Question			Expected Answers	Further Guidance	Mk
1	a	i	(Jupiter's) moons/satellites		1
		ii	The moons pass in front of/behind Jupiter as they orbit		1
	b		1 Sunspots	no credit for explanations	
			Heavenly 'imperfections'	without matching discoveries	
			2 Phases of Venus		2
			cannot be explained by geocentric model }any two		2
			3 Mountains on Moon:		
			Heavenly 'imperfections'		
			4 Milky way made up of stars		
			stars very distant (so very small parallax in heliocentric model)		
			Total		**[6]**
2	a		An atom may only absorb radiation at certain wavelengths	allow energy level diagram	1
			corresponding to transitions between energy levels in that atom	showing upwards transition	
			OR		
			stars produce a continuum spectrum		
			absorption/re-radiation argument		1
	b		Identify elements from characteristic absorption wavelengths		1
			Obtain abundance from strength of absorption line		
			or other relevant detail	**comparison with spectra**	1
			Total		**[4]**
3	a		$\Delta m = 1.000 - 0.993 = 0.007$ kg	-1 for incorrect Δm	1
			$\Delta E = mc^2$		1
			$= 0.007 \times (3 \times 10^8)^2$	ecf	1
			$= 6.3 \times 10^{14}$ kg s^{-1}	full marks for correct answer	1
	b		Rate of consumption $= 3.9 \times 10^{26}$ J s^{-1}/6.3×10^{14} J kg^{-1} (ecf)		1
			$= 6.2 \times 10^{11}$ kg s^{-1}	full marks for correct answer	1
	c	i	10% of 2×10^{30} kg $= 2 \times 10^{29}$ kg		1
			MS lifetime $= 2 \times 10^{29}$ kg/6.2×10^{11} kg s^{-1}	ecf	1
			$= 3.2 \times 10^{17}$ s ($= 1 \times 10^{10}$ y) (unit penalty -1)	no marks for answer only	1
		ii	sun is 100% H at start of MS life/constant power output/temperature/other valid point		1
			Total		**[10]**
4			Correctly drawn- disc and central bulge		1
			Correctly drawn - spiral arms		1
			On spiral arm, more than half way out from centre		2
			Total		**[4]**
5	a		points plotted correctly (-1 for each error/omission, min 0)	± 0.5 division	2
			smooth curve through points		1
	b		relative motion between source/observer		1
			doppler effect	allow redshift/receding or	
				blueshift/approaching (2 marks)	1
	c		$v = (\Delta\lambda/\lambda)c$		1
			$= ((393.7 - 393.4)/393.4) \times 3 \times 10^8$		1
			$= (2.3 \pm 0.1) \times 10^5$ m s^{-1}	full marks for correct answer	1
	d	i	Period measurement from graph $= 70 \pm 3$ hours		1
			$T = 70 \times 3600 = 2.52 \times 10^5$ s		1
		ii	$v = 2\pi r/T$		1
			So $r = vT/2\pi = 2.29 \times 10^5 \times 2.52 \times 10^5/2\pi$		1
			$r = (9.2 \pm 0.4) \times 10^9$ m (allow ecf) (unit penalty -1)		1
			Total		**[13]**
6	a		1 <u>far</u> - ultraviolet, x-ray, γ-ray	<u>must</u> be named regions	1
			2 radio, far infra red		1
	b		radio, or microwaves, infra-red, ultraviolet		1
			Total		**[3]**

Question			Expected Answers	Further Guidance	Mk
7	a		Corresponds to T ≈ 3 K	allow 2.7-3 K	1
			Blackbody spectrum		1
			Uniform/isotropic		1
			shows ripples	COBE result	
	b		Early universe very hot		
			radiation has origin in BB		
			matter and radiation in equilibrium	5 max	
			universe expands/cools	NB. Correct sequence	
			atoms form/matter and radiation decoupled/universe becomes transparent	1 of 3	5
			radiation has stretched with the universe	allow doppler shifted/red shifted	
	c	i	Homogeneous - the same everywhere, uniform	1 only if wrong way round	1
			Isotropic - looks the same in every direction		1
		ii	CMB is highly uniform (so the universe must be uniform too)		1
			Total		**[11]**
8	a		situation diagram: 2 observers, clocks, relative motion, time interval defined	be flexible to give credit for alternative	
			interval measured	experiments.	
			improper observer sees longer time because longer path		
			speed of light is constant for both observers		
			or other detail	eg reciprocity of observations	
			<u>Muon decay expt:</u> v. high speed muons (1) count rates compared on		
			mountain/sea level (1), count rate higher than expected at sea level because		
			lifetime is greater (1).	3 max - NOT a thought expt	4
	b	i	$t = \gamma t_0$		
			$\gamma = [1-v^2/c^2]^{-1/2} = 1.67$	allow $[1-v^2/c^2]^{1/2} = 0.6$	
			$t = 1.67 \times 26$ ns = <u>43.3 ns</u>	full marks for correct answer	
		ii	$s = 0.8 \times 3 \times 10^8 \times 43.3 \times 10^{-9}$	ecf	
			= <u>10.4 m</u>	full marks for correct answer	
		iii	$s = 0.8 \times 3 \times 10^8 \times 26 \times 10^{-9}$		
			= <u>6.24 m</u>	full marks for correct answer	
			Total		**[10]**
9	a		gravity and acceleration	1 for grav = acc	2
			are equivalent/indistinguishable/ have same effects	correct link	
	b	i	in GR, gravity = spacetime curvature (produced by mass)	allow warped/curved space	1
			light takes shortest path in curved spacetime	light follows curved path, allow	
				acceleration argument	1
		ii	a massive object eg. a galaxy, bends the light coming from an object behind	allow strong grav. field	
			producing a ring shaped virtual image		2
		iii	diagram showing:		
			object galaxy + intermediate lensing object + observer	allow deflection of star image by Sun	1
			bending light rays		1
			location/dircetion of image shown		1
			Total		**[9]**

10 (a)   sensible feature **and** reason one mark for each up to a maximum of 4, e.g.**(4)**
- Graph has low value over the first 6 h **and** ref. to low demand as most people are sleeping
- Demand peaks at mid-day **and** ref. to (electricity consumed for) cooking
- Demand peaks at 1800 / 1900 h **and** ref. to (consumption for) cooking
- Peaks greater in January at tea time / 1700 h **and** ref. to heating and cooking at the end of work
- Demand does not fall below a min. value **and** ref. to reason such as street lights / storage heaters
- Similar shapes of graphs for January and August **and** suggestion that the pattern of the day is similar
- Graph for January is higher than for August **and** ref. to more energy needed for heating
- Graph has a steep slope in morning **and** ref. to industry switching on appliances (allow 'graph goes up in the morning as people go to work)

(b)   look for reference to **time** in both marking points one mark for each up to a maximum of 2, e.g.**(2)**
- it takes <u>time</u> for (added) coal to burn or / it takes time for coal to give out heat at the required rate
- coal fires do not go out <u>straight away</u> or / it takes <u>time</u> to cool down
  allow alternative response here if a sensible comment is made about the problems / costs associated with allowing a power station to cool i.e. it is uneconomical to get going again

(c)(i)   66 +/- 2 GW Allow single unlabelled line on graph if it lies in the range   **(1)**
(ii)   74 – graph value e.g. 66 = <u>8 GW</u>   allow 73.5 to 74 GW for peak value   **(1)**
      A bald answer of 8 GW with no graph value gets 1 mark

(d)(i)   <u>Δ gpe = mgΔh</u> or words or numbers **clearly** arranged to show the change in gpe
      e.g. Δgpe = m x 9.8 x 100   **(1)**
      <u>power = energy converted / time taken</u> or numbers **clearly** arranged to show power
      e.g. power = 1.0×10^9 = m x 9.8 x 100 / **1**   **(1)**
      <u>volume = mass / density</u> or equivalent   **(1)**
      calculation e.g. volume (s^{-1}) = 1.02×10^6 / 1.0×10^3 = $1.02 \times 10^3 \, m^3$ (s^{-1}) **(1)**
(ii) 1.0×10^3 = 35 x area of reservoir **(1)** **or** Vol / s x time = total volume
                                             total volume = 1.0×10^3 x 4 x 60 x 60 **(1)**
      area = 28.6 m^2 (in one second)   **(1)** **or** total volume = $1.44 \times 10^7 \, m^3$ **(1)**
      area for 4 h = 28.6 x 4 x 60 x 60   **or** 1.44×10^7 = 35 x l^2 **(1)**
      = $4.11 \times 10^5 \, m^2$ **(1)**
      $(4.11 \times 10^5)^{0.5}$ = 641 m (648m)   **(1)or** $(4.11 \times 10^5)^{0.5}$ = 641 m (648m)   **(1)**
(iii)   Two comments relevant to the feasibility **ecf (ii)** one mark for each to a maximum of 2 e.g. **(2)**
- ref. to physical dimensions / very large area needed
- drop of 100 m may be a problem with regard to geographical siting
- 7 more lakes needed to meet the demand **ecf (c)**
- argument for this type of pumped storage facility may gain credit if *rapid* response to change in demand is mentioned
- use of peak power at night to store energy as gpe
- sensible comment on a *stated* effect on the environment e.g. destroys habitat / affects ecology **do not allow any reference to costs or noise**

(iv) look for energy conversions for both marks one mark each to max. 2 e.g. **(2)**
- turbine is inefficient as some of the ke of water is converted into heat
- conversion to heat energy is due to friction in turbine / friction in generator / friction in pipes
- some ke retained by water after passing through turbine / not all ke given to turbine