HOLY CROSS COLLEGE
Life to the Full

Western Australian Certificate of Education
ATAR course examination, 2017

Question/Answer Booklet

12 PHYSICS

Name	SOLUTIONS

Test 8 – Modern Physics

Student Number: In figures

Mark: $\overline{}$ 48

In words ______________________________

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Time allowed for this paper
Reading time before commencing work: five minutes
Working time for paper: sixty minutes

Materials required/recommended for this paper
To be provided by the supervisor
This Question/Answer Booklet
Formulae and Data Booklet

To be provided by the candidate
Standard items: pens, (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: non-programmable calculators satisfying the conditions set by the School Curriculum and Standards Authority for this course

Important note to candidates
No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Short Answers	-	-	-	-	-
Section Two: Problem-solving	10	10	60	50	100
Section Three: Comprehension	-	-	-	-	-
				Total	100

Instructions to candidates

1. The rules for the conduct of examinations at Holy Cross College are detailed in the College Examination Policy. Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in this Question/Answer Booklet.

3. Working or reasoning should be clearly shown when calculating or estimating answers.

4. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

5. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

   - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
   - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(is) that you are continuing to answer at the top of the page.

6. Answers to questions involving calculations should be ***evaluated and given in decimal form.*** It is suggested that you quote all answers to ***three significant figures***, with the exception of questions for which estimates are required. Despite an incorrect final result, credit may be obtained for method and working, providing these are ***clearly and legibly set out***.

7. Questions containing the instruction "estimate" may give insufficient numerical data for their solution. Students should provide appropriate figures to enable an approximate solution to be obtained. Give final answers to a maximum of two significant figures and include appropriate units where applicable.

8. Note that when an answer is a vector quantity, it must be given with magnitude and direction.

9. In all calculations, units must be consistent throughout your working.

Additional Data

Fundamental particles

Table of common mesons

Particle	Structure	Charge	Baryon Number	Strangeness
π^0	$u\bar{u}$ or $d\bar{d}$	0	0	0
π^+	$u\bar{d}$	+1	0	0
π^-	$\bar{u}d$	-1	0	0
K^0	$d\bar{s}$	0	0	+1
K+	$u\bar{s}$	+1	0	+1
K^-	$\bar{u}s$	-1	0	-1

Properties of quarks

antiquarks have opposite signs

type	*charge*	*baryon number*	*strangeness*
u	$+\frac{2}{3}e$	$+\frac{1}{3}$	0
d	$-\frac{1}{3}e$	$+\frac{1}{3}$	0
s	$-\frac{1}{3}e$	$+\frac{1}{3}$	-1

Properties of leptons

	lepton number
particles: e^-, ν_e ; μ^-, ν_μ	+1
antiparticles: e^+, $\overline{\nu_e}$; μ^+, $\overline{\nu_\mu}$	−1

Common Baryons

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

Common Mesons

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	$b\bar{b}$

Redshift and recessional velocity

$$z = \frac{\Delta\lambda}{\lambda}$$

It can also be shown that: $$z = \frac{v}{c_0}$$

where:

z = redshift
$\Delta\lambda$ = change in wavelength (moving source) (nm)
λ = wavelength of stationary source (nm)
v = recessional speed of galaxy (ms^{-1})
c_0 = speed of light in a vacuum (ms^{-1})

Hubble's Law

$$v_{galaxy} = H_0 d$$

where
v_{galaxy} = recessional speed of galaxy (ms^{-1})
d = distance to galaxy (Mpc)
H_o = Hubble's constant ($kms^{-1}Mpc^{-1}$)

1. A spacecraft moving at 95.0 % of the speed of light passes the Earth on a journey to the star Lalande-21185, a distance of 8.29 light years.

In the frame of reference of the spacecraft (experienced by the crew), what time and spatial measurements of the journey are different compared to those measured by an Earth -based observer? Which ***TWO*** statements are correct? [2 marks]

(a) Length contraction states, 'the path length through space is longer than 8.29 light years'.

(2) (b) Length contraction states, 'the path length through space is shorter than 8.29 light years'.

(c) Time dilation states, 'the clock on earth is moving slower'.

(d) Time dilation states, 'the clock on the spacecraft is moving slower'.

In the frame of reference of the Earth, what time and spatial measurements of the journey are different compared to those measured by an observer on the spacecraft? Which ***TWO*** statements are correct? [2 marks]

(a) Length contraction states, 'the path length through space is shorter than 8.29 light years'.

(2) (b) Length contraction states, 'the path length through space will be 8.29 light years'.

(c) Time dilation states, 'the clock on earth is moving slower'.

(d) Time dilation states, 'the clock on the spacecraft is moving slower'.

2. Explain what is meant by the term, ***'inertial reference frame'***. [1 mark]

- Moves at constant velocity. (1)

3. State the two postulates of Einstein's theory of Special Relativity. [2 marks]

- No law of Physics can identify a state of absolute rest. (1)

- Speed of light is the same in all reference frames. (1)

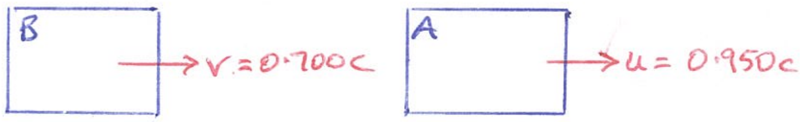
4. Two spaceships are moving away from a star and travelling in the same direction. Spaceship A is travelling at 0.950 c while spaceship B is moving at 0.700 c.

(a) What would an observer on spaceship A determine to be the speed of the starlight passing by? Explain your answer. [3 marks]

- $3{\cdot}00 \times 10^{8}\ ms^{-1}$ (1)
- c is constant in all reference frames. (1)
- This is the second postulate of Special Relativity. (1)

[Can also prove that c is conserved using $u = \dfrac{u' + v}{1 + \frac{u'v}{c^2}}$]

(b) According to an observer on Starship B, what is the speed of starship A? [3 marks]



$$u' = \frac{u - v}{1 - \frac{uv}{c^2}} \quad (1)$$

$$= \frac{0{\cdot}950c - 0{\cdot}700c}{1 - \frac{(0{\cdot}950c)(0{\cdot}700c)}{c^2}} \quad (1)$$

$$= 0{\cdot}746c$$

$$= \underline{2{\cdot}24 \times 10^{8}\ ms^{-1}} \quad (1)$$

5. Consider the proposed new Sydney to Perth bullet train that travels at a speed of 0.365 c. A passenger on the bullet train measures the dimensions of the carriage she is in as 3.50 m high and 25.0 m long.

As the train passes through a level crossing, a stationary observer notices the dimensions of the carriage. What would be the dimensions measured by this observer?

[6 marks]

• Height remains constant = 3.50 m (1)

$$l = l_0 \sqrt{\left(1 - \frac{v^2}{c^2}\right)} \quad (1)$$

$$= (25.0)\sqrt{1 - \frac{(0.365c)^2}{c^2}} \quad (3)$$

$$= 23.3 \text{ m} \quad (1)$$

∴ Dimensions are 23.3 m x 3.50 m

6. One of the biggest accelerators in the world is at CERN in Geneva, the site of the Large Electron-Positron (LEP) collider. It is 27.0 km long and accelerates charged particles to enormous energies in the 50.0 GeV energy range.

(a) Calculate the relativistic mass of a proton travelling along the particle accelerator with a speed of 0.915 c

[4 marks]

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

$$= \frac{1.67 \times 10^{-27}}{\sqrt{\left(1 - \frac{(0.915c)^2}{c^2}\right)}} \quad (2)$$

$$= 4.14 \times 10^{-27} \text{ kg} \quad (1)$$

(b) What is the ***total energy*** of a proton travelling along the particle accelerator with a speed of 0.915 c? [6 marks]

$$E_T = m_o c^2 + \frac{1}{2} m v^2 \quad (2)$$

$$= (1.67\times10^{-27})(3.00\times10^8)^2 + \frac{1}{2}(4.14\times10^{-27})(0.915\times3.00\times10^8)^2 \quad (3)$$

$$= \underline{3.06\times10^{-10}\ \text{J}} \quad (1)$$

(c) Will the proton ever be able to reach the speed of light? Explain your answer. [3 marks]

- No. (1)

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

- As $v \to c$, m approaches infinity (becomes heavier). (1)
- More energy (approaching infinity) would be needed to accelerate it, which is impossible. (1)

7. One of the most intense sources known to radio astronomers is the Galaxy NGC5128. Long exposure photographs show it to be a giant elliptical galaxy crossed by a band of dark. It lies about 1.50×10^7 light years away from earth. Using a value of the Hubble constant of 73.0 $kms^{-1}Mpc^{-1}$, calculate the recessional velocity of NGC5128. [4 marks]

$$v = H_0 d \quad (1)$$

$$= (73.0)\left(\frac{1.50\times10^7}{3.26\times10^6}\right) \quad (1)$$

$$= \underline{3.36\times10^2 \ kms^{-1}}$$
(1) (1)

8. The K-line of light from singly ionised calcium has a wavelength of 393.3 nm when measured in a laboratory. The same line in the spectrum of galaxy NGC 4889 has a wavelength of 401.8 nm. Calculate the recessional velocity of NGC4889. [4 marks]

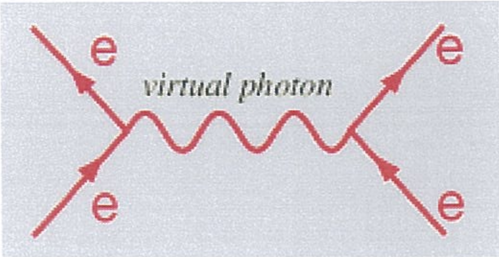
$$v = \frac{\Delta\lambda}{\lambda}c \quad (1)$$

$$= \frac{[(401.8 - 393.3)\times10^{-9}]}{(393.3\times10^{-9})} \times 3.00\times10^8 \quad (2)$$

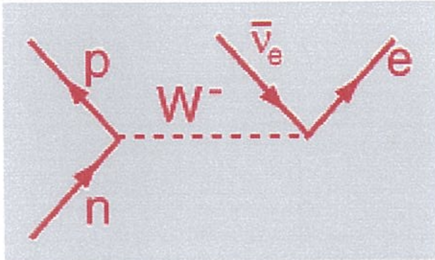
$$= \underline{6.48\times10^6 \ ms^{-1}} \quad (1)$$

9. Consider the Feynman diagrams shown below. Identify the fundamental force described in each diagram. Write your answer in the space provided below the diagram.

[4 marks]

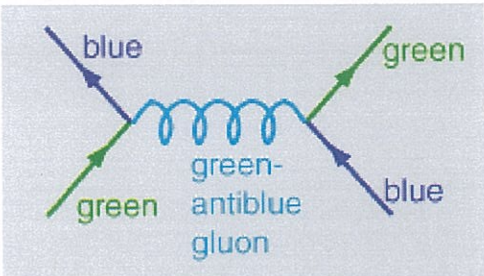


a) electromagnetic force

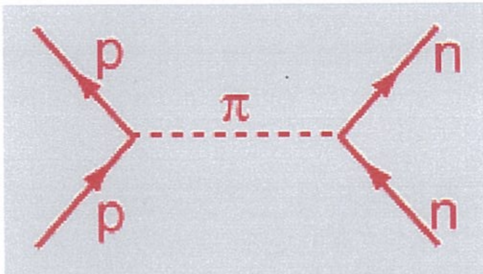


b) weak nuclear force

[1 mark each]



c) strong nuclear force



d) strong nuclear force

10. Determine which of the following reactions are forbidden. Explain your answer.

(a) $p^+ + p^- \rightarrow \mu^+ + e^-$

[2 marks]

	Charge	Baryon	Lepton
LHS	1−1 = 0	1−1 = 0	0+0 = 0
RHS	1−1 = 0	0+0 = 0	−1+1 = 0

∴ Allowed.

(b) $p^+ + p^+ \rightarrow p^+ + \pi^+$

[2 marks]

	Charge	Baryon	Lepton
LHS	1+1 = 2	1+1 = 2	0+0 = 0
RHS	1+1 = 2	1+0 = 1	0+0 = 0

∴ Not allowed.

Baryon number not conserved.

(c) $\pi^- + p^+ \rightarrow p^+ + \pi^+$

[2 marks]

	Charge	Baryon	Lepton
LHS	−1+1 = 0	0+1 = 1	−1+0 = −1
RHS	1+1 = 2	1+0 = 1	0+1 = 1

∴ Not allowed.

Charge and lepton number not conserved.