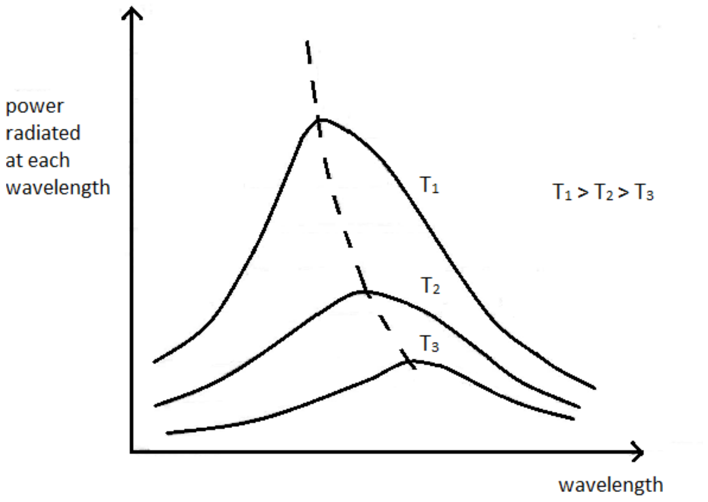
ASTROPHYSICS

2-2 Classifying stars

1. A black body spectrum has a characteristic curve for any given temperature.



A black body is a perfect absorber or emitter of radiation and emits a continuous spectrum of wavelengths. A star can be assumed to be a black body as any radiation incident on it would be absorbed and the spectrum of a star has an intensity distribution that matches the shape of a black body radiation curve.
The wavelength corresponding to the peak intensity of a black body curve is related to the Kelvin temperature of the object by Wien's law:

$\lambda_{max} T = 0.0029$ m K (note that this is not units of milliKelvin!)

which can be used therefore to calculate the temperature of the star's light-emitting surface.

2. (a)

Spectral Class	Temperature range/K
O	25000 – 50000
B	11000 – 25000
A	75000 – 11000
F	6000 – 7500
G	5000 – 6000
K	3500 – 5000
M	2500 – 3500 approx

(b) $\lambda_{max} = 620$ nm $= 6.20 \times 10^{-9}$ m

$\lambda_{max} T = 0.0029$ m K so $T = \dfrac{0.0029 \cancel{m} K}{\lambda_{max} \cancel{m}} = \dfrac{0.029}{6.20 \times 10^{-9}}$ K

$= 4677$ K

$= 4700$ K to 2 sf

3. $T_{star} = 2T_{sun}$ and $d_{star} = 4d_{sun}$
Surface area of a sphere = $4\pi r^2 = \frac{4\pi d^2}{4} = \pi d^2$

$P = \sigma A T^4$

$$\frac{P_{star}}{P_{sun}} = \frac{\sigma A_{star} T_{star}{}^4}{\sigma A_{sun} T_{sun}{}^4} = \frac{\sigma \pi d_{star}{}^2 T_{star}{}^4}{\sigma \pi d_{sun}{}^2 T_{sun}{}^4} = \frac{\sigma \pi 4^2 d_{sun}{}^2 (2T_{sun})^4}{\sigma \pi d_{sun}{}^2 T_{sun}{}^4}$$

After cancellation of terms in common in numerator and denominator this gives:

$$\frac{P_{star}}{P_{sun}} = 4^2 \times 2^4$$

$= 256$
≈ 250

4. $P_X = 100P_Y$

(a) The stars are in the same spectral class so their temperatures are not dissimilar and no more than a factor of 2 different so we can reasonably consider $T_X = T_Y$

From Stefan's law

$$\frac{P_X}{P_Y} = \frac{\sigma A_X T_X{}^4}{\sigma A_Y T_Y{}^4} = \frac{\sigma \pi d_X{}^2 T_X{}^4}{\sigma \pi d_Y{}^2 T_Y{}^4} = \frac{d_X{}^2 T_X{}^4}{d_Y{}^2 T_Y{}^4} = 100$$

But as the temperatures are approximately equal then d_x is greater than d_Y. (A factor of 2 difference in the temperatures could only produce a factor of 16 difference in the power output).

(b) $P_X = 6.0 \times 10^{26}$ W, $T_X = 5400$ K, $\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}

$P_X = \sigma A_X T^4$ so rearranging $A_X = \frac{P_x}{\sigma T^4}$

$$= \frac{6.0 \times 10^{26}}{5.67 \times 10^{-8} \times 5400^4}$$

$= 1.244.... \times 10^{19}$ m^2
$= 1.2 \times 10^{19}$ m^2 to 2 sf

$A_X = \pi d_X{}^2$

So $$d_X = \sqrt{\frac{A_X}{\pi}} = \sqrt{\frac{1.2 \times 10^{19}}{\pi}}$$ = 2.0×10^9 m to 2 sf