Surname		Other Names	
Centre Number			Candidate Number									
Candidate Signature												

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General Certificate of Education
January 2002
Advanced Subsidiary Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

PHYSICS (SPECIFICATION A) PA01
Unit 1 Particles, Radiation and Quantum Phenomena

Monday 14 January 2002 Morning Session

In addition to this paper you will require:
- a calculator;
- a pencil and a ruler.

Time allowed: 1 hour 30 minutes

Instructions
- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions in the spaces provided. All working must be shown.
- Do all rough work in this book. Cross through any work you do not want marked.

Information
- The maximum mark for this paper is 60.
- Mark allocations are shown in brackets.
- The paper carries 30% of the total marks for Physics Advanced Subsidiary and carries 15% of the total marks for Physics Advanced.
- A *Data Sheet* is provided on pages 3 and 4. You may wish to detach this perforated sheet at the start of the examination.
- You are expected to use a calculator where appropriate.
- In questions requiring description and explanation you will be assessed on your ability to use an appropriate form and style of writing, to organise relevant information clearly and coherently, and to use specialist vocabulary where appropriate. The degree of legibility of your handwriting and the level of accuracy of your spelling, punctuation and grammar will also be taken into account.

For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
5			
6			
7			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

Data Sheet

- A perforated *Data Sheet* is provided as pages 3 and 4 of this question paper.
- This sheet may be useful for answering some of the questions in the examination.
- You may wish to detach this sheet before you begin work.

DATA SHEET

DATA SHEET

LEAVE MARGIN BLANK

Answer **all** questions in the spaces provided

1 (a) The most abundant isotope of cobalt is represented by $^{59}_{27}\text{Co}$.

How many protons, neutrons and orbital electrons are there in a neutral atom of this element?

..... protons

..... neutrons

..... electrons *(2 marks)*

(b) How is the nuclide that has one less proton than the nickel nuclide, $^{61}_{28}\text{Ni}$, represented?

.....

(2 marks)

(c) (i) The heaviest isotope of hydrogen, whose nucleon number is 3, is called tritium. How is tritium represented?

.....

(ii) Calculate the charge per unit mass, in C kg^{-1}, for a tritium nucleus.

.....

.....

.....

(3 marks)

— 7

TURN OVER FOR THE NEXT QUESTION

2 (i) Calculate the energy, in J, of a photon of wavelength 4.50×10^{-7} m.

.....

.....

.....

.....

(ii) Calculate the speed of an electron which has the same wavelength as the photon in part (i).

.....

.....

.....

.....

.....

(5 marks)

5

3 (a) When monochromatic light is incident on a metal plate, electrons are emitted only when the frequency of the light exceeds a certain threshold frequency.

Explain, in terms of energy, why this threshold frequency exists.

.....

.....

.....

.....

.....

(3 marks)

(b) A sodium metal surface is illuminated with incident light of frequency 9.70×10^{14} Hz. The maximum kinetic energy of an emitted electron is 2.49×10^{-19} J.

Calculate

(i) the wavelength of the incident light,

.....

.....

(ii) the energy, in J, of each incident photon,

.....

.....

(iii) the work function, in J, of sodium,

.....

.....

(iv) the work function, in eV, of sodium.

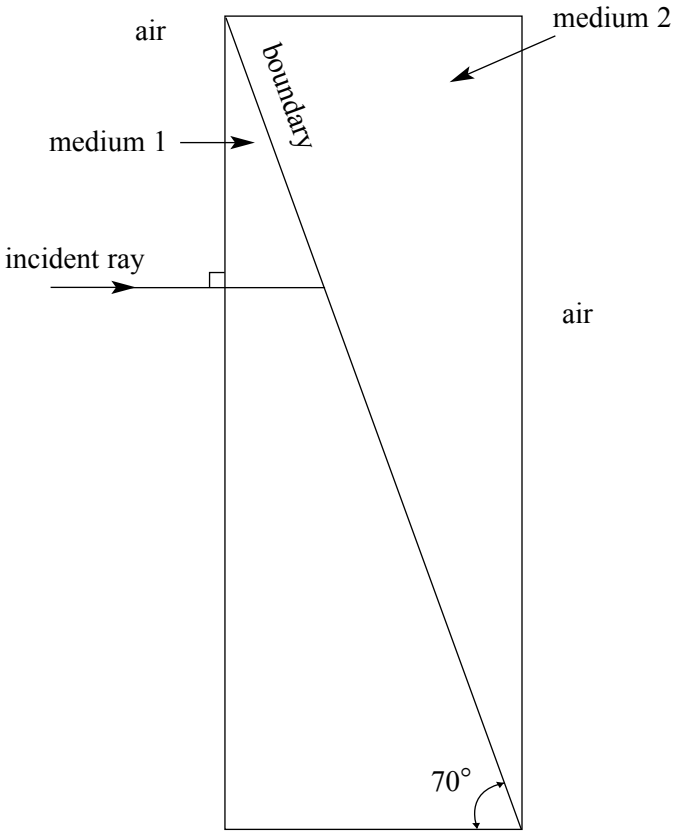
.....

.....

(7 marks)

10

4 Two prisms made from different glass are placed in perfect contact to form a rectangular block surrounded by air as shown.
Medium 1 has a smaller refractive index than medium 2.



(a) A ray of light in air is incident normally on medium 1 as shown. At the boundary between medium 1 and medium 2 some light is transmitted and the remainder reflected.

(i) Sketch, without calculation, the path followed by the refracted ray as it enters medium 2 and then emerges into the air.

(ii) Sketch, without calculation, the path followed by the reflected ray showing it emerging from medium 1 into the air.

(4 marks)

(b) The refractive index of medium 1 is 1.40 and that of medium 2 is 1.60.

(i) Give the angle of incidence at the boundary between medium 1 and medium 2.

.....

(ii) Calculate the angle of refraction at this boundary.

.....

.....

.....

.....

.....

(4 marks)

(c) Calculate the critical angle for a ray passing from medium 2 into the air.

.....

.....

.....

.....

.....

.....

(2 marks)

10

TURN OVER FOR THE NEXT QUESTION

5 (a) An electron and a positron travelling with equal speeds meet head-on and annihilate, releasing 2.0×10^6 eV of energy. This energy is shared equally by two photons.

Calculate the energy, in J, of each photon.

.....

.....

(1 mark)

(b) Complete the tables by writing **true** or **false** in the right hand column.

The first table has been completed as an example.

a neutron is a fundamental particle	false
an antineutron is not a fundamental particle	true

a neutron is a stable particle	
an antineutron is an unstable particle	

a neutron has a rest mass of 1.67×10^{-27} kg	
a antineutron has a rest mass of -1.67×10^{-27} kg	

a neutron has no charge	
an antineutron has a charge of 1.60×10^{-19} C	

(3 marks)

(c) (i) The exchange particle responsible for the weak interaction is either a W boson or a Z boson.

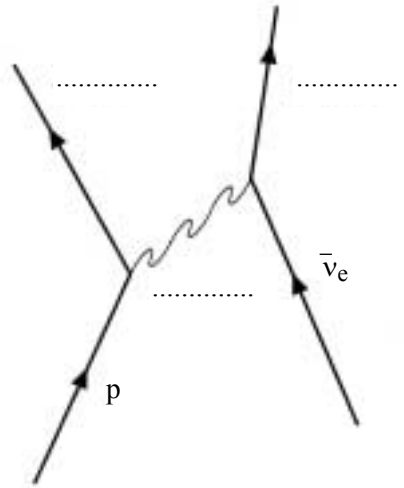
Give the name of another exchange particle and the interaction for which it is responsible.

exchange particle .....

interaction .....

(ii) An antineutrino may be detected via its weak interaction with a proton as shown in the Feynman diagram.

Complete the labelling on the diagram.



(5 marks)

9

TURN OVER FOR THE NEXT QUESTION

6 (a) (i) How do hadrons differ from all other subatomic particles?

.....

.....

(ii) Give the quark composition of the following particles.

neutron .....

neutral pion .....

(iii) Classify the following as either leptons, baryons or mesons.

kaon .....

muon .....

(5 marks)

(b) Which is the most stable baryon?

.....

(1 mark)

(c) This table may be useful in answering the questions which follow.

particle	baryon number	lepton number	strangeness
π^-	0	0	0
p	1	0	0
$\bar{p}$	–1	0	0
e^-	0	1	0
e^+	0	–1	0
$\bar{\nu}_e$	0	–1	0

The particle X, which is a strange particle, decays in the following way:

$$X \rightarrow \pi^- + p$$

(i) State whether X is a meson, a baryon or a lepton.

.....

(ii) Use conservation laws to decide whether each of the following decays of the π^- is possible. Give a reason for your answer.

(A) $\pi^- \rightarrow e^+ + \nu_e$

Is this decay possible? .....

reason .....

(B) $\pi^- \rightarrow \bar{p} + e^- + e^+$

Is this decay possible? .....

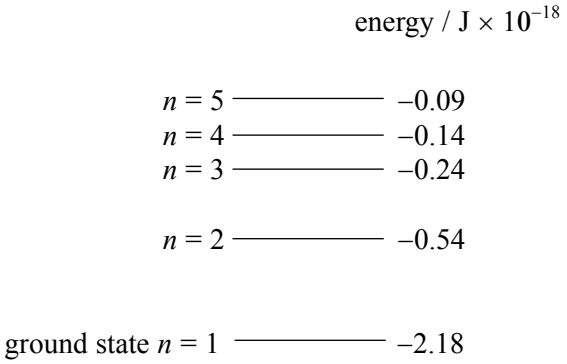
reason .....

(5 marks)

11

TURN OVER FOR THE NEXT QUESTION

7 The lowest energy levels of a hydrogen atom are represented in the diagram below, which is **not** to scale.



(i) Describe what happens when a hydrogen atom is ionised.

.....

.....

(ii) State the minimum amount of energy, in J, required to ionise a hydrogen atom from its ground state.

.....

(iii) A hydrogen atom excited to the $n = 3$ energy level may emit either a single photon or two photons in returning to the ground state.

Describe what happens to the electron in each case.

.....

.....

.....

.....

.....

.....

.....

(iv) Use the diagram opposite to identify the transition which produces a photon of energy 2.09×10^{-18} J.

.....

(v) Calculate the frequency of an emitted photon due to a transition from level $n = 2$ to the ground state.

.....

.....

.....

(8 marks)

8

END OF QUESTIONS

THERE ARE NO QUESTIONS PRINTED ON THIS PAGE