

YEAR 12 PHYSICS
ASSIGNMENT 7 - STANDARD MODEL

Name: _____

Mark: $\frac{\quad}{41}$

1. The Milky Way galaxy (our galaxy) and the Andromeda galaxy are approximately 250 000 light years apart, and they are approaching each other at a rate of 110 km s^{-1} . Scientists know this because of the blue-shift of light coming from the Andromeda galaxy.

Read the following statements and circle 'True' or 'False'.

(3 marks)

Light reaching the Milky Way from the Andromeda galaxy arrives slightly faster than $3 \times 10^8 \text{ m s}^{-1}$.	True	False
Light reaching the Andromeda galaxy from the Milky Way galaxy would be red-shifted.	True	False
The Andromeda galaxy must be on a collision course with the Milky Way galaxy.	True	False

2. The recession speed of a Cepheid variable star was determined as $28\,800 \text{ km s}^{-1}$ moving away from the Earth. Assume that the star's motion was due only to the expansion of space.

The star's recession speed v_{rec} is linked to Hubble's constant, H_0 , by the relationship:

$$v_{\text{rec}} = H_0 \times d$$

where d is the distance of the star from the observer.

- (a) Using appropriate assumptions and Hubble's constant of $1.86 \times 10^{-5} \text{ km s}^{-1} \text{ light-year}^{-1}$, determine the star's distance from an observer on the Earth. Include units in your answer, and show **all** workings. (3 marks)

- (b) Estimate the star's current distance from the Earth (in light-years), taking account of the distance that the star travelled while the light from the star travelled to Earth. Show **all** assumptions and workings. (5 marks)

- (c) Estimate how long it would take for light to travel from the current position of the star to an observer on Earth. Explain why this must be an estimate. (2 marks)

3. An exotic hadron, initially seen over 40 years ago, has recently been confirmed at the European Organization for Nuclear Research (CERN). The Z(4430) particle consists of four quarks: a charm, an anti-charm, a down, and an anti-up.

Use the following table to show the calculation required to determine the charge of the Z (4430) particle. (2 marks)

Table of quarks		
Name	Symbol	Electrostatic charge
Up	u	$+\frac{2}{3}e$
Down	d	$-\frac{1}{3}e$
Strange	s	$-\frac{1}{3}e$
Charm	c	$+\frac{2}{3}e$
Bottom	b	$-\frac{1}{3}e$
Top	t	$+\frac{2}{3}e$

4. A space probe travels along a line from the Earth to Uranus at a constant speed of $0.95c$ relative to the solar system. Just as it reaches midway between the two planets, it sends laser beams out to the Earth and Uranus at the same time. At what speed do the laser beams approach the Earth and Uranus, respectively? (3 marks)

Speed of laser beam approaching the Earth:

Speed of laser beam approaching Uranus:

To an observer on Uranus, will the light from the space probe appear red shifted, or blue shifted? Circle the correct answer.

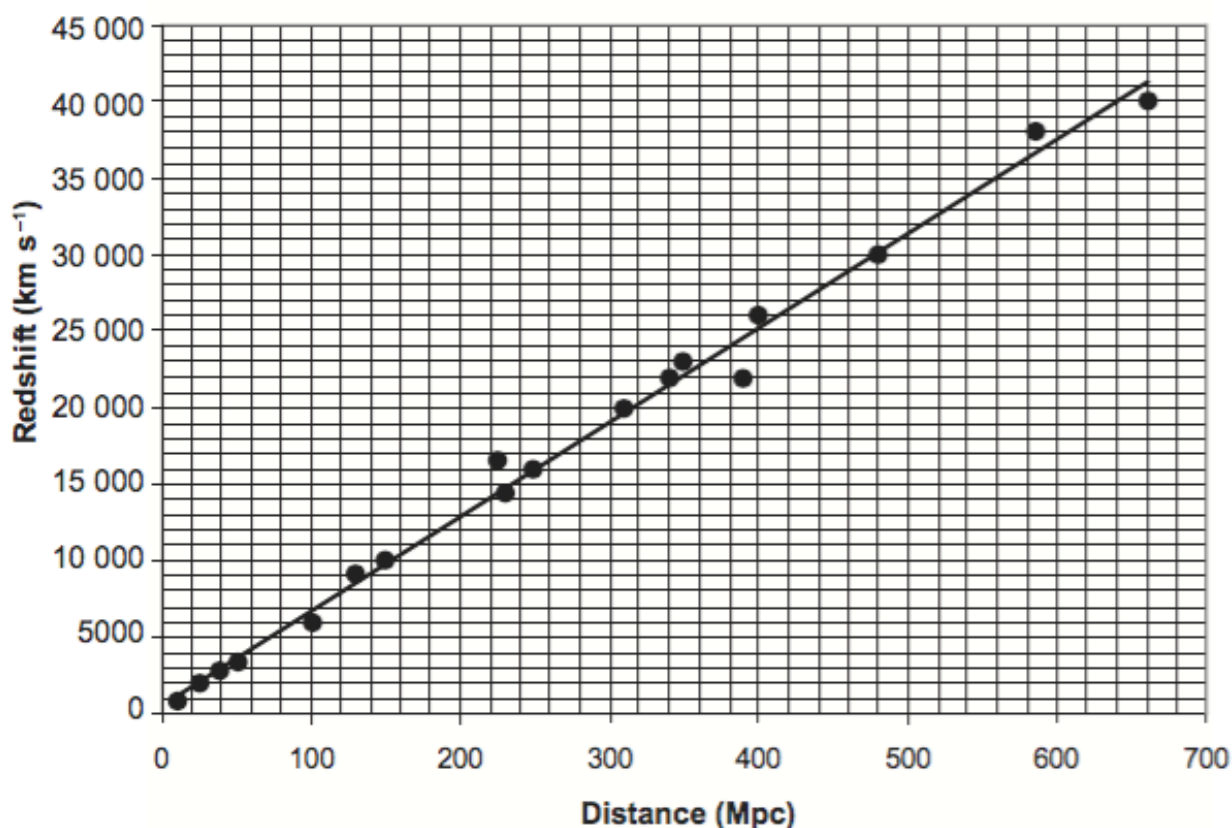
red shifted

blue shifted

5. Describe briefly the relationship between the mass and energy of an accelerating object as its speed approaches, but cannot exceed, the speed of light in vacuum, c . (3 marks)

6. Hubble's law can be used to estimate the maximum size of the observable Universe. The graph below indicates the relationship between recessional speed of a star (or galaxy) and the distance to that star (or galaxy).

Distances are given in megaparsecs (Mpc) where 1 Mpc = 3.26 light years.



- (a) The vertical axis is labelled 'redshift' with units for velocity (km s^{-1}). Explain briefly the relationship between redshift and the speed of the object. (2 marks)
- (b) Use the gradient of the graph to extrapolate a value for the maximum distance, in Mpc, for a galaxy to be observed from the Earth. Show **all** workings. (3 marks)

7. A distant star is seen by an astronomer using a powerful telescope to be travelling toward the Earth with a velocity of $0.1c$.

(a) At what velocity does the light reach the telescope? (1 mark)

(b) What is it about the starlight's spectrum that tells the astronomer that the star is approaching? Explain your answer. (2 marks)

8.

Table of quarks

Name	Symbol	Electrostatic charge
Up	u	$+\frac{2}{3}e$
Down	d	$-\frac{1}{3}e$
Strange	s	$-\frac{1}{3}e$
Charmed	c	$+\frac{2}{3}e$
Bottom	b	$-\frac{1}{3}e$
Top	t	$+\frac{2}{3}e$

Table of baryons

Particle	Composition
p^+	u u d
n	u d d
Σ^+	u u s
Σ^0	u d s
Σ^-	d d s
Ω^-	s s s

(a) Use the information in the above tables to explain why the electrostatic charge on the Σ^0 particle is neutral. (2 marks)

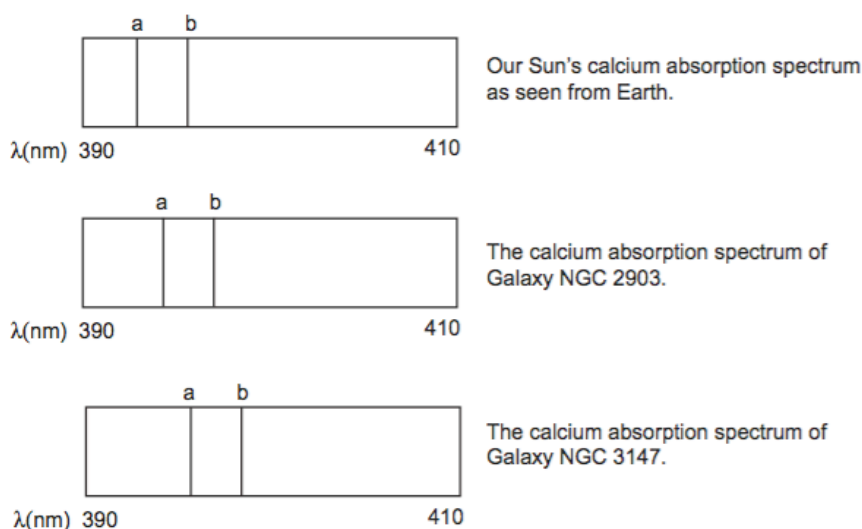
(b) It is possible for another baryonic particle to exist in nature with a positive electrostatic charge equal to that of the proton. What would its quark composition be, given that this particle contains two up quarks and is **not** a proton? (1 mark)

9. A geostationary satellite orbits the Earth at an altitude of 35 000 km. It travels at a speed of approximately 3000 ms^{-1} .

Relativistic effects may cause a clock on board the satellite to run a little slower or a little faster than the same clock on the surface of the Earth. Considering the factors that may lead to relativistic effects, complete the table below. (3 marks)

Factor leading to relativistic effect	Change in factor	Effect on time shown by clock
gravitational field	decreased	faster

10. The figure below shows three simplified absorption spectra for ionised calcium. Many of the absorption lines and the background colour have been removed. In all three spectra the same two absorption lines, 'a' and 'b', are shown. The top spectrum is an example of a spectrum recorded in a laboratory on Earth; the lower two have been recorded from two different galaxies.



- (a) Explain why absorption spectra appear as dark lines on an otherwise continuous electromagnetic spectrum. (3 marks)
- (b) Which galaxy is further away from Earth? Justify your answer. (3 marks)