Introductory Astrophysics.

A.1

a) Using Wien's law $\lambda T_e = 2.9 \times 10^{-3}$

$$T = \frac{2.9 \times 10^{-3}}{828 \times 10^{-9}} = \boxed{3502.415\ K}$$

Yes, as λ_{max} remains the same, the surface temperature remains constant

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b) Using Stefan-Boltzman Law $L = 4\pi R^2 \sigma T^4$ where $\sigma = 5.67 \times 10^{-8} J s^{-1} m^{-2} K^{-4}$

$R = \sqrt{\cancel{\frac{[illegible]}{4\pi\sigma\, 3502.415^4}}}$ and as $L_\odot = 3.827 \times 10^{26}$ we know that $L = 24035 \times 3.827 \times 10^{26}$

$$\therefore R = \sqrt{\frac{24035 \times 3.827 \times 10^{26}}{4\pi\sigma\, 3502.415^4}} = \boxed{2.929 \times 10^{11}\ m}$$

No, as the luminosity of the star is varying, and the temperature remains constant, the radious of the star must be changing.

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c) ~~Ud~~ ~~A~~ A star in hydrostatic equilibrium, the inwards gravitational force is balanced by the outwards pressure force at every level of the star. Therefore the ~~radious~~ radius of a star in hydrostatic equilibrium won't vary (stays constant).

On the other hand, a star undergoing free-fall gravitational collapse, the inwards gravitational force component is much bigger than the outwards pressure force component. Therefore the radius of the star will be shrinking as particles accelerate towards the centre of the star.

d)

- The radius of Betelgeuse on the 9th Feb 2020 is :

$$R = \sqrt{\frac{7959 \times 3.827 \times 10^{26}}{4\pi\sigma 3502.415^4}} = \underline{1.685 \times 10^{11}}$$

- Therefore the distance the particles have accelerated inwards will be: ~~Radius 9th Feb Radius~~

R 26th Nov 2019 - 9th Feb 2020 $= 2.929 \times 10^{11} - 1.685 \times 10^{11} = \underline{1.244 \times 10^{11}\,m}$

- And we know the time it took the particles to cover that distance was 75 days $\therefore$ $75 \times 24 \times 60 \times 60 = \underline{6480000\,s}$

- Using Newton's $s = u \cdot t + \frac{1}{2} a t^2$; $a = \frac{2 \cdot s}{t^2}$

$$\therefore a = \frac{2 \times 1.244 \times 10^{11}}{(6.48 \times 10^6)^2} = 5.925 \times 10^{-3}\,ms^{-2}$$

- Therefor using $a = \frac{GM}{R^2}$; $M = \frac{a \cdot R^2}{G}$ and using the initial radius.

$$\therefore M = \frac{5.925 \times 10^{-3} \times (2.929 \times 10^{11})^2}{6.67 \times 10^{-11}} = 7.6208 \ldots \times 10^{30} = \boxed{7.621 \times 10^{30}\,kg}$$

e)

- Given that Betelgeuse is a massive supergiant star, its should have a mass of around 10-40 solar masses.

On exercise d we calculated it's mass as $\frac{7.621 \times 10^{30}}{3.827 \times 10^{30}} = 3.832$ solar masses.

- So we got in d) a value smaller than expected.
- Seeing how Betelgeuses radius is varying this way, I think that Betelgeuse is a red supergiant undergoin stellar pulsation.
- ~~The~~ So as in stellar pulsation the contraction of the star isn't really free fall, the acceleration parameter due to gravity should be bigger than the calculated one. Therefore the mass of Betelgeuse in reality is bigger.

f)

knowing $E_{grav} = -\frac{3}{5}\frac{GM^2}{R}$; $E_{KE} = \frac{3kT}{2}$ and

knowing that for the cloud to collapse $-E_{grav} \geq 2\, E_{thermal}$

we compute:

$$\left(\cancel{\frac{3}{5}\frac{GM^2}{R} \geq 3kT}\right)$$

The thermal energy of the cloud is $E_{KE} \times$ no of particles

$\therefore\ E_{Thermal} = \frac{3kT}{2}\frac{M}{m}$ (where m is the average mass of a particle)

$$\therefore\ \frac{3}{5}\frac{GM^{\cancel{2}}}{R} \geq \cancel{2} \times \frac{3kT}{\cancel{2}} \times \frac{\cancel{M}}{m} \implies \frac{M}{R} \geq \frac{5kT}{Gm}$$

$\therefore\ R \leq \frac{M \cdot G \cdot m}{5kT}$ and knowing that $n = N/V = \frac{M}{m(4\pi/3)R^3}$

we get that $M = n \cdot m\,(4\pi/3)\,R^3$

$$\frac{n \cdot m\,(4\pi/3)\,R^3}{R} \geq \frac{5kT}{Gm} \implies R^2 \leq \frac{5kT}{Gm^2 n\left(\frac{4\pi}{3}\right)}$$

$$\implies R \leq \sqrt{\frac{15 \cdot k}{4\pi G}} \times m^{-1} \times n^{-1/2} \cdot T^{1/2}$$

Therefore $K = \sqrt{\frac{15k}{4\pi G}}$, $X = 1/2$, $Y = -1$, $Z = -1/2$

B.1

a) Galaxy A is spiral:

- In a spiral galaxy, (~~stars are still being formed~~) the (~~gas~~) cold gas present is highly collisional, therefore as neighbouring patches of gas stay close together, the friction over time and the initial movment end up ~~the~~ setteling all the gas into a thin rotating disc. Therefore a disc is a property of spiral ~~stars~~ galaxies.

- (~~As spiral galaxies are~~) Having gas is one of the main characteristics of spiral galaxies. Without gas no spiral arms would be formed, therefore having gas is a property of spiral galaxies.

- In the disc area of the spiral galaxy, the rotating cold gas still forms stars that maintain the same rotation, forming the spiral arms. (~~This stars being [illegible] formed are the~~ ~~are~~) Some of the new stars formed are massive stars that produce blue light. This stars are short lived, so if the galaxy wasn't forming new stars we wouldn't see any blue stars. Therefore having blue and red stars is a characteristic of spiral galaxies.

Galaxy B is irregular.

- In an irregular star there might be two reasons for it's lack of disc. It can be because the gas hasn't yet settled down, or it can be because the disc has been disrupted due to a collision with another galaxy. Anyways not having a disc is a characteristic of an irregular galaxy.

- Having gas is a main property of irregular galaxies. Irregular galaxies are actively forming stars, so they need gas in order to do so.

- As irregular ~~Stars~~ galaxies have gas, they form new stars. These new stars can be red, or they can be massive blue stars.

Galaxy C is elliptical

- Elliptical galaxies are older, so there's no gas left, these for they have no disc and no gas.
- As they don't have gas, they cannot form new stars. So ~~as~~ as all the massive blue stars are short lived, only red stars remain.

b)

i) Using $\frac{F}{F_0} = e^{-x/x_e}$:

$$e^{-\frac{2000 \times 3.086\times10^{16}}{2450 \times 9.461\times10^{15}}} = 0.0698$$

we get that the light flux is reduced dow to a 6.98% of its original flux

ii) Dust particles in the interestellar medium are responsible for this.

- One of the extinction processes is true absorption, where a dust particle absorbs the photon, therefore extinguishing a bit of the light flux.
- The other process is light scattering, where the dust particle changes the direction of the photon, therefore deviating a bit of the light flux.

c)

i) we know that $n(M) = \phi(L) \cdot \frac{\partial L}{\partial M}$

as $L \propto M^{\beta}$; $\frac{\partial L}{\partial M} \propto M^{\beta-1}$

therefore $n(M) \propto \phi(L) \cdot M^{\beta-1}$

ii) As we know that $\phi(L) \propto L^{-\alpha}$:

$n(M) \propto L^{-\alpha} \cdot M^{\beta-1}$ and as $L \propto M^{\beta}$:

$n(M) \propto M^{-\beta\alpha} \cdot M^{\beta-1} \propto M^{\beta-\beta\alpha-1}$ if we assign

$\gamma = \beta(1-\alpha)-1$ we have $n(M) \propto M^{\gamma}$

and $4(1-1.28)-1 = -2.12$ $\therefore$ $\boxed{n(M) \propto M^{-2.12}}$

iii) As we know $n(M) \propto M^{-2.12}$

$1.3 \propto 0.8^{-2.12}$ and $x \propto 2.1^{-2.12}$

$\therefore \frac{x}{1.3} = \frac{2.1^{-2.12}}{0.8^{-2.12}} \Rightarrow x = 1.3 \times \frac{0.8^{2.12}}{2.1^{2.12}} = \boxed{0.168\ pc^{-3}}$

C-1

a) As we know that $F = \frac{L}{4\pi D^2}$:

$L = F \times 4\pi D^2 = 3.3\times10^{-4} \times 4\pi \times (220 \times 3.086\times10^{16})^2 = 1.911\times10^{35}$ W

Dimensional analysis:

For $L = \underbrace{F}_{W/m^{+2}} \times \underbrace{4\pi}_{none} \times \underbrace{D^2}_{m^2}$ $\therefore L = W m^{-2} \cdot m^2 = W$

Now to convert it to solar luminosity we use

$L_\odot = 3.83\times10^{26}$ Watts

$\therefore L = \frac{1.911\times10^{35}}{3.83\times10^{26}} = 498\,955\,613.6$ solar luminosities.

Dimensional analysis:

~~For~~ as 3.83×10^{26}'s units are $W/_{solar\ luminosities}$

in $L = \frac{1.911\times10^{35}}{3.83\times10^{26}}$ we have $L = \frac{W}{W/_{solar\ luminosities}}$ = solar luminosities

~~b) A standard candle is an astronomical object ~~(that)~~ of ~~a~~ known magnitude (in most cases of a known luminosity). That way as we know their luminosity, measuring their flux we can calculate at what distance they are. As Betelgeuse's supernova isn't of type 1A we don't know it's luminosity, therefore it cannot be used as a standard candle.~~

b) A standard candle is an astronomical object of which it's luminosity is known.
That way if we know it's luminosity and we measure it's flux we can calculate at what distance this object is from the earth.
As Betelgeuse's supernova isn't of type 1A we don't know it's luminosity. ~~But as we have calculated it beforehand, we could~~
But as we know its distance, we could calculate it and use that luminosity as a standard candle for similar red supergiant stars.

c) $$D_L = \frac{c(1+z)\left(z - \frac{1+q}{2} z^2\right)}{H_0}$$

$$\rightarrow z - \frac{1+q}{2} z^2 = \frac{D_L H_0}{c(1+z)} \Rightarrow -(1+q) = \frac{2\left(\frac{D_L H_0}{c(1+z)} - z\right)}{z^2}$$

$$q = \frac{-2\left(\frac{D_L H_0}{c(1+z)} - z\right)}{z^2} - 1 = -0.316$$

d) ~~As q is negative, the expansion of the universe is accelerating. So if an observer looks into our universe through a telescope in the future, they will see how our time slows down. Because they will recive the lightwaves at~~

d) As q is negative, this means that the universe is accelerating away. This means that the velocity between galaxies. is increasing. That means that the red shift between galaxies is increasing aswell. So if in the future someone looked into our universe through a telescope, he will see that galaxies are very scattered.