# 3AB Physics

# Atomic Physics, Standard Model, Relativity and Astrophysics.

# Test

# 2012

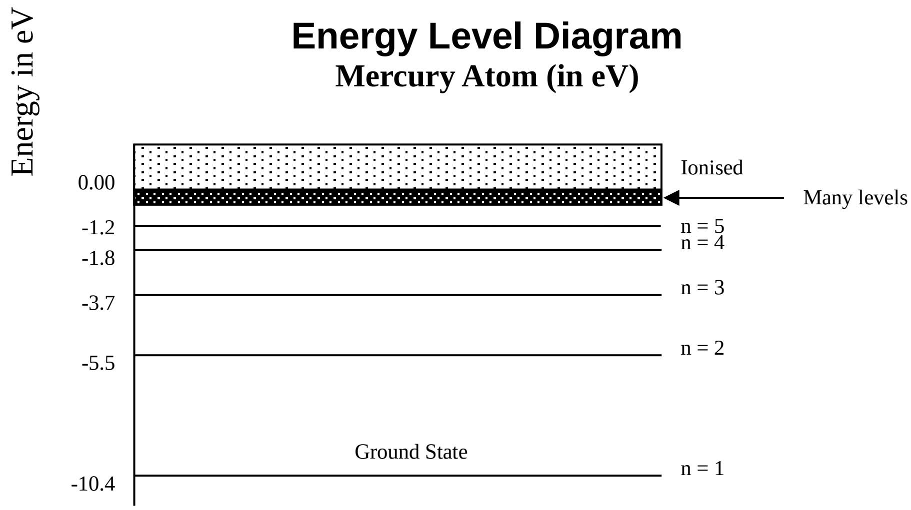
| **Constants** |
| --- |
| See Constants Sheet |

Name ____________________________________________________________

Marks ________________________________________________________/ 44

| **Instructions** |
| --- |
| • Please show **all** working to obtain **all** marks. |

1. A fluorescent tube contains mercury vapour. Electrons emitted at one end of the tube are accelerated towards the other end of the tube by a strong electric field. As they travel down the tube they collide with the mercury vapour. The kinetic energy of the bombarding electrons that hit the mercury vapour is 9.00 eV.




a) What is the highest energy level to which the electron can be excited?

(1 mark)

b) How many different photons can potentially be produced by the excited mercury atoms?

(1 mark)

c) What are the possible energies of the scattered bombarding electrons in eV?

(2 marks)

d) Which of the photons produced by the mercury atoms is definitely in the infra red range? Explain with the support of calculations.

(2 marks)

e) The chemical composition of a common white powder is $3Ca_3(PO_4)_2 \cdot Ca(F \cdot Cl)_2$:Mn,Sb. What type of spectra is most likely to be produced when the UV photons from the mercury atoms strike the white powder?

(1 mark)

2. A 2.00 kg shot put ball is constantly accelerated from rest by a 1000 N force which is continuously acting.

a) What will happen to the mass of the shot put ball as it begins to approach the speed of light? Explain.

(2 marks)

The formula for the mass of a moving object is ...

$$m = \frac{m_0}{\sqrt{(1-(\frac{v^2}{c^2})}}$$

Where

| Symbol | Definition | Units |
|---|---|---|
| m | Mass of the moving object | Hz |
| $m_o$ | Mass of the moving object when stationary | Hz |
| c | Speed of light in a vacuum ($3 \times 10^8$ m $s^{-1}$) | m $s^{-1}$ |
| v | Speed of the moving. | m $s^{-1}$ |

b) By what percentage has the mass increased if it is moving at $2 \times 10^8$ m $s^{-1}$?

(3 marks)

c) What will be that acceleration of the object at the instant it is travelling at $2 \times 10^8$ m $s^{-1}$?

(1 mark)

3. Classify the different particles below according to the standard model.

(4 marks)

| Example | How would you classify according to the standard model |
|---|---|
| Protons | |
| Electrons | |
| Photon | |
| $W^+$ | |

4. An astronomer suspects that a star is moving through space relative to the earth. The astronomer analyses the hydrogen spectrum from the star and compares it with one from a hydrogen gas discharge tube in their lab.

Spectra from the hydrogen discharge tube.

Spectra from moving star

a) Is the star moving towards or away from the earth?

(1 mark)

Towards Away From

b) Name this phenomena.

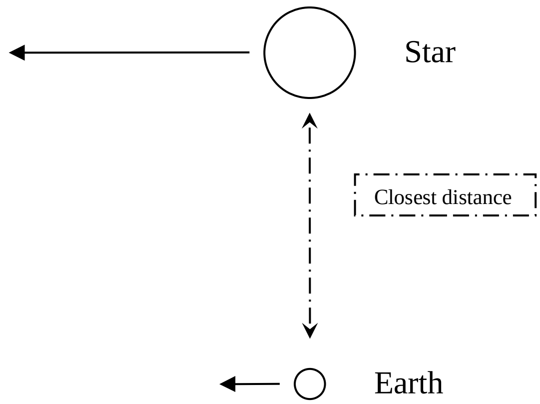
(1 mark)

c) Explain why these differences exist between the two diagrams

(2 marks)

d) If the star was moving parallel with the earth but faster than the earth, how much "shifting" of its light would occur when the star is at is closest distance to the earth.

(1 mark)




e) Is the single line emission diagram on the previous page sufficient evidence to support the big bang theory? Explain.

(2 marks)

5. How many astronomical units are in a light year?

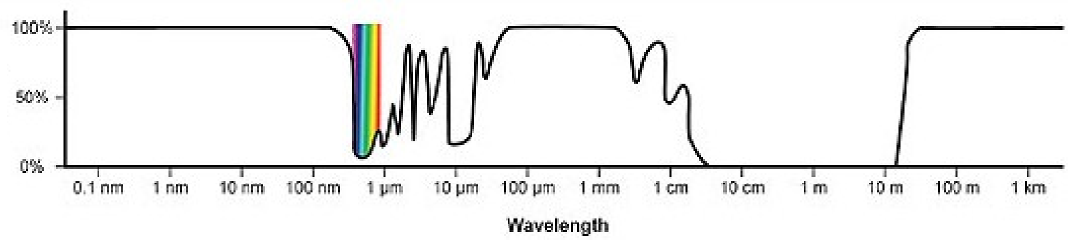
(2 marks)

6 An Astronomer wishes to record data about X-rays that are given off by stars.

a) Circle the region on the graph or axis below that corresponds with the X-ray part of the electromagnetic spectrum.

(1 mark)

Atmospheric Absorption




Graph showing the absorption of different parts of the Electro Magnetic Spectrum by the atmosphere.

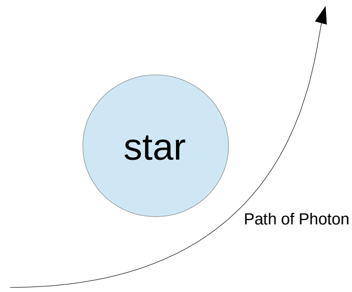
b) Will they be able to collect the data using their collecting devices which are set up in the middle of the desert? Explain why or why not.

(2 marks)

c) What types (regions) of electromagnetic radiation do penetrate the earth's atmosphere?

(2 marks)

7. Light can be bent by gravity as it passes by a star.




a) According to the standard model classify photons of light and explain their role in interacting with other matter.

(2 marks)

b) Estimate with the support of calculations the energy contained in a photon of green light in joules.

(1 mark)

c) According to Einstein's famous equation $E = mc^2$ the photon will behave as if it has a mass as it passes the star. This is called the virtual (not real) mass of the photon. It is for this reason that the gravity of the star is able to bend of the path of the light. Calculate the virtual mass of the green photon?

(2 marks)

d) If the star which the green photon is travelling past has a mass 4 times that of our sun and the photon is $1.00 \times 10^9$ m from the centre of the star, what will be the force of attraction between the photon and the star?

(3 marks)

e) How will the speed of the light change as it approaches and then leaves the star?

(1 mark)

f) How will the appearance of the photon be different when it is travelling in zero gravity as compared to when it is $1.00 \times 10^9$ m from the centre of the star and is experiencing the star's gravity?

**End of Test**

# 3AB Physics

# Atomic Physics, Standard Model, Relativity and Astrophysics.

# Test

# 2012

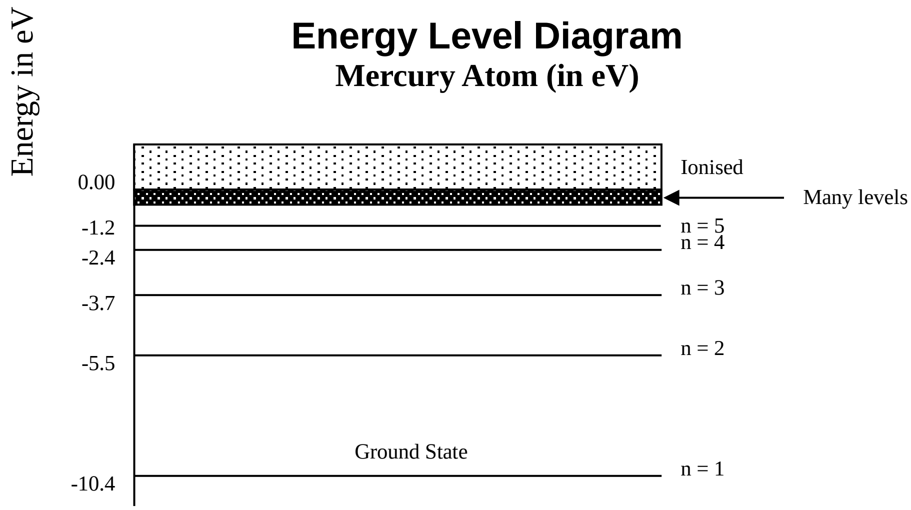
| **Constants** |
| --- |
| See Constants Sheet |

Name ANSWERS

Marks ______________________________________________________/ 44

| **Instructions** |
| --- |
| • Please show **all** working to obtain **all** marks. |

1. A fluorescent tube contains mercury vapour. Electrons emitted at one end of the tube are accelerated towards the other end of the tube by a strong electric field. As they travel down the tube they collide with the mercury vapour. The kinetic energy of the bombarding electrons that hit the mercury vapour is 9.00 eV




a) What is the highest energy level to which the electron can be excited?

(1 mark)

n = 4

b) How many different photons can potentially be produced by the excited mercury atoms?

(1 mark)

6

c) What are the possible energies of the scattered bombarding electrons in eV?

(2 marks)

9 eV, 4.1 eV, 2.3 eV, 0.4 eV

d) Which of the photons produced by the mercury atoms is definitely in the infra red range? Explain with the support of calculations.

(2 marks)

The downward electron transition from n = 4 to n = 3 will most likely produce an infra red photon because it is on the Paschen series.

E(eV) = 3.7 – 2.4
**E(eV) = 1.3 eV**

E(J) = $1.3 \times 1.6 \times 10^{-19}$
**E(J) = $2.08 \times 10^{-19}$ J**

E = hf
$2.08 \times 10^{-19} = 6.63 \times 10^{-34} \times f$
**f = $3.14 \times 10^{14}$ Hz**

e) The chemical composition of a common white powder is $3Ca_3(PO_4)_2 \cdot Ca(F \cdot Cl)_2$:Mn,Sb. What type of spectra is most likely to be produced when the UV photons from the mercury atoms strike the white powder?

(1 mark)

Continuous Emission or Band Emission

2. A 2.00 kg shot put ball is constantly accelerated from rest by a 1000 N force which is continuously acting.

a) What will happen to the mass of the shot put ball as it begins to approach the speed of light? Explain.

(2 marks)

The mass of the shot put ball will increase.

It is impossible of an object with mass to reach the speed of light.

In the formula for kinetic energy ... $E = ½ m v^2$ the velocity can no longer continue to increase so the mass begins to increase instead this allows the object to continue to accumulate energy due to the force continuously acting.

In summary - is velocity cannot continue to increase in the same way the mass must increase by the law of conservation of energy.

The formula for the mass of a moving object is ...

$$m = \frac{m_o}{\sqrt{(1-(\frac{v^2}{c^2})}}$$

Where

| Symbol | Definition | Units |
|---|---|---|
| m | Mass of the moving object | Hz |
| $m_o$ | Mass of the moving object when stationary | Hz |
| c | Speed of light in a vacuum ($3 \times 10^8$ m $s^{-1}$) | m $s^{-1}$ |
| v | Speed of the moving. | m $s^{-1}$ |

b) By what percentage has the mass increased if it is moving at $2 \times 10^8$ m $s^{-1}$?

(3 marks)

$$m = \frac{m_o}{\sqrt{(1-(\frac{v^2}{c^2})}}$$

$m = 2 / (1 – (2 \times 10^8 / 3 \times 10^8)^2)^{1/2}$
$m = 2 / (1 – (2/3)^2)^{1/2}$
$m = 2 / (1 – (4/9))^{1/2}$
$m = 2 / (5/9)^{1/2}$
$m = 2 / 0.745355$
**m = 2.683 kg**

% = ([2.683 – 2]/2) x 100
**% = 34.2 %**

c) What will be that acceleration of the object at the instant it is travelling at $2 \times 10^8$ m $s^{-1}$?

(1 mark)

F = ma

1000 = 2.683 x a
**a = 373 m/s$^2$**

3. Classify the different particles below according to the standard model.

(4 marks)

| Example | How would you classify according to the standard model |
|---|---|
| Protons | Hadrons |
| Electrons | Leptons |
| Photon | Bosons |
| $W^+$ | Bosons |

4. An astronomer suspects that a star is moving through space relative to the earth. The astronomer analyses the hydrogen spectrum from the star and compares it with one from a hydrogen gas discharge tube in their lab.

Spectra from the hydrogen discharge tube.

Spectra from moving star

a) Is the star moving towards or away from the earth?

(1 mark)

Towards Away From

b) Name this phenomena.

(1 mark)

Red shift

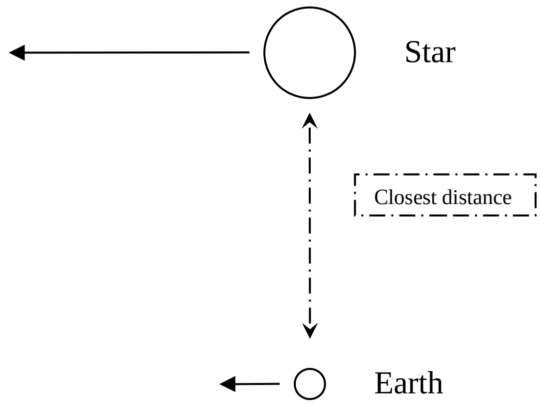
c) Explain why these differences exist between the two diagrams

(2 marks)

Doppler effect.
This is caused by the photon that is moving having less energy and hence less frequency, without having less velocity.

d) If the star was moving parallel with the earth but faster than the earth, how much "shifting" of its light would occur when the star is at is closest distance to the earth.

(1 mark)




At this instant the star is neither approaching or leaving the earth and so the Doppler shift is zero.

There is no shift

e) Is the single line emission diagram on the previous page sufficient evidence to support the big bang theory? Explain.

(2 marks)

As a single diagram (data point) ... No.

Theories are not constructed around a single data point or measurement.

Theories are constructed around a trend in a collection of data points.

If the majority of stars (luminous objects) are red shifted then ... yes.

5. How many astronomical units are in a light year?

(2 marks)

1 ly is the distance light travels in a year.
v = s/t
s = t x v
s = (365.25 x 24 x 3600) x (3 x $10^8$)
s = 3.156 x $10^7$ x 3 x $10^8$
s = 9.46728 x $10^{15}$ m

**1 AU = 1.5 x $10^{11}$ m**

The number of AU's in an ly is ...

s = 9.46728 x $10^{15}$ m / 1 AU = 1.5 x $10^{11}$ m

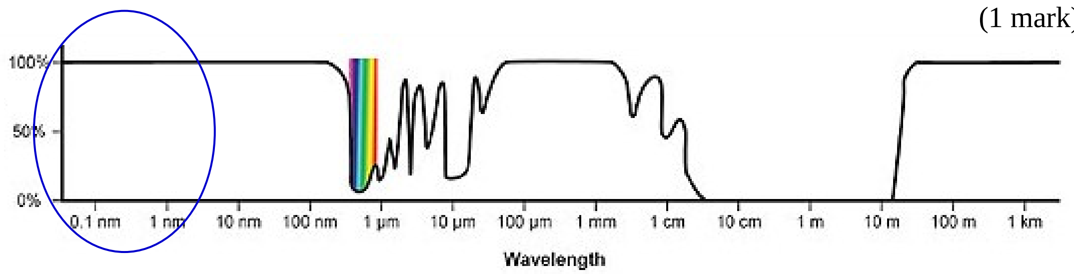
**6.31 x $10^4$ AU's fit in a light year.**

6 An Astronomer wishes to record data about X-rays that are given off by stars.

a) Circle the region on the graph or axis below that corresponds with the X-ray part of the electromagnetic spectrum.

(1 mark)

Atmospheric Absorption




Graph showing the absorption of different parts of the Electro Magnetic Spectrum by the atmosphere.

b) Will they be able to collect the data using their collecting devices which are set up in the middle of the desert? Explain why or why not.

(2 marks)

No

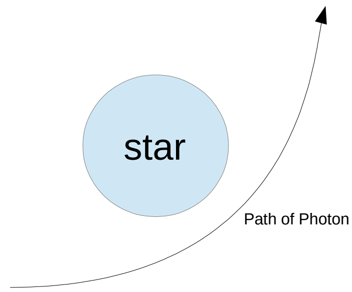
X- rays do not penetrate the earth's atmosphere.

c) What types (regions) of electromagnetic radiation do penetrate the earth's atmosphere?

(2 marks)

Visible, some IR and Radio waves.

7. Light can be bent by gravity as it passes by a star.




a) According to the standard model classify photons of light and explain their role in interacting with other matter.

(2 marks)

Bosons.

These are exchanged between matter that is charged to mediate forces associated with electric field and magnetic field.

b) Estimate with the support of calculations the energy contained in a photon of green light in joules.

(1 mark)

By the 4 – 7 rule

Green in the middle of the spectrum has a frequency of approximately $5.5 \times 10^{14}$ Hz

$E = hf$
$E = 6.63 \times 10^{-34} \times 5.5 \times 10^{14}$
**$E = 3.6465 \times 10^{-19}$ J**

c) According to Einstein's famous equation $E = mc^2$ the photon will behave as if it has a mass as it passes the star. This is called the virtual (not real) mass of the photon. It is for this reason that the gravity of the star is able to bend of the path of the light. Calculate the virtual mass of the green photon?

(2 marks)

$E = mc^2$
$3.6465 \times 10^{-19} = m \times (3.00 \times 10^8)^2$
**$m = 4.05 \times 10^{-36}$ kg**

d) If the star which the green photon is travelling past has a mass 4 times that of our sun and the photon is 1.00 x $10^9$ m from the centre of the star, what will be the force of attraction between the photon and the star?

(3 marks)

$F = G\ m\ m / r^2$
$F = 6.67 \times 10^{-11} \times (4 \times 1.99 \times 10^{30}) \times (4.05 \times 10^{-36}) / (1.00 \times 10^{9})^{2}$
**$F = 2.15 \times 10^{-33}$ N**

e) How will the speed of the light change as it approaches and then leaves the star?

(1 mark)

The speed of light will not change. It is constant regardless of the speed of the source.

f) How will the appearance of the photon be different when it is travelling in zero gravity as compared to when it is 1.00 x $10^9$ m from the centre of the star and is experiencing the star's gravity?

If will be blue shifted when it is travelling in the stars gravity as compared to its normal colour in zero gravity as observed by a stationary observer.

**End of Test**