# SOLUTION SET 9
## Physics 2022

**1.** $m = +14.3 \qquad L_* / L_{sun} = 88 \qquad M_{sun} = +5.0$

$M_{sun} - M_* = 2.5 \log ( L_* / L_{sun} ) = 2.5 \log ( 88 ) = 4.86$

$M_* = 5.0 - 4.86 = 0.14$ mag

$m - M = 5 \log ( d / 10 ) = 14.3 - 0.14 = 14.16$

$D = [ \text{dex} ( 14.16 / 5 ) ] ( 10 ) \approx 6800$ pc

**2.** $E = h c / \lambda = (6.63 \times 10^{-34} \text{ Js}) (3 \times 10^{8} \text{ m/s}) / (0.21 \text{ m}) = 9.5 \times 10^{-25}$ J

$(= 5.9 \times 10^{-6}$ eV)

**3a.** $P = 2\pi d / v = 2\pi (20{,}000 \text{ pc}) (3.086 \times 10^{13} \text{ km}) / [(400 \text{ km/s}) (60 \times 60 \times 24 \times 365.25)]$

$P = 9.72 \times 10^{15}$ s $= 3.08 \times 10^{8}$ year $= 308$ million years

**3b.** $\mathcal{M} = d^3 / P^2 = [ (20{,}000 \text{ pc}) (206265 \text{ AU/pc}) ]^3 / [ 3.08 \times 10^{8} \text{ yr}]^2$

$\mathcal{M} = 7.4 \times 10^{11}$ solar masses

**4a.** $P = 2\pi d / v = 2\pi (16{,}000 \text{ pc}) (3.086 \times 10^{13} \text{ km}) / [(270 \text{ km/s}) (60 \times 60 \times 24 \times 365.25)]$

$P = 3.64 \times 10^{8}$ yr

**4b.** $\mathcal{M} = d^3 / P^2 = [ (16{,}000 \text{ pc}) (206265 \text{ AU/pc}) ]^3 / (3.64 \times 10^{8} \text{ yr})^2$

$\mathcal{M} = 2.7 \times 10^{11}$ solar masses

**5a.** $R_{sch} = 2 G \mathcal{M} / c^2$

$R_{sch} = 2(6.67 \times 10^{-11}\ N\ m^2/kg^2)\ (3.7 \times 10^6)\ (1.989 \times 10^{30}\ kg) / (3 \times 10^8\ m/s)^2$

$R_{sch} = 10.9 \times 10^9\ m = 10.9 \times 10^6\ km = 0.073\ AU$

**5b.** $\sin \theta = D / d = (0.073\ AU) / [\ (8{,}000\ pc)\ (206265\ AU/pc)\ ] = 4.42 \times 10^{-11}$

$\theta = 2.53 \times 10^{-9}$ degree $= 9.12 \times 10^{-6}$ arcsec half-angle

full-angle $= 2\theta = 1.8 \times 10^{-5}$ arcsec

**5c.** $\sin \theta = D / d = (0.073\ AU) / [\ 120\ AU\ ] = 6.08 \times 10^{-4}$

$\theta = 3.49 \times 10^{-2}$ degree $= 125$ arcsec half-angle

full-angle $= 2\theta = 250$ arcsec Can be seen by naked eye

**6a.** $C = 2 \pi r = 2 \pi\ (530\ AU)\ (1.5 \times 10^8\ km/AU) = 5.0 \times 10^{11}\ km$

$P = C / v = (5.0 \times 10^{11}) / 2500\ km/s = 2.0 \times 10^8$ seconds $= 6.3$ years

**6b.** $(\mathcal{M}_1 + \mathcal{M}_2) = a^3 / P^2 = (530\ AU)^3 / (6.3\ yr)^2 = 3.8 \times 10^6$ solar masses

**7.** $d = v / H_o = (16{,}000\ km/s) / (70\ km/s/Mpc)$

$d = 229\ Mpc = 229 \times 10^6\ pc\ (\times 3.26\ ly/pc) = 745 \times 10^6\ ly$

**8.** $d = v / H_o = (10{,}800\ km/s) / (71\ km/s/Mpc)$

$d = 152\ Mpc = 152 \times 10^6\ pc = 496 \times 10^6\ LY$

**9.** $m - M = 5 \log (d / 10) = +10 - (-19.9) = 29.9$

$d = 9.5 \times 10^6\ pc = 9.5\ Mpc$

Some possibly useful constants

$1\ \text{pc} = 206{,}265\ \text{AU} = 3.26\ \text{ly}$

$1\ \text{AU} = 1.5 \times 10^{8}\ \text{km}$

$1\ \text{yr} = 3 \times 10^{7}\ \text{s}$

$c = 3 \times 10^{8}\ \text{m/s}$

$\sigma = 5.669 \times 10^{-8}\ \text{Wm}^{-2}\text{K}^{-4}$

$G = 6.7 \times 10^{-11}\ \text{N m}^2 / \text{kg}^2$

$h = 6.63 \times 10^{-34}\ \text{Js}$

$\mathcal{M}_{\text{sun}} = 2.0 \times 10^{30}\ \text{kg}$

$R_{\text{sun}} = 6.96 \times 10^{5}\ \text{km}$

$H_o = 71\ \text{km/s/Mpc}$