a) State two similarities and 2 differences between the gravitational red shift of a photon and the ionisation energy of an electron and atom.

(4 marks)

|  |  |  |
| --- | --- | --- |
|  | **Grav. Red Shift** | **Ionisation Energy** |
| **Similarities** | Fields. Ionisation energy lost vs gravitational potential lost  Min energy required to escape | |
|  | Energy loss due to escape.  Word done in escaping. | |
| **Differences** | Loss of Ek | Loss of f |
|  | Virtual particle | Mass particle |

b) Based on cosmological red shift what will be the frequency of an originally blue photon of wavelength 500 nm that that has been emitted from an electric torch moving away from an astronaut in empty space at a speed of 20 000 km s-1?

(3 marks)

fL = fs

fS  = fL = 6 x 1014

fS = 6 x 1014 Hz fL = 6 x 1014

fL = 5.61 x 1014 Hz

c) To which part of the electromagnetic spectrum does the photon received by the astronaut belong?

(1 mark)

Visible (green) (4 to 7 rule)

d) The astronaut returns to earth and is looking through a telescope at the torch which is still flying away one hour later. Explain **two** ways in which the photons from the torch will now look different from your answer to part b).

(2 marks)

- Dimmer - further away

- On passing through the earth’s atmosphere – twinkles

- Frequency acted on by earth’s gravitational field. fL slightly **increased**.

e) Using the gravitational red shift formula, state the new frequency of a 9.00 x 1015 Hz photon originating at the surface of our sun. The new frequency is received / measured in empty space outside the sun’s gravitational field.

(4 marks)

fL = fS

fL = 9.00 x 1015

fL = 9.00 x 1015 Hz (unchanged when rounded to 3 sig fig)

f) Would Edwin Hubble need to take gravitational red shift into account in formulating his theory of an expanding universe? Explain why or why not.

(2 marks)

Yes – Light from big (large mass) stars is increasingly red shifted and so appears to be receding faster.

No – Unless light emitting object is very massive gravitational red shift is only slight.

g) A satellite orbiting the earth is set to receive signals at a frequency of 3.00 x 106 Hz. Should the signal be sent from the transmitter at the surface of the earth at a frequency above, equal to or below 3 x 106 Hz taking into account gravitational red shift? Do not calculate your answer.

(2 marks)

Above.

Photon will lose frequency as it leaves earth’s gravitational field.