$ Expected flux of neutrinos from galactic supernova

$$\sim \frac{10^{59}}{10^{-2}\times 4\pi \times (3\times10^{22})^2}$$

$$\sim 8.8\times10^{14}$$

$$\boxed{F_{\nu,SN} \sim 10^{15} \text{ particles}\cdot\text{cm}^{-2}\,\text{s}^{-1}}$$

Solar neutrino flux $F_{\nu,\odot} \sim 10^{11}$ particles cm^{-2} s^{-1}

Thus, expected neutrino flux from galactic supernova is $\sim 10^{4}$ times more than expected solar neutrino flux.