Physics ATAR - Year 12
Particles Waves and Quanta
2017

Name:	Mark: / 58 = %</td>

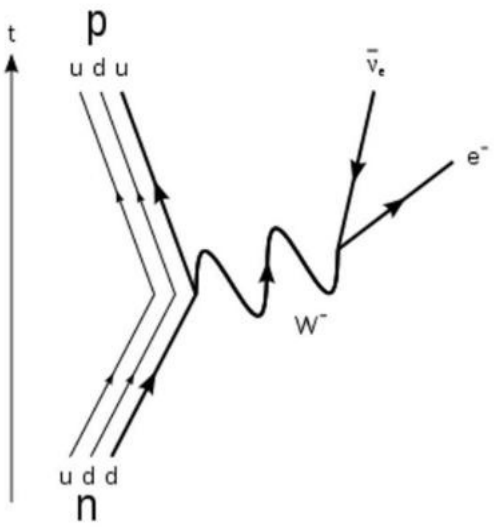
Time Allowed: 50 Minutes

Notes to Students:

1. You must include **all** working to be awarded full marks for a question.
2. Marks will be deducted for incorrect or absent units and answers stated to an incorrect number of significant figures.
3. **No** graphics calculators are permitted – scientific calculators only.

Question 1 **(11 marks)**

The following Feynman diagram shows the Beta (-) decay process in a nuclei, as described by the standard model of matter.



(a) Name the Boson(s) present in the diagram.

(1 mark)

(b) Name the Baryons(s) present in the diagram.

(1 marks)

(c) Name the Lepton(s) present in the diagram.

(1 mark)

The particle equation for beta (-) decay is:

$$n \rightarrow p + e^{-} + \bar{\nu}$$

(d) Explain why an anti-neutrino must be emitted in the beta (-) decay process.

(2 marks)

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The table below shows the quark composition of some common particles.

Name	Symbol	B	S	c	b	t	Quarks
Pion-plus	π^+	0	0	0	0	0	$u\bar{d}$
Pion-minus	π^-	0	0	0	0	0	$\bar{u}d$
Kaon-plus	K^+	0	+1	0	0	0	$u\bar{s}$
Kaon-minus	K^-	0	−1	0	0	0	$\bar{u}s$
Rho-plus	ρ^+	0	+1	0	0	0	$u\bar{d}$
Rho-minus	ρ^-	0	−1	0	0	0	$\bar{u}d$
phi	φ	0	0	0	0	0	$s\bar{s}$
D-plus	D^+	0	0	+1	0	0	$c\bar{d}$
D-zero	D^0	0	0	+1	0	0	$c\bar{u}$
D-plus-s	D^+_s	0	+1	+1	0	0	$c\bar{s}$
B-minus	B^-	0	0	0	−1	0	$b\bar{u}$
Upsilon	Υ	0	0	0	0	0	$b\bar{b}$

Name	Symbol	B	S	c	b	t	Quarks
Proton	p	+1	0	0	0	0	uud
Anti-proton	$\bar{p}$	−1	0	0	0	0	$\overline{uud}$
Neutron	n	+1	0	0	0	0	udd
Anti-neutron	$\bar{n}$	−1	0	0	0	0	$\overline{udd}$
Lambda-plus	Λ^+	+1	0	+1	0	0	udc
Lambda-zero	Λ^0	+1	−1	0	0	0	uds
Sigma-plus	Σ^+	+1	−1	0	0	0	uus
Sigma-zero	Σ^0	+1	−1	0	0	0	uds
Sigma-minus	Σ^-	+1	−1	0	0	0	dds
Xi-zero	Ξ^0	+1	−2	0	0	0	uss
Xi-plus	Ξ^+	+1	−2	0	0	0	dss
Omega-minus	Ω^-	+1	−3	0	0	0	sss

(e) Determine whether the following particle interactions are possible by using two conservations laws found in particle interactions.

(4 marks)

i. $\pi^+ + p \rightarrow K^+ + \Sigma^+$

ii. $n \rightarrow p + e^- + \nu$

(f) State the quark constituents, charge and name of the anti-particle of the Kaon-plus particle.

(2 marks)

Question 2 **(14 marks)**

A 275 m long spaceship rushes past a stationary observer at a speed of 2.40×10^8 ms^{-1}

(a) Calculate the length of the spaceship as measured by the stationary observer as it rushes past.

(3 marks)

(b) If an atomic clock on the spaceship has an oscillating period of 1.40 nanoseconds (relative to a stationary reference frame), calculate the period that would be measured by the stationary observer as the atomic clock travels past.

(3 marks)

(c) An astronaut has a rest mass of 60.0 kg, calculate her relativistic kinetic energy as observed by a stationary observer. The equation for relativistic kinetic energy is below:

(2 marks)

$$E_k = \frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}} - mc^2$$

$$= mc^2\,(\gamma - 1)$$

(c) Both observers argue that their measurement of time of the oscillating atomic clock is correct and the other person is wrong. Using your knowledge of special relativity, explain who is correct with an appropriate justification.

(3 marks)

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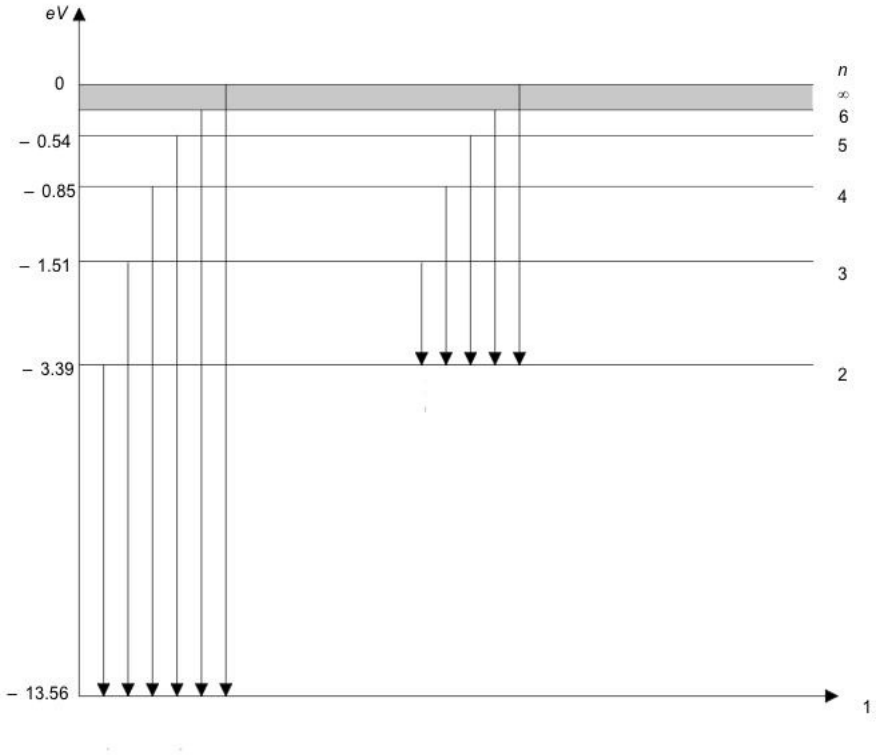
A second spaceship then travels towards the 275 m long spaceship at a speed of 2.10×10^8 ms^{-1} (measured by the stationary observer).

(d) Calculate the relativistic speed of one spaceship as observed from the reference frame of the other.

(3 marks)

Question 3 **(11 marks)**

The first few energy levels of hydrogen are shown below. Use the values provided for required calculations.



(a) Photons of wavelength 103.07 nm are found to be absorbed by hydrogen. Show this absorption process by means of an arrow on the above diagram. You must justify your choice with a calculation.

(3 marks)

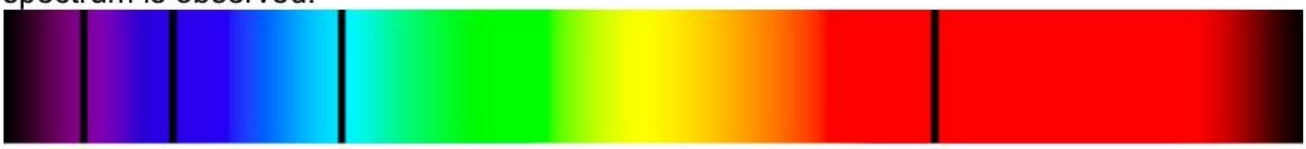
(b) Of the transitions present on the diagram, calculate the wavelength of the least energetic photon and state what region of the EMR spectrum this photon belongs in.

(4 marks)

(c) If an external source of energy excites electrons into the n = 4 energy level, state the number of possible lines there would be in the emission spectrum.

(1 mark)

When white light is passed through a cold source of hydrogen gas, the following absorption spectrum is observed:



(d) Explain why the majority of the photons pass through the hydrogen unaffected.

(3 marks)

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Question 4 **(6 marks)**

A 5.00 mW 'class 3A' laser emits visible light of wavelength 532 nm.

(a) Calculate the energy of a photon in eV.

(2 marks)

It has been determined that the photon emission of the laser light is due to the transition from n = 2 to n = 1 of an Aluminium gallium arsenide (GaAlAs) crystal.

(b) On the energy level diagram below, complete the energy axis of the diagram.

(2 marks)

n = 5 ---------- - 0.60 eV
n = 4 ---------- - 0.85 eV

n = 3 ---------- - 1.57 eV

n = 2 ---------- - 2.90 eV

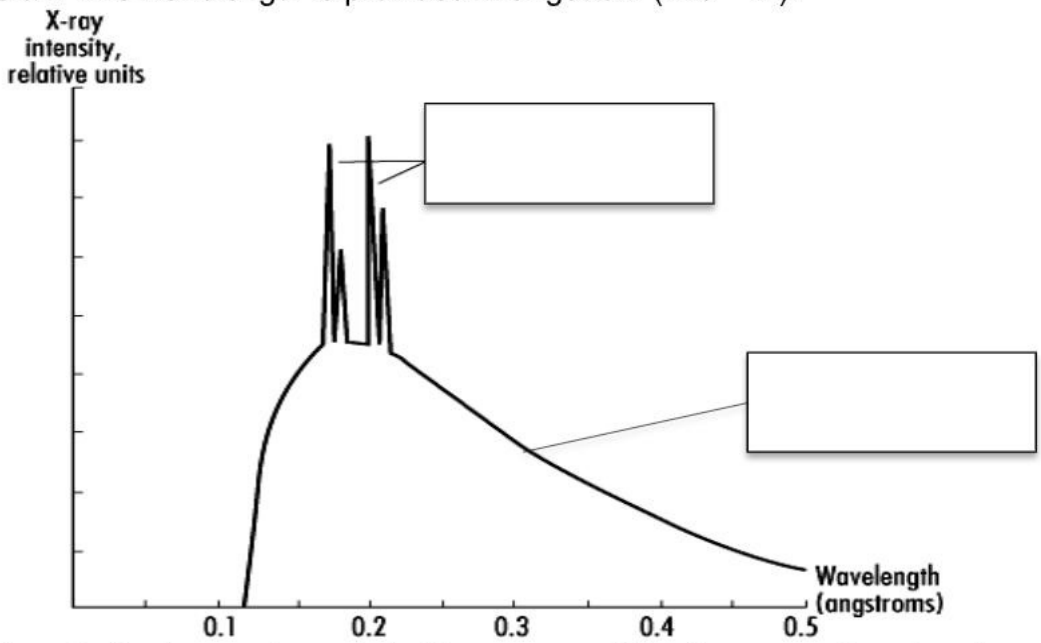
n = 1 ---------- 

(c) Calculate the number of photons emitted per second by the laser.

(2 marks)

Question 5 **(10 marks)**

The relative intensity of X-rays emitted from a Tungsten target is shown on the graph below. The wavelength is provided in angstrom ($x10^{-10}$ m).



(a) In the boxes above, label the names of the X-rays produced and provide an explanation of how one of these X-ray types are produced.

(3 marks)

(b) Calculate the accelerating voltage of the X-ray tube.

(3 marks)

(c) On the graph above, sketch a new curve if the accelerating voltage is doubled.

(2 mark)

(d) Complete the table below by adding the appropriate effect (on the variable listed) caused by the modifications. The first modification has been completed for you.

(2 marks)

Modification to X-ray Tube	Variable affected	Effect
X-ray tube filled with low pressure air	Relative Intensity of X-rays	**Reduced**
Voltage decreased	Minimum wavelength emitted	
Voltage decreased	Relative Intensity of X-rays	

Question 6 **(6 marks)**

State and explain one observation or experiment that supports the wave model of light and one observation or experiment that supports the particle model of light.

Wave:

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Particle:

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END OF TEST

Question 1 Addendum

The particle equation for beta (-) decay is:

$$n \rightarrow p + e^{-} + \bar{\nu}$$