AQA

A Level

A Level Physics

ASTROPHYSICS: Stars 2

(Answers)

Name:

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Total Marks: /30

1. Whilst classification by temperature and luminosity are both effective schemes, being able to assign a star to a class based on its measurable spectra is particularly useful.

Total for Question 1: 9

(a) Hydrogen absorption lines are most prominent at approximately 10,000 K; above and below this temperature, their prominence diminishes rapidly. Why is this? [2]

Solution: Above 10000 K, most H will be ionised; it will have no ability to absorb photons as the electrons cannot be excited.
Below 10000 K, the electrons are not excited enough for H to contribute much to the spectrum.

(b) Fill in the blanks in the table below. [7]

Class	Colour	Temperature / K	Absorption lines
		25000 - 50000	He^{+}, He, H
B	blue		
	blue - white		H, ionised metals
F	white	6000 - 7500	
G	yellow - white	5000 - 6000	ionised & neutral metals
K	orange	3500 - 5000	neutral metals
		≤ 3500	

Solution:
1st col: O; A; M
2nd col: blue; red
3rd col: 11000-25000; 7500-11000
4th col: He, H; ionised metals; neutral atoms, TiO

2. Amongst all that you see in the night sky, there exist a variety of stars. Yet, it is thought that all stars originate from clouds of dust and gas. Understanding how stars are formed and how they evolve is an important aspect of our understanding of the universe.

Total for Question 2: 21

(a) A protostar is an extremely hot, dense sphere of dust and gas. Why don't all protostars evolve to form stars? [2]

Solution: Nuclear fusion must take place.
Extremely high temperatures and pressures are required to overcome the electrostatic repulsion between hydrogen nuclei. In some cases, when sufficient mass is added to the protostar, its core may become sufficiently hot for the KE of the nuclei to overcome this repulsion. This results in fusion and the formation of a main sequence star.

(b) The majority of most stars' lives are spent in the main sequence phase. During this time they are stable and maintain an approximately constant size. Therefore, since gravitational forces act to compress the star, other forces must resist this compression. Give an example of one and state what causes it and where it originates. [2]

Solution:
1/ Gas pressure; thermonuclear fusion; the core.
2/ Radiation pressure; photons emitted during fusion.

(c) As the nuclear fuel inside a main sequence star is exhausted, gravitational forces cause it collapse very rapidly. Explain how this results in the formation of a neutron star. [5]

Solution:
- Collapse and very high T in the core causes Fe to dissociate, forming alpha particles, protons and neutrons.
- Reaction of protons and electrons: ${}^{1}_{1}\mathrm{p} + {}^{0}_{-1}\mathrm{e} \longrightarrow {}^{1}_{0}\mathrm{n} + \nu$
- Extremely high T allows reactions to restart, producing a lot of energy in a short amount of time. - Rebound of collapsing matter on the neutron-rich core induces shockwave, which takes high-energy material away in supernova (2).
- This leaves behind the neutron-rich core.

(d) A Hertzsprung-Russell diagram is a graph showing the relationship between stellar luminosity and temperature.

i. Explain why, when a red giant becomes a white dwarf, it moves towards the lower left of the diagram. [2]

Solution: The fusing shell of a red giant drifts off to form planetary nebula. This leaves behind the very hot core - a white dwarf. Since this core is hotter than the shell (which has been cooling), the star moves left on the diagram.
Its luminosity decreases because the only emission of energy is because of photons formed in earlier stages of evolution.

ii. Black holes are not usually plotted on Hertzsprung-Russell diagrams. Explain why this is the case. [2]

Solution: Black holes emit no light since photons cannot have a velocity greater than the escape velocity of a black hole (speed of light). Therefore they would plot off the bottom of the scale, at approximately L=0.

(e) Why do astronomers draw the conclusion that our sun and its solar system must have originated from the remnants of a supernova? [2]

> **Solution:** Fusion in stars' cores can only generate elements with atomic numbers up to that of iron. To go any higher requires a supernova. Since heavier elements exist in our solar system, they must have been produced in old supernovae.

(f) By equating the kinetic energy of a spaceship with the gravitational potential energy of a black hole, show that the spaceship can go no closer than $\frac{2GM}{c^2}$ if it wishes to return. M is the black hole's mass, G is the gravitational constant and c is the speed of light in a vacuum. [4]

> **Solution:** $\frac{mv^2}{2} \geq \frac{GmM}{R} \rightarrow R \geq \frac{2GM}{v^2}$
> At the point of no return the minimum velocity needed for the spaceship to escape is c since the escape velocity of a black hole is c.
> Thus, $R_s = \frac{2GM}{c^2}$

(g) Estimate the radius of the event horizon of a black hole with a mass equal to precisely twenty solar masses. [2]

> **Solution:** 59.0 km