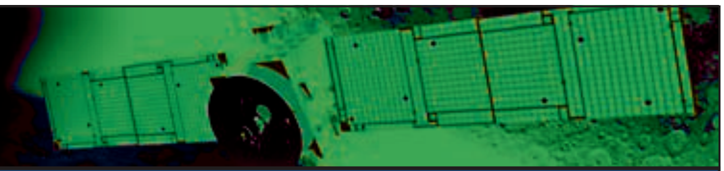
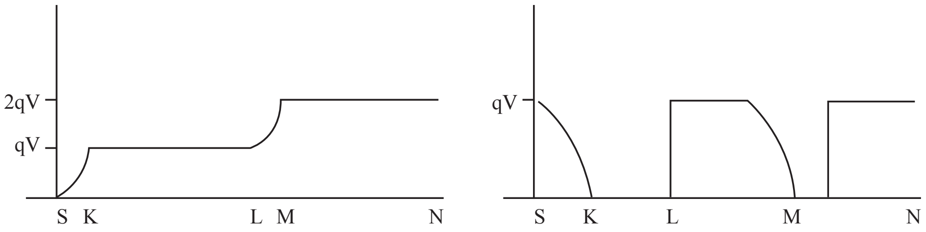


Motion and Forces in a Gravitational Field: Comprehension 2

Set	Number	Solution
Comp2	1a	Heliocentric means centred around the Sun
	1b	Mercury is the nearest planet to the Sun
	1c	An average distance from Mercury to the Sun is provided because Mercury's orbit is noticeably elliptical and its nearest distance of approach to the Sun is significantly different to its furthest approach distance
	1d(i)	In the next billion years, all values quoted in the table will remain relatively similar with the Sun well into the second half of its stable stage by this time. The temperatures may be a little cooler, since more of its mass has been used up so fewer fusion reactions will occur. However its mass, stated to three significant figures will not change. Its age will of course now be 6×10^9 years.
	1d(ii)	However, after 5 billion years, the Sun is becoming / has become a red giant. Therefore its radius will be much greater while its mass will be less, but only just. Its temperature will be significantly cooler, hence the reddish colour, as opposed to its yellowish colour. The nearest planet will have probably been engulfed by the red giant however due to the reduced mass and therefore weakened gravitational pull, the Earth will almost certainly occupy a wider orbit and hence be further away. It will of course be twice as old.
	2a	The distance from the Sun's surface to the Earth's Surface, will be the Earth's radius of orbit – (the sum of the Sun and Earth's radii). So, the distance light has to travel will be given by: $d = 1.50 \times 10^{11}\ \text{m} - (6.96 \times 10^{8}\ \text{m} + 6.38 \times 10^{6}\ \text{m}) = 1.493 \times 10^{11}\ \text{m}$ Now, since speed of light = distance ÷ time, then $t = \frac{d}{c} = \frac{1.493 \times 10^{11}\ \text{m}}{3.00 \times 10^{8}\ \text{m s}^{-1}} = 498\ \text{s}$
	2b	Since light takes just over 8 minutes to travel from the surface of the Sun to the Earth's surface, then we effectively see the Sun as it was 8 minutes in the past, so you could argue that it is possible to look back in time. Other stars are significantly further away of course, so this statement becomes if more true when we look at these more distant celestial bodies.
	2c	$g = G\frac{M}{r^2} = \frac{6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 1.99 \times 10^{30}\ \text{kg}}{(6.96 \times 10^{8}\ \text{m})^2} = 274\ \text{N kg}^{-1}$
	2d	If the mass of the hydrogen nucleus is m and the mass of the Sun is M, then at the surface of the Sun, their separation is equal to the radius of the Sun, R. Then: $F = \frac{mv^2}{R} = \frac{GMm}{R^2}$ $\therefore v^2 = \frac{GM}{R}$ so, $v = \sqrt{\frac{GM}{R}}$ $\therefore v = \sqrt{\frac{6.67 \times 10^{-11}\ \text{Nm}^2\text{kg}^{-2} \times 1.99 \times 10^{30}\ \text{kg}}{(6.96 \times 10^{8}\ \text{m})}}$ $= 4.37 \times 10^{5}\ \text{m s}^{-1}$
	3a	Sufficiently high temperatures at the Sun's core provide ideal conditions for hydrogen nuclei to fuse, forming helium nuclei (initially, the compressive forces caused fusion to occur). In this process, mass is 'lost', converted to energy according to Einstein's equation, $E = mc^2$, and this energy takes the form of light and heat.
	3b	This nuclear process described above in the solution to question 5 creates huge temperatures which cause natural expansion to occur and hence tremendous forces exerted outwards form the Sun's core.
	3c	The huge mass from which the Sun is formed creates the inward gravitational forces.
	4a	The nebula which formed our solar system was the result of dust and gases contracting and compressing to predominantly form the Sun, whereas planetary nebula is the result of a star exploding and dying and therefore expanding outwards.
	4b	Since the planetary nebula is expanding outwards, then it is extremely unlikely that the matter will condense back together to restart the cycle.

Motion and Forces in a Gravitational Field: Set 1

Set	Number	Solution
Comp. 2	5	In the red giant phase of a star, core temperatures are still very high since the last of the hydrogen fuel is being used up and the star is expanding. However, the white dwarf stage includes a relatively cool core since all the fuel has gone and the gravitational forces have caused the matter to collapse into a relatively tiny volume.
	6a	Although the majority of the mass of the exploding red giant remains within the white dwarf, it has become a sphere which has a significantly reduced radius, r therefore since $g = G\frac{M}{r^2}$, the gravitational forces increase dramatically.
	6b	Since the Sun is losing its mass at the rate of about 4×10^9 kg s^{-1}, then during its approximate life span to date (5×10^9 years), it will be lighter by an amount given by: 4×10^9 kg s^{-1} × (5×10^9 years × 365.25 days × 24 hrs × 60 mins × 60 secs) = 6.31×10^{26} kg. Therefore, its original mass must have been 1.99×10^{30} kg + 6.31×10^{26} kg = 1.991×10^{30}
	6c	The Sun will become a red giant after another 5 billion years, since it is now approximately half way through its life, by which time it will have used up another 6.31×10^{26} kg of its mass. Therefore, its new mass will be 1.99×10^{30} kg - 6.31×10^{26} kg = 1.989×10^{30} kg
	7a	In a neutron star, gravitational forces are so intense that the electrons have been compressed right into the nuclei of the atoms of the matter which formed the star. Each electron will therefore combine with a proton in the nucleus, leaving only neutrons. This is like beta decay in reverse and the process will likewise involve additional particles such as neutrinos. 
	7b	Black holes are so dense, yet so small that their gravitational forces are so immense that not even light can escape their pull – hence, they are black ('absence of light') holes.
	7c