Higher Universe

Past Paper Answers

Contents

The Big Bang Theory and The Expanding Universe	pg 2-3
Doppler Effect	pg 3-6
Gravitational Force	pg 7-11
Redshift	pg 12
Special Relativity	pg 12-13
Temperature of Stars	pg 13

Higher Universe Answers

The Big Bang Theory and The Expanding Universe

1. E   2. D   3. C   4. B   5. E

6a)	Description of what Big Bang theory is e.g. The Universe was initially in a hot and very dense state and then rapidly expanded. *or* The Universe started from a point/singularity and rapidly expanded One supporting factor e.g. abundance of hydrogen/helium Cosmic Microwave Background Radiation/present temperature of Universe Darkness of the sky at night/Olbers' paradox Redshift of galaxies	(1) (1)
6b)	**Show teacher if possible* *Answer could include correct information on the speed of light and how it takes time to travel from distance stars and galaxies - so it is old light, showing how stars or galaxies looked years ago. This could then lead into Olbers' paradox and the fact that the night sky isn't completely full of light as light from some distant galaxies still hasn't reached us yet. Or it could relate to the fact that the light observed through a telescope may be redshifted/blueshifted depending on whether or not a galaxy is moving towards/away from Earth. Could look at redshift "z" and the equations that relate to this. Could mention the amount of redshift is based on the speed of distant galaxies, and the further away it is the faster it is travelling away from us: Hubble's Law. Could include a graph sketch of Hubble's Law or the equation $v = H_0 d$, discussing what they show/mean. Could talk about microwave telescopes revealing Cosmic Microwave Background Radiation and how this relates to the origins of the Universe.*	(3)
7ai)	X = 0.016 ($m\ s^{-1}$) Y = 0.024 ($m\ s^{-1}$)	(1) (1)
7aii)	More distant galaxies are moving away at a greater velocity/have a greater recessional velocity.	(1)
7b)	$z = \frac{\lambda_{observed} - \lambda_{rest}}{\lambda_{rest}}$ $z = \frac{667 \times 10^{-9} - 656 \times 10^{-9}}{656 \times 10^{-9}}$ z = 0.0168	(1) (1) (1)

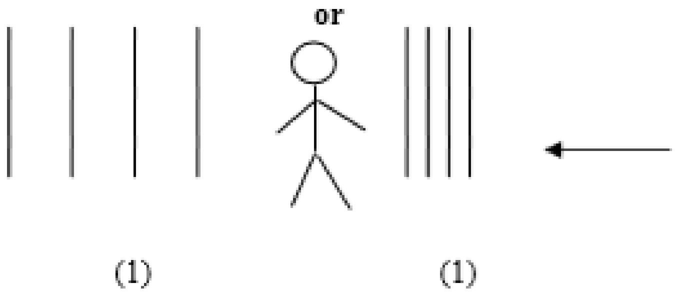
8a)	Cosmic Microwave Background Radiation ("*CMBR*" alone not accepted) *or* Olbers' Paradox *or* Abundance of hydrogen and helium in the Universe *or* Abundance of light elements in the Universe	(1) *any one*
8bi)	age of universe $= \frac{1}{H_0}$ age of universe $= \frac{1}{2 \times 10^{-17}}$ age of universe $= 5 \times 10^{16}$ s age of universe $= 1.59 \times 10^{9}$ (years) *Must have turned final answer correctly into years for second mark.*	(1) (1)
8biiA)	Value for H_0 *is incorrect/too large/not accurate.* *or* Incorrect line of best fit drawn. *or* The gradient (which is H_0) is too large. *or* New/more data is available/more accurate (compared to his 1929 data) *or* Not enough data at large distances. *or* H_0 varies/decreases as age of the universe increases. H_0 *is different is* <u>*not*</u> *accepted. A comparison of the student's value to the real value from the data sheet is fine as this shows that the student's value is too large.*	(1) *any one*
8biiB)	The student could draw the (correct) line of <u>best</u> fit *or* Student could use a larger sample/all of the 1929 Hubble data. *or* Student would use current data *"draw a different line of best fit" alone is* <u>*not*</u> *accepted.*	(1) *any one*

<u>Doppler Effect</u>

1. C 2. E 3. E 4. B

5ai)	The Doppler Effect	(1)

5aii)	$f_o = f_s \left(\frac{v}{v \pm v_s}\right)$ $f_o = 510 \left(\frac{340}{340 - 12}\right)$ f_o = 529 Hz *It's fine to have written the equation with just the minus symbol in the first line of working. It's always a negative when something noisy is coming towards you.*	(1) (1) (1)
5b)	$\Delta f = \frac{2f\, v_{rbc}\ \cos\theta}{v}$ $286 = \frac{2 \times 3.7 \times 10^6 \times v_{rbc} \times \cos 60}{1540}$ v_{rbc} = 0.119 m s^{-1}	 (1) (1)
6a)	$f_o = f_s \left(\frac{v}{v \pm v_s}\right)$ $f_o = 1020 \left(\frac{340}{340 - 22}\right)$ f_o = 1090 Hz (*3 significant figures*) *or* 1091 Hz (*4 s. f.*) *It's fine to have written the equation with just the minus symbol in the first line of working.*	(1) (1) (1)
6b)	$f_o = f_s \left(\frac{v}{v \pm v_s}\right)$ $1107 = 1020 \left(\frac{340}{340 - v_s}\right)$ v_s = 26.7 m s^{-1} *It's fine to have written the equation with just the minus symbol in the first line of working.*	(1) (1) (1)
7a)	$f_o = f_s \left(\frac{v}{v \pm v_s}\right)$ $f_o = 200 \left(\frac{340}{340 + 30}\right)$ f_o = 184 Hz *It's fine to have written the equation with just the plus symbol in the first line of working. It's always a positive when something noisy is moving away from you.*	(1) (1) (1)

7b)	It is moving away as it is redshifted/as the wavelengths appear longer. *No attempt to justify means 0 marks, even if you said moving away. "**must** justify your answer".*	(1) (1)
8a)	It is a higher frequency when approaching and a lower frequency after passing.	(1)
8b)	The wavefronts are closer together when approaching and more spaced out when moving away so more wavefronts are observed per second when approaching and less per second when moving away *or by diagram* 	(1) (1)
8c)	$f_o = f_s \left(\frac{v}{v \pm v_s}\right)$ $760 = 800 \left(\frac{340}{340 + v_s}\right)$ $v_s = 17.9 \text{ m s}^{-1}$ *It's fine to have written the equation with just the plus symbol in the first line of working. The frequency was less, so the train must be moving away, hence why you need to use the plus symbol. If you used minus for any part of the working then you get no marks for this part.*	(1) (1) (1)
9ai)	The wavefronts are closer together when approaching the alarm so more wavefronts are observed per second.	(1) (1)
9aii)	$f_o = f_s \left(\frac{v + v_o}{v}\right)$ $f_o = 1250 \left(\frac{340 + 25}{340}\right)$ $f_o = 1340 \text{ Hz}$ *Equation was given - no mark is awarded for this.*	 (1) (1)
9b)	The distant star is moving away from us	(1)

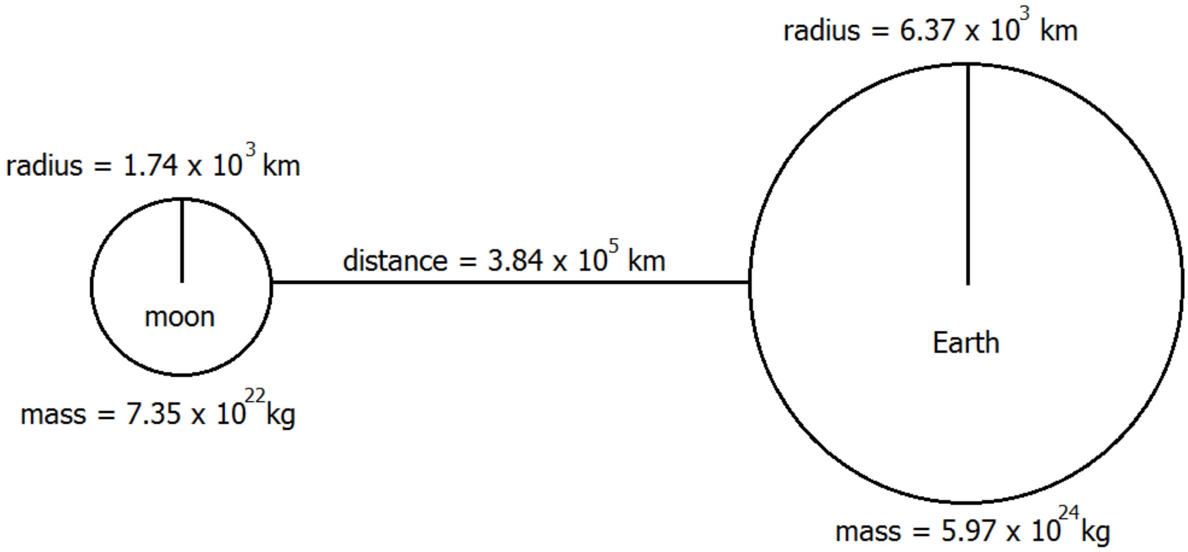
	as the wavelengths appear longer (so redshifted).	(1)
10a)	$f_o = f_s \left(\frac{v}{v \pm v_s}\right)$ $f_o = f_s \left(\frac{v}{v - v_s}\right)$ $\frac{f_o}{f_s} = \frac{v}{v - v_s}$ $\frac{f_s}{f_o} = \frac{v - v_s}{v}$ $\frac{f_s v}{f_o} = v - v_s$ $\frac{f_s v}{f_o} + v_s = v$ $v_s = v - \frac{f_s v}{f_o}$ *If you managed to get the correct final answer by a different method then 2 marks still awarded. Maybe better to show your teacher your working to make sure you've done it correctly.*	(1) *for minus* *flip both sides* (1)
10bi)	$f_o = f_s \left(\frac{v}{v \pm v_s}\right)$ $f_o = 294 \left(\frac{340}{340 - 28}\right)$ f_o = 320 Hz	(1) (1) (1)
10bii)	$f_o = f_s \left(\frac{v}{v \pm v_s}\right)$ $f_o = 294 \left(\frac{340}{340 + 28}\right)$ f_o = 272 Hz	(1) (1) (1)

Gravitational Force

1. B 2. E 3. C 4. A

5a)	$F = G\frac{m_1m_2}{r^2}$ $F = 6.67 \times 10^{-11}\frac{6.42 \times 10^{23} \times 5.6 \times 10^3}{(3.7 \times 10^6 + 3.39 \times 10^6)^2}$ F = 4770 N	(1) (1) (1)
5b)	W = mg $4770 = 5.6 \times 10^3 \times g$ $g = 0.852\ N\,kg^{-1}$ *Gravitational force and weight are the same thing. This is important to remember as you'll need to use your F value as W when calculating gravitational field strength. An easy 3 marks if you remember this.*	(1) (1) (1)
6a)	$F = G\frac{m_1m_2}{r^2}$ $F = 6.67 \times 10^{-11}\frac{5.97 \times 10^{24} \times 900}{(400 \times 10^3 + 6370 \times 10^3)^2}$ F = 7820 N	(1) (1) (1)
6b)	W = mg 7820 = 900 x g $g = 8.69\ N\,kg^{-1}$	(1) (1) (1)
7a)	When in orbit the people on-board are in <u>constant free-fall</u> towards the planet (so appear to float). *Not because there is no gravity. If there was no gravity then the satellite wouldn't stay in orbit around the planet.*	(1)
7bi)	$F = G\frac{m_1m_2}{r^2}$ W = mg W = F $mg = G\frac{m_1m_2}{r^2}$ $g = G\frac{m_1}{r^2}$	(1) both eq. (1) *or (2) if you started*

	$m_1 = \frac{gr^2}{G}$ *Sometimes rather than using m_1 and m_2, the symbol for a bigger mass is M and for a smaller mass is m - i.e.* $$F = G\frac{Mm}{r^2}$$ *This tends to be used in Advanced Higher Physics to distinguish two different mass values.*	*here*
7bii)	$m_1 = \frac{gr^2}{G}$ $m_1 = \frac{25 \times (69.9 \times 10^6)^2}{6.67 \times 10^{-11}}$ $m_1 = 1.83 \times 10^{27}$ kg	(1) (1)
7ci)	$F = G\frac{m_1 m_2}{r^2}$ $F = 6.67 \times 10^{-11} \; \frac{1.83 \times 10^{27} \times 100}{(7 \times 10^6 + 69.9 \times 10^6)^2}$ F = 2060 N *Answer given so no mark for this part. As this is a "show" question you <u>must</u> give the answer exactly as the question asks for it. 2064 N would be incorrect.*	(1) (1)
7cii)	distance/circumference = $2\pi r$ distance = $2 \times \pi \times (7 \times 10^6 + 69.9 \times 10^6)$ distance = $4.83... \times 10^8$ m d = vt $4.83... \times 10^8 = 40 \times 10^3 \times t$ t = 12100 s	(1) (1) (1) (1)

8a)	 Correct numbers and units Moon and Earth labelled	(1) (1)
8b)	$F = G\dfrac{m_1 m_2}{r^2}$ $F = 6.67 \times 10^{-11}\dfrac{5.97 \times 10^{24} \times 7.35 \times 10^{22}}{(6.37 \times 10^{6} + 1.74 \times 10^{6} + 3.84 \times 10^{8})^2}$ $F = 1.90 \times 10^{20}$ N	(1) (1) (1)
8c)	W = mg $1.90 \times 10^{20} = 7.35 \times 10^{22} \times g$ $g = 2.59 \times 10^{-3}$ N kg^{-1}	(1) (1) (1)
9.	$mg = G\dfrac{m_1 m_2}{r^2}$ $g = G\dfrac{m_1}{r^2}$ $3.7 = 6.67 \times 10^{-11}\dfrac{6.4 \times 10^{23}}{r^2}$ $r = 3.4 \times 10^{6}$ m *Important to remember the weight and gravitational force are the same thing. You could have done W = mg (using any value for m) then $F = Gm_1m_2/r^2$ (using the same m value for m_2) to answer this question too.*	(1) (1)

10.	$F = G\frac{m_1m_2}{r^2}$ $4.47 \times 10^{-2} = 6.67 \times 10^{-11}\ \frac{1.31 \times 10^{22} \times 320}{r^2}$ $r = 7.90... \times 10^7$ (m) r = planet radius + distance $7.90... \times 10^7 = 1.89 \times 10^6$ + distance distance = 7.72×10^7 m	(1) (1) (1) (1)
11.	$F = G\frac{m_1m_2}{r^2}$ $3.31 \times 10^{-2} = G\ \frac{8.93 \times 10^{22} \times 500}{(3 \times 10^8)^2}$ $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}	(1) (1)
12ai)	30 - 27 = 3 <u>The star</u> is 3 orders of magnitude larger *or* <u>The exoplanet</u> is 3 orders of magnitude smaller	(1) (1)
12aii)	$F = G\frac{m_1m_2}{r^2}$ $F = 6.67 \times 10^{-11}\ \frac{3.83 \times 10^{30} \times 5.69 \times 10^{27}}{(3.14 \times 10^{11})^2}$ $F = 1.47 \times 10^{25}$ N	(1) (1) (1)
12bi)	$z = \frac{v}{c}$ $z = \frac{6.6 \times 10^3\ (\mathrm{m\ s^{-1}})}{3 \times 10^8\ (\mathrm{m\ s^{-1}})}$ $z = 2.2 \times 10^{-5}$ *Notice how the m s^{-1} cancel each other out, hence why "z" has no units. Same when using wavelengths to find "z" - the metres in the numerator and denominator cancel each other out.*	(1) (1) (1)
12bii)	Greater than as the greater the mass, the greater the gravitational force.	(1) (1)
13a)	($36 \times 10^6 + 6.4 \times 10^6$ =) 42.4×10^6 m *or* 4.24×10^7 m	(1)
13b)	$F = G\frac{m_1m_2}{r^2}$	(1)

	$57 = 6.67 \times 10^{-11} \frac{6 \times 10^{24} \times m_2}{(42.4 \times 10^{6})^2}$ m_2 = 256 kg	(1) (1)
13c)	W = mg 57 = 256 x g g = 0.223 N kg^{-1}	(1) (1) (1)
13d)	Force is the same *Could prove by calculation:* $F = G \frac{m_1 m_2}{r^2}$ $F = 6.67 \times 10^{-11} \frac{6 \times 10^{24} \times (0.25 \times 256)}{(0.5 \times 42.4 \times 10^{6})^2}$ F = 57 N *or* a quarter of the mass results in a quarter of the force a half of the distance results in quadrupling the force (so these effects cancel each other out meaning the force is the same)	(1) *calc.* (1) (1) *or* (1) (1)

Redshift

1. C 2. A 3. B

Special Relativity

1. C 2. B 3. C 4. B 5. C 6. B

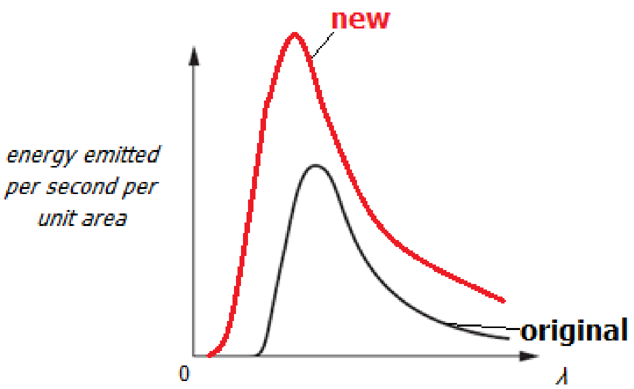
7. D 8. C

9a)	(0.83 + 1.20) - 1.80 = 0.23 m s^{-1} *Full marks still if you just gave the correct final answer without working.*	(1) (1)
9bi)	3×10^8 m s^{-1} as the speed of light is constant, no matter which frame of reference an observer is in.	(1) (1)
9bii)	$l' = l\sqrt{1 - (\frac{v}{c})^2}$ $l' = 71\sqrt{1 - (\frac{0.8c}{c})^2}$ $l' = 71\sqrt{1 - (0.8)^2}$ l' = 42.6 m	(1) *c values cancel* (1) (1)
9biii)	Correct - if observed in the stationary observer's reference frame. *or* Incorrect - if observed in the on-board observer's reference frame. *or* Not possible to say/could be correct and incorrect - dependant on which frame of reference it is being observed in.	(1) *any one*
10a)	d = vt $d = (0.995 \times 3 \times 10^8) \times 2.2 \times 10^{-6}$ d = 660 m	(1) (1)

10b)	$t' = \dfrac{t}{\sqrt{1 - (\frac{v}{c})^2}}$ $t' = \dfrac{2.2 \times 10^{-6}}{\sqrt{1 - (0.995)^2}}$ $t' = 2.2 \times 10^{-5}\ m\,s^{-1}$	(1) (1) (1)
10c)	More than as the speed of the muons is now greater than before/is now closer to the speed of light. *Could prove by calculation but still need to state "more than".*	(1) (1)

Temperature of Stars

1. B 2. B 3. C 4. D

5a)	 Line added should always be above the original Peak wavelength of new line should be less than the original's *No labels = no marks*	 (1) (1)
5b)	$7700 \times 3.76 \times 10^{-7} = 2.9 \times 10^{-3}$ $8500 \times 3.42 \times 10^{-7} = 2.9 \times 10^{-3}$ $9600 \times 3.01 \times 10^{-7} = 2.9 \times 10^{-3}$ $12000 \times 2.42 \times 10^{-7} = 2.9 \times 10^{-3}$ therefore $T \times \lambda_{peak} = 2.9 \times 10^{-3}$ *or* $T \times \lambda_{peak} =$ constant *Alternatively you could have calculated the temperatures* ***or*** *wavelengths using the equation, but a statement saying this proves the relationship is still needed for third mark. Could also have plotted data correctly as a graph (1), calculated the gradient (1) and given a correct statement (1).*	(2) for 4 correct calculations (1) for 3 correct calcs. (0) for less than 3 calcs. (1) correct statement