HALE SCHOOL
PHYSICS
Particles, Relativity and Cosmology
YEAR 12 Unit 3B
Diagnostic Test 2010

Test Score:

Teacher: **JAA** **ICT**

Name: Solutions and Marking guide Set:

INSTRUCTIONS:

- ☐ Time Allowed = 60 minutes
- ☐ Total Marks = 57 marks
- ☐ Answer all questions in the space provided.
- ☐ Rough working is permitted on the question paper.
- ☐ Show all relevant working details in order to acquire full marks.
- ☐ Graphic Calculators are Not permitted for this paper.
- ☐ ***Do Not write in pencil. (Note: a 1 mark penalty will be incurred)**

POST ASSESSMENT REVIEW (to be completed upon return of your marked paper)

SELF-ASSESSMENT:

Relative Weaknesses –Objective No.

Relative Strengths –Objective No.

Major Concerns: (be specific)

Action Plan: (be specific)

Q1[4 marks]
Complete the following table:

Fundamental Force	Gauge Bosons
ELECTROMAGNETIC	PHOTON
GRAVITATION.	GRAVITON
STRONG NUCLEAR	GLUON
WEAK NUCLEAR	W^+ W^- Z^0

(1/2 MARK EACH)

Q2[9 marks]
2a) List each of the known quark flavours.

UP
DOWN
STRANGE
CHARM
TOP
BOTTOM

+ 1 MARK FOR ANTI QUARKS
eg ANTI-UP, ANTI-DOWN etc
1/2 MARK EACH
=> 3 MARKS

(4marks)

2b) How many quarks do "Baryons" consist of.

THREE
(1mark)

2c) Protons and neutrons are "Hadrons". Which quarks do protons and neutrons consist of?

UP AND DOWN QUARKS
(1mark)

2d) The electron is a well known "Lepton". Name two other particles which are also leptons.

SELECT TWO FROM : MUON, TAU, NEUTRINOS, POSITRON, ANTI-NUTRINOS
(1mark)

2e) Name a particle that is classified as anti-matter.

(ELECTRON, MUON, TAU)
SELECT FROM : POSITRON, ANTI-NUTRINOS
(1mark)

2f) Briefly describe the properties of a neutrino.

MASSLESS, NEUTRAL CHARGE, HARD TO DETECT ~ LITTLE INTERACTION
(1mark)

Q3 [10 marks]

3a) What are Einstein's two postulates of Special relativity?

I) NO LAW OF PHYSICS CAN IDENTIFY A STATE OF ABSOLUTE REST (I.E NO SINGLE INERTIAL FRAME OF REFERENCE IS SUPERIOR)

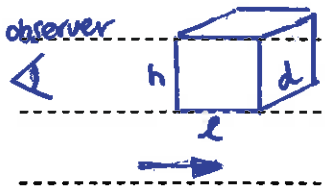
II) THE SPEED OF LIGHT WILL ALWAYS BE THE SAME FOR ALL OBSERVERS. (IRRESPECTIVE OF THE MOTION OF THE LIGHT SOURCE OR OBSERVER) (2marks)

3b) Briefly describe the predicted change, if any, to the following dimensions for an object on approaching the speed of light:

Dimension	Predicted change
length	LENGTH CONTRACTS IN DIRECTION OF MOTION
mass	MASS INCREASES
time	TIME IS DILATED (SLOWER)

(3marks)

3c) If a box was moving away from you at nearly the speed of light, describe any changes to the length, height and depth of the box from your perspective.



THE HEIGHT AND DEPTH ARE UNCHANGED HOWEVER, THE LENGTH IS CONTRACTED BECAUSE IT IS THE "LENGTH" IN THE DIRECTION OF MOTION AWAY FROM OBSERVER (2marks)

3d) Briefly describe what is meant by "relativity of simultaneity" ?

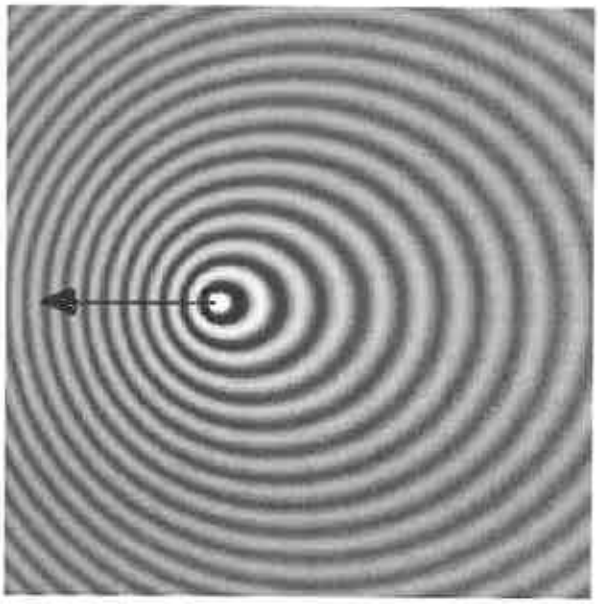
OBSERVERS OF AN EVENT (EG LIGHTNING STRIKES) IN DIFFERENT FRAMES OF REFERENCE / RELATIVE TO EACH OTHER CANNOT AGREE ON THE SIMULTANEOUS TIMING OF EVENTS. WHAT HAPPENS (FIRST) DEPENDS ON THE RELATIVE MOTION OF THE OBSERVER. (2marks)

3d) Briefly describe the aim of the Michelson-Morley experiment.

ATTEMPTED TO MEASURE THE "AETHER WIND" THAT SHOULD BE BLOWING AGAINST THE EARTH AS IT MOVES THROUGH THE AETHER. THE AETHER DOES NOT EXIST! (1mark)

Q4 [2 marks]

The following photograph is of a vibration pattern produced by a moving object in a ripple tank.



4a) Clearly identify, on the diagram provided, the direction in which the vibrating source is moving

TO THE LEFT (1mark)

4b) Briefly justify your answer.

WAVES ARE CLOSER TOGETHER ON THE LEFT RESULTING IN HIGHER FREQUENCY AS PREDICTED BY DOPPLER EFFECT.

(1mark)

Q5 [5 marks]

An emergency services vehicle approaches an intersection at 110 km h^{-1} continuously sounding a horn of frequency 750 Hz. A pedestrian on the footpath at the intersection hears the horn of the approaching vehicle at a different frequency.

5a) Briefly describe what the pedestrian would hear.

SINCE THE SOURCE of SOUND IS MOVING TOWARDS THE OBSERVER, IT WOULD BE AT A HIGHER FREQUENCY (1mark)

The observed frequency can be calculated using the formula:

$$\text{frequency observed} = \text{true frequency} \times \left[\frac{v}{v - v_s}\right]$$

where v is the speed of sound in the medium,
v_s is the velocity of the moving source.

5b) As the driver approaches the intersection, in the equation is the sign allocated to the velocity of the source + or – to match what the observer hears? Justify your choice.

MUST BE -VE FOR THE DENOMINATOR TO BE SMALLER, TO RESULT IN A HIGHER VALUE of FREQUENCY (2marks)

5c) Calculate the frequency of the sound heard by the pedestrian.

110 kmh^{-1} = 30.56 ms^{-1}

$\therefore$ OBSERVED FREQUENCY = $750 \times \frac{340}{340 - 30.6}$

= 824 Hz

(2marks)

Q6 [9 marks]

The visible emission spectrum of a hydrogen atom has three bright lines – red, blue-green, and violet. The blue-green line is caused by the emission of a photon as it moves from energy level 4 to energy level 2.

The energy of each level (in eV) can be calculated using the formula $E_n = \frac{-13.6}{n^2}$

6a) What is the energy of the photon emitted (in eV) that causes the blue-green line?

$E_4 = \frac{-13.6}{4^2} = -0.85$ eV , $E_2 = \frac{-13.6}{2^2} = -3.4$ eV

$\therefore E_{4\to 2} = 3.4 - 0.85 = 2.55$ eV (1mark)

6b) What is the wavelength of this line in nanometres?

$E = 2.55 \times 1.6 \times 10^{-19} = 4.08 \times 10^{-19}$ J

$\lambda = hc/E = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{4.08 \times 10^{-19}}$

$\therefore \lambda = 7.8 \times 10^{-7}$ m $= 488$ nm (2marks)

6c) The blue-green line of the hydrogen spectrum from a close galaxy is observed at 537.4 nm.

The redshift Z can be calculated $Z = \frac{\lambda_{obs} - \lambda_{rest}}{\lambda_{rest}}$ Calculate the red shift of the galaxy.

$Z = \frac{537.4 - 487.5}{487.5}$

$= 0.102$ (1mark)

6d) For close galaxies receding at a relatively low velocity, the recessional velocity of the galaxy can be calculated from $Z = \frac{v}{c}$ where c is the speed of light.

Use the value of the redshift to calculate the recessional velocity of the galaxy (in km s^{-1}).

since $Z = v/c$

$\therefore v = Z \times c = 0.102 \times 3 \times 10^8$

$\therefore v = 3.02 \times 10^7$ ms^{-1} $= 3.02 \times 10^4$ $km\,s^{-1}$ (2marks)

6e) Using Hubble's law calculate the distance in light-years to this relatively close galaxy using the redshift value from part (c). (1megaparsec = 3261636.26 light-years)

Hubble's law: $v = H_0 D$ where v is the velocity (in km s^{-1}),
D is the distance (megaparsecs Mpc),
H_0 is Hubble's constant [$H_0 = 74.2 \pm 3.6$ (km s^{-1} Mpc^{-1})]

$3.02 \times 10^4 = 74.2 \pm 3.6 \times D$

$\therefore D = \frac{3.02 \times 10^4}{74.2 \pm 4.85\%} = 4.07 \times 10^2$ Mpc $\pm$ 4.85%

$= 4.07 \times 10^8$ pc $\pm$ 4.85%

$= 1.35 \times 10^9$ ly $\pm 2.0 \times 10^8$ ly (3marks)

Q7 [2 marks]

The redshift of the Andromeda galaxy has been calculated as 0.301.

A radio telescope monitoring H radio emission (normally at 21.106 cm) will need to monitor a different wavelength to pick up emissions from Andromeda.

The following equation is used for calculating red shift, Z: $Z = \frac{\lambda_{obs} - \lambda_{rest}}{\lambda_{rest}}$

Which wavelength must be monitored?

$0.301 = \frac{\lambda_{obs} - 21.106}{21.106}$

$\therefore \lambda_{obs} = (0.301 \times 21.106) + 21.106$

$= 27.459$ cm

(2marks)

Q8 [4 marks]

In 1054 AD Chinese astronomers noticed the appearance of a bright star visible in the constellation of Taurus. It was a supernova explosion – the death of a star. The Crab Nebula is the shattered remnant of that massive star. The nebula is about 6 500 light-years away from the Earth and is 5 light-years across, and has a pulsar (a rotating neutron star) at its centre.

8a) In which year (BC) did this supernova actually take place?(Show your working)

$1054 - 6500 = -5446$

∴ EXPLOSION WAS IN 5446 BC

(2marks)

8b) What is the distance, in km, across this nebula?

DISTANCE $= v \times t$

$= 5 \times 365.25 \times 24 \times 60 \times 60 \times 3 \times 10^8$

$= 4.733 \times 10^{16}$ m

$= 4.733 \times 10^{13}$ km

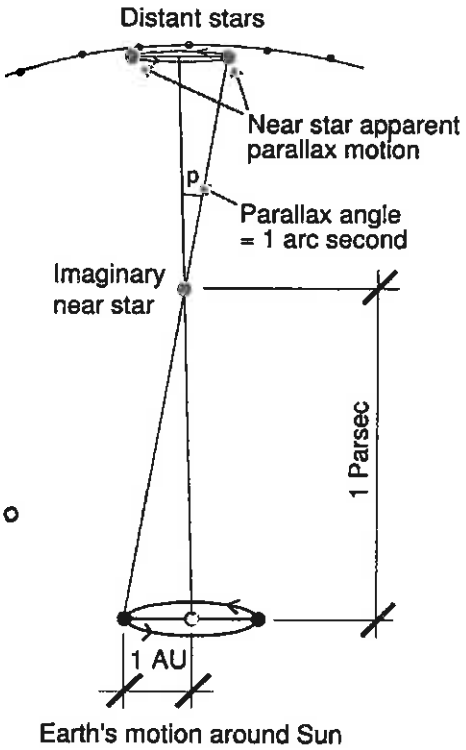
(2marks)

Q9 [5 marks]

Before satellites were available, stellar parallax was measured from Earth using annual parallax as the Earth orbits around the sun.

1 parsec = 3.26156 light-years and is also the distance for which the annual parallax is 1 arcsecond.

1 Earth year = 365.25 solar days)



9a) If the imaginary star in the diagram above is 1 parsec away, how distant is this star in metres?

$1_{PARSEC} = 3.26156 \times 3 \times 10^8 \times 365.25 \times 24 \times 60 \times 60$

$= 3.088 \times 10^{16}$ m

(1 mark)

9b) Compass headings are given in degrees, minutes and seconds. What is one second as a decimal of a degree?

THERE ARE 60 s IN 1 MINUTE AND 60 MINUTES IN ONE DEGREE

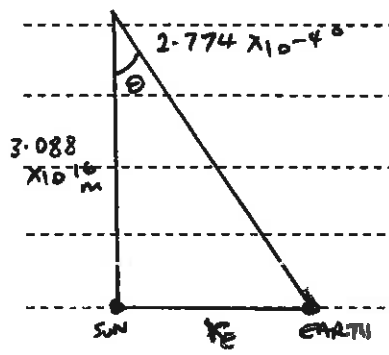
$\therefore 1\text{ s} = \frac{1}{60 \times 60}$ DEGREE

$= \frac{1}{3600}^\circ$

$= 2.774 \times 10^{-4}\,^\circ$ (DEGREES)

(2marks)

9c) Calculate the radius of the Earth's orbit around the Sun in metres.



$\tan\theta = \text{opp}/\text{adj}$

$\tan 2.774 \times 10^{-4}\,^\circ = r_E / 3.088 \times 10^{16}$

$\therefore r_E = \tan 2.774 \times 10^{-4} \times 3.088 \times 10^{16}$

$= 1.497 \times 10^{11}$ m

(2marks)

Q10 [3 marks]

On the Hubble website, the claim is made that "Hubble is one of NASA's' most successful and long-lasting science missions. It has beamed hundred of thousands of images back to Earth, shedding light on many of the great mysteries of astronomy. Its gaze has helped determine the age of the universe, the identity of quasars and the existence of dark energy. "

10a) Provide a reason why the Hubble telescope has been so successful compared to larger Earth-based telescopes.

- THE HUBBLE TELESCOPE IS ABLE TO VIEW EMR THAT IS NOT ABSORBED BY THE EARTH'S ATMOSPHERE (EG INFRA RED / H_2O, CO_2)
- LIGHT IS NOT DISTORTED / OBSCURED BY ATMOSPHERE (1mark)

10b) It has been stated that the Hubble telescope allows us to look back in time to billions of years ago. Explain this statement.

THE TELESCOPE IS ABLE TO RECORD IMAGES OF THE UNIVERSE'S MOST DISTANT OBJECTS. THE LIGHT THAT FORMS THESE IMAGES HAS TAKEN BILLIONS OF YEARS TO REACH THE TELESCOPE. (2marks)

Q11 [4 marks]

The 'Big Bang' theory is a model used to explain the origin of the universe. Describe two pieces of scientific evidence which support this theory.

SELECT FROM:
- RED SHIFT
- HUBBLE'S LAW
- ABUNDANCE OF LIGHT ELEMENTS
- COSMIC MICROWAVE BACKGROUND RADIATION

(4marks)