Insert School Logo

PHYSICS

UNITS 3 & 4

2019

Sect A = /54
B = /90
C = /36
180

Name: ANSWERS

Teacher: ____________________

TIME ALLOWED FOR THIS PAPER

Reading time before commencing work: Ten minutes
Working time for the paper: Three hours

MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER

To be provided by the supervisor:

- This Question/Answer Booklet; Formula and Constants sheet

To be provided by the candidate:

- Standard items: pens, pencils, eraser or correction fluid, ruler, highlighter.
- Special items: Calculators satisfying the conditions set by the SCSA for this subject.

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.

Check formatting P14/15
Units P16

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 answer	13	13	50	54	30
Section Two: Extended answer	7	7	90	90	50
Section Three: Comprehension and data analysis	2	2	40	36	20
			Total	180	100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2019*. Sitting this examination implies that you agree to abide by these rules.

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

3. When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

   When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

4. You must be careful to confine your responses to the specific questions asked and 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.
   - 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. Refer to the question(s) where you are continuing your work.

Section One: Short response **30% (54 Marks)**

This section has **thirteen (13)** questions. Answer **all** questions. Write your answers in the space provided. Suggested working time for this section is 50 minutes.

Question 1 **(4 marks)**

Mars' mass is 6.39×10^{23} kg and has an orbital radius around the Sun of 228 million kilometres. Calculate the weakest gravitation force that can act between Earth and Mars, assuming both Earth and Mars have circular orbits.

formula = 1 working 3

$R_m = 228 \times 10^6$ km $R_E = 1.50 \times 10^{11}$ m
$= 2.28 \times 10^{11}$ m

$M_m = 6.39 \times 10^{23}$ kg

$F_{weakest} = \frac{M_m M_E}{r_{max}^2} \times G = \frac{5.97 \times 10^{24} \times 6.39 \times 10^{23} \times 6.67 \times 10^{-11}}{\{(2.28 + 1.50) \times 10^{11}\}^2} = \underline{1.78 \times 10^{15}\ N}$

$d_{max} = 2.28 \times 10^{11} + 1.50 \times 10^{11}$
$= \underline{3.78 \times 10^{11}\ m}$

If $d_{min} = 2.28 \times 10^{11} - 1.50 \times 10^{11}$
$= 0.78 \times 10^{11}$ [7.8×10^{10} m]
$F_{strong} = \underline{4.18 \times 10^{16}\ N}$

Answer: 1.78×10^{15} N

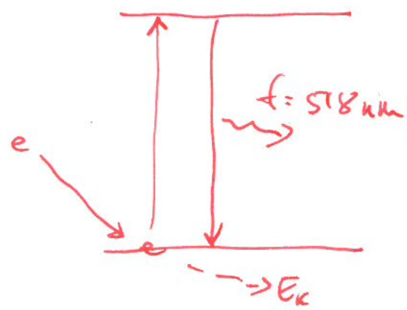
Question 2 **(4 marks)**

An electron with 2.80 eV of kinetic energy bombards an atom with a single ground state electron. The atom's electron is excited and later transitions back to the ground state, emitting a single 518 nm photon. Calculate the kinetic energy of the bombarding electron after it scattered off the atom.

$E_e = 2.80$ eV $= 2.80 \times 1.60 \times 10^{-19} = 4.48 \times 10^{-19}$ J

$E_p = 518$ nm $= \frac{ch}{\lambda} = \frac{3.00 \times 10^8 \times 6.63 \times 10^{-34}}{518 \times 10^{-9}}$
$= \underline{3.84 \times 10^{-19}\ J}$ (2marks)

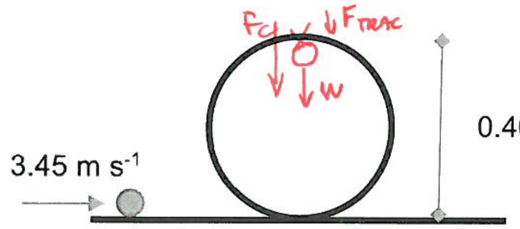
$E_k = 4.48 \times 10^{-19} - 3.84 \times 10^{-19}$
$= \underline{6.40 \times 10^{-20}\ J}$
$= \underline{0.400\ eV}$ (2marks)



Answer: 0.400 eV

Question 3 **(4 marks)**

A 30.0 g golf ball at a mini golf course approaches a small vertical loop obstacle at 3.45 m s^{-1}. The ball follows the track, completing the vertical loop.



Calculate the magnitude of the reaction force applied to the ball by the track when the ball is at the top of the loop.

$w = mg = 0.030 \times 9.80 = 0.294$ N

$F_c = \frac{mv^2}{r} = \frac{0.030 \times 2.02^2}{0.2} = 0.609$ N

$v_{top} = ?$

$E_{start} = E_{k\,after} + mgh$

$0.5 \times 0.030 \times 3.45^2 = \frac{1}{2} \times 0.030 \times v^2 + 0.030 \times 9.80 \times 0.400 \times 2$

$v^2 = 3.45^2 - 9.80 \times 0.400 \times 2$

$= 4.0625$

$v = 2.02$ m s^{-1}

(2) find v

$F_{TRACK} = 0.609 - 0.294$

$= 0.315$ N

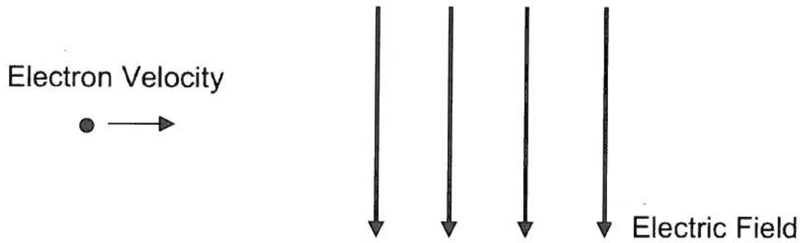
(find F (2))

If forget v_{TOP}
$F_c = 1.79$ N ↓
$w = 0.294$ N ↓
$F_{app} = 2.08$ (1) Max 2
$1.79 = F_{track} + 0.294$
$F_{track} = 1.79 - 0.294 = 1.496$ N

Answer: 0.315 N

Question 4 **(4 marks)**

The diagram below shows an electron entering a uniform 2.00 N C^{-1} electric field. There is also a magnetic field in this region (not shown on the diagram).



The electron has a constant velocity of 8540 m s^{-1} while in the presence of the two fields. State the direction of the magnetic field and calculate its strength.

$v = 8540$ m s^{-1}

$\vec{E} = 2.00$ N C^{-1}

$F_B = Bqv = Eq$ (1)

$B = \frac{E}{v} = \frac{2.00}{8540} = 2.34 \times 10^{-4}$ T — (2)

(1)

Direction: INTO PAGE Strength: 2.34×10^{-4} T

Question 5 **(4 marks)**

Mary observes a spaceship moving at 0.800c to have a 32.0 m length along the direction of its velocity. Quinn sees this spaceship moving at 0.450c along the same direction as Mary. Calculate the length of the spaceship as seen by Quinn.

$v_M = 0.800c$
$l_M = 32.0\ m$
$v_Q = 0.450c$
$l_Q = ?$

$l_o = \frac{l}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{32.0}{\sqrt{1-\frac{0.8^2}{1.0^2}}} = \frac{32.0}{\sqrt{0.36}} = \frac{32.0}{0.6} = 53.3\ m$ 2

$l = l_o\sqrt{1-\frac{v^2}{c^2}} = 53.3\sqrt{1-\frac{0.45^2}{1.0^2}} = 53.3\sqrt{1-0.45^2}$

$= 47.6\ m$ 2

Forget original length
$l = l_o\sqrt{1-\frac{v^2}{c^2}}$
$= 32.0\sqrt{1-\frac{0.45^2}{1.0^2}}$
$= 28.5\ m$ (2 marks)

$v_Q = 0.450c$
$v_M = 0.800c$

Error in original length calc
3

Answer: 47.6 m

Question 6 **(4 marks)**

The following particle reaction is proposed by a PhD student while studying new, exotic particles of the standard model.

$$udb \rightarrow c\bar{c} + s\bar{u} + uud$$

Justify whether this reaction is possible based on baryon number and electric charge.

LHS

(2) B: $\frac{1}{3} + \frac{1}{3} + \frac{1}{3} = 1$

(2) Q: $\frac{2}{3} + -\frac{1}{3} + -\frac{1}{3} = \frac{0}{3} = 0$

RHS:

B: $\frac{1}{3} + -\frac{1}{3} + \frac{1}{3} + -\frac{1}{3} + \frac{1}{3} + \frac{1}{3} + \frac{1}{3} = 1$

Q: $\frac{2}{3} + -\frac{2}{3} + -\frac{1}{3} + -\frac{2}{3} + \frac{2}{3} + \frac{2}{3} + -\frac{1}{3} = 0$

$B_{LHS} = B_{RHS}$ ∴ BN conserved
$Q_{LHS} = Q_{RHS}$ ∴ charge conserved

∴ possible reaction

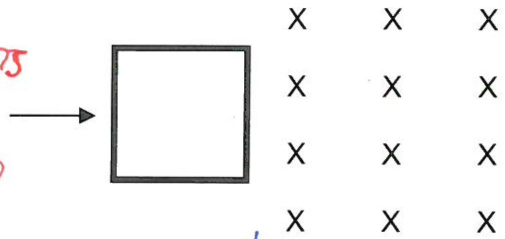
Need to say (1)

Question 7 **(4 marks)**

A square coil moves into a uniform 260 mT magnetic field which is aligned perpendicular to the area of the coil. The coil is induced with a 0.650 V emf as it enters the field at 4.75 m s^{-1}. For what amount of time does the coil have an induced emf?

$B = 260\,mT$
$v = 4.75\,ms^{-1}$
$Emf = 0.650\,V$
$L^2 = A = 0.277\,m^2$
$N = 1$
$Emf = -N\frac{\Delta BA}{\Delta t}$
$\Delta t = -\frac{N \Delta BA}{Emf}$
$= \frac{1 \times 260\times10^{-3} \times 0.277}{0.650} = 1.11\times10^{-1}$ sec

$Emf = BLv$
$0.650 = 260\times10^{-3} \times L \times 4.75$
$L = 0.526\,m$
(2)



OR
$v = 4.75\,ms^{-1}$
$l = 0.526\,m$
$t = \frac{s}{v} = \frac{0.526}{4.75} = 0.110$ sec

(2)

$\phi = BA = 0.260 \times 0.277$
$= 0.0720$ Wb

Answer: 0.111 s

Question 8 **(4 marks)**

Victor, an amateur rocketeer, performs a calculation showing the amount of work the combustion of the rocket fuel needs to do to the rocket to get it to the upper atmosphere from the surface of the Earth. Victor assumes the work is $W = \Delta E = mgh$ where m is the mass of the rocket, g is 9.80 m s^{-2} and h is the altitude the rocket needs to reach. Describe two issues with Victor's method for determining the work required.

g changes – gets less as h increases $\propto \frac{1}{r^2}$
m decreases as it moves upwards – fuel used up
air resistance – in the first 40km of flight not calculated

* Did not include Ek (1pt)
velocity
Efficiency of engine (1pt)

issue – (1)
reason – (1) each

2 reqd

Question 9 **(4 marks)**

Describe how an operating coloured LED and a voltmeter could be used to estimate Planck's constant. Include the measurements or data that would need to be obtained and any calculations required.

Assume minimum current through LED ~ 2.0 mA. (1)

(1) Find threshold voltage – indicates frequency of LED. (1)

Calc: $E_{photon} = E_{LED} \Rightarrow \frac{ch}{\lambda}$ or $hf = Vq$

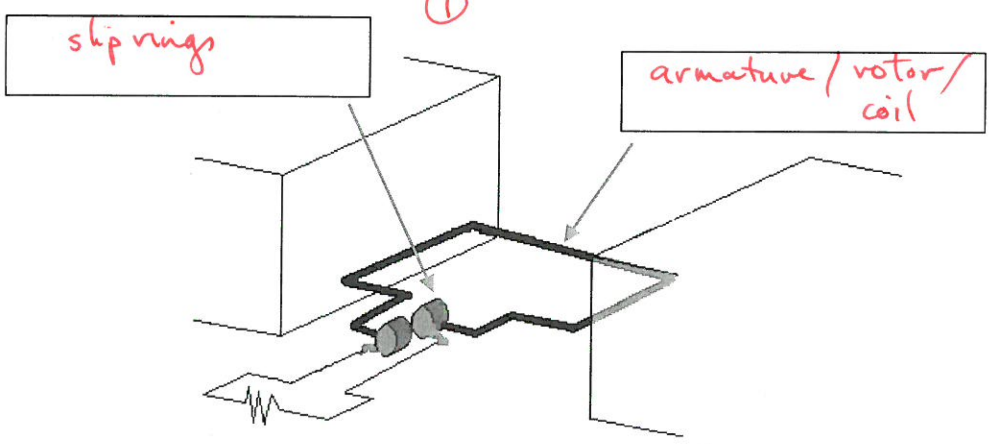
$h = \frac{Vq}{f}$ OR $h = \frac{Vq\lambda}{c}$ (2)

Plot V and f – slope gives h. Ve ↑ / → f $m = \frac{\Delta Ve}{\Delta f}$

multiply by e to get h in Js.

Question 10 **(4 marks)**

A diagram of a simple AC generator is shown below.



(a) Label the two components indicated in the diagram by writing in the two boxes provided. (2 marks)

(b) Describe the role each of these two labelled components play in the operation of the generator. (2 marks)

armature / rotor / coil rotates in B-field to produce emf across slip rings. ✓ (1) (2)

slip rings conduct current into load. ✓ The current produced is AC. (1)

Question 11 **(4 marks)**

An induction hotplate first converts the 50.0 Hz electrical supply, common to households in Australia, into a new frequency. By referring to physical principles, explain the benefit of the frequency change and whether the frequency is increased or decreased.

Power = V I

V ∝ rate of change of B.

$= -N \frac{\Delta\phi}{\Delta t}$

ie $f = \frac{1}{\Delta t}$

∴ frequency is increased ①
f(F)

V increases

P increased

Question 12 **(4 marks)**

The redshift of light from galaxies not our own is supporting evidence of the Big Bang Theory. Describe what causes the increasing amount of redshift of light from galaxies further away and also describe why **only** nearby galaxies may have blueshifted light.

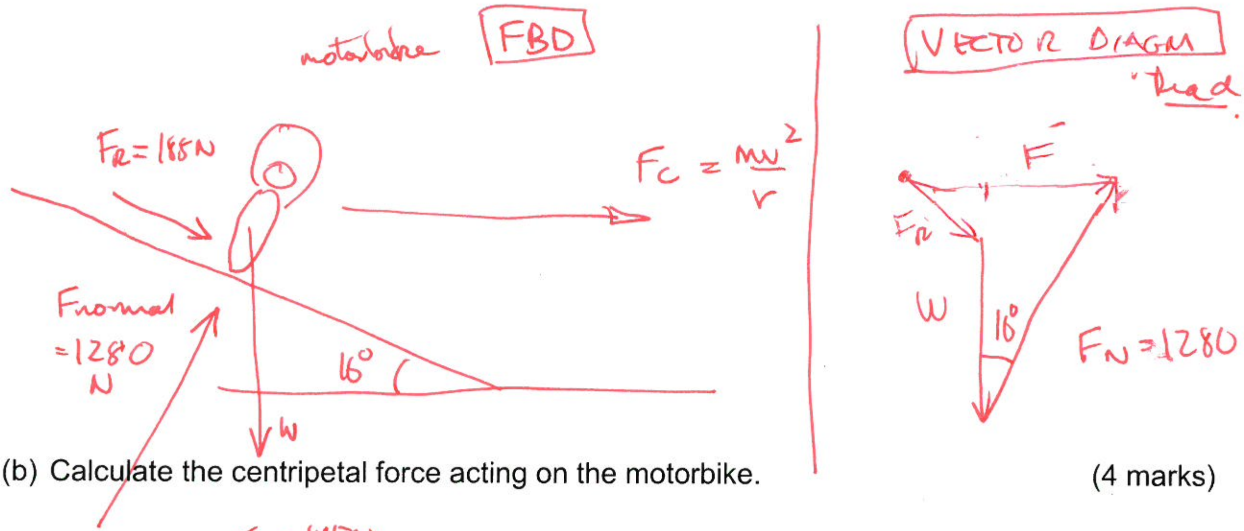
galaxies further away are travelling faster (Hubble's law)
∴ light from distant galaxies is only red shifted

Nearby galaxies are moving slowly/er.
Galaxies rotate so those parts of the galaxies rotating moving towards us will have blue shifted light.

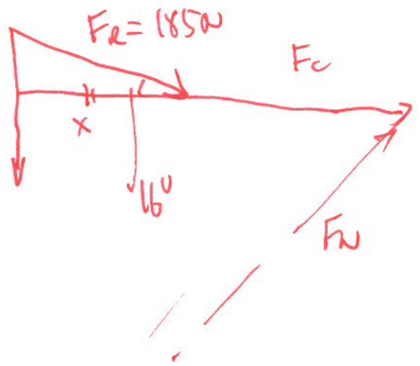
Question 13 **(6 marks)**

A motorbike is using a 16.0° banked curve to assist with making a turn with a 35.0 m radius at 60.0 km h^{-1}. While the road supplies a normal force of 1280 N, the wheels of the motorbike supply an additional 185 N frictional force, along the plane of the surface, to assist with making the corner.

(a) Draw a vector diagram which shows all the physical forces acting on the motorbike in this scenario and the resulting net force. (2 marks)



(b) Calculate the centripetal force acting on the motorbike. (4 marks)

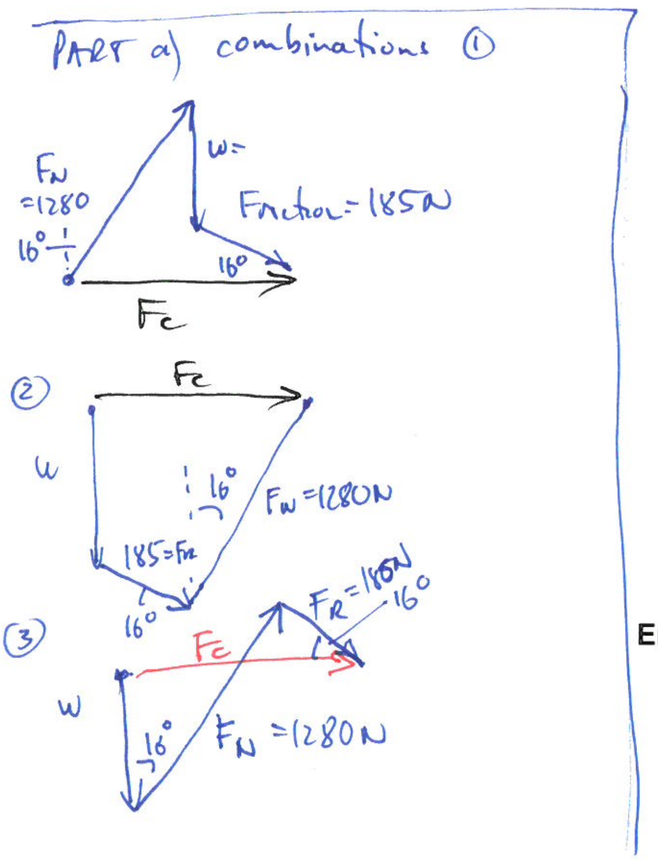


$x = F_R \cos 16° = 185 \times \cos 16° = 177.8 N$

$F_C = F_N \sin 16° + x$

$= 1280 \sin 16° + 177.8$

$= 352N + 177.8 N$



Answer: 531 N

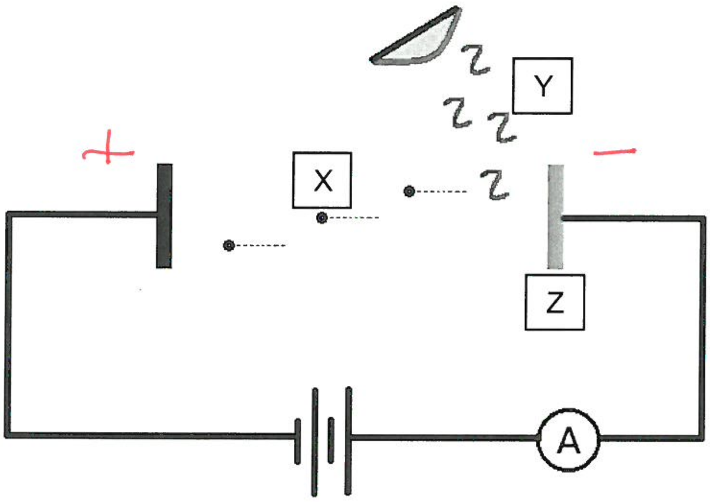
End of Section One

Section Two: Problem-solving **50% (90 Marks)**

This section has **seven (7)** questions. You must answer **all** questions. Write your answers in the space provided. Suggested working time for this section is 90 minutes.

Question 14 **(13 marks)**

The equipment below is used in an experiment to test the particle nature of light.



(a) The part "Y" is the monochromatic light. Name and describe the function of the parts labelled "X" and "Z" (4 mark)

Label	Name	Description of function/behaviour
X	photoelectrons	carriers of photcurrent from Z (cathode) to anode
Z	metal (cathode) surface	releases photoelectrons (cathode / photocathode)

(b) Describe what the "work function" means in the context of this experiment. (2 marks)

The work function is the minimum energy required to remove photoelectron from the metal surface.

NOT IN (−1)

(c) To test for the particle nature of light, the light source is monochromatic (i.e.: consisting of a single colour). Explain why this is important for this experiment. (3 marks)

1 monochromatic light is light of a single frequency.
2. single frequencies of light are required because we need to know the threshold frequency to find the relationship between frequency and kinetic energy of photoelectrons.

(d) Calculate the minimum voltage required between the two plates to ensure the ammeter detects zero current when the wavelength of the incident light is 345 nm and the work function is 1.50 eV. (4 marks)

$E_{kmax} = hf - hf_0 \ (wf)$

$E_{kmax} = Vq$

$hf_0 = 1.50 \text{ eV}$

$hf = \frac{ch}{\lambda} = \frac{3.00\times10^{8} \times 6.63\times10^{-34}}{345\times10^{-9}} = 5.76\times10^{-19} \text{ J}$ ①

$= 3.60 \text{ eV}$ ①

$Vq = 3.60 \text{ eV} - 1.50 \text{ eV}$ ①

$Vq = 2.10 \text{ eV} \Rightarrow V = 2.10 \text{ V}$ ①

$E_{kmax} = Vq$

$wf = 1.50 \text{ eV} = 2.40\times10^{-19} \text{ J}$ ①

$hf = \frac{ch}{\lambda} = \frac{3.00\times10^{8} \times 6.63\times10^{-34}}{345\times10^{-9}} = 5.76\times10^{-19} \text{ J}$ ①

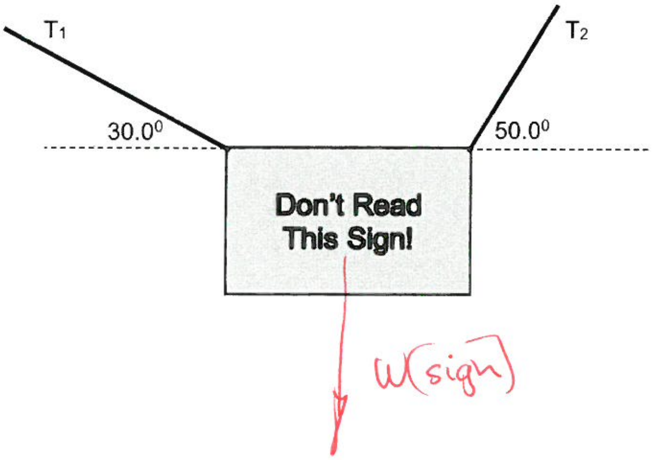
$Vq = 5.76\times10^{-19} - 2.40\times10^{-19} = 3.36\times10^{-19} \text{ J}$ ①

$V = \frac{3.36\times10^{-19}}{1.60\times10^{-19}} = 2.10 \text{ V}$ ①

Answer: 2.10 V

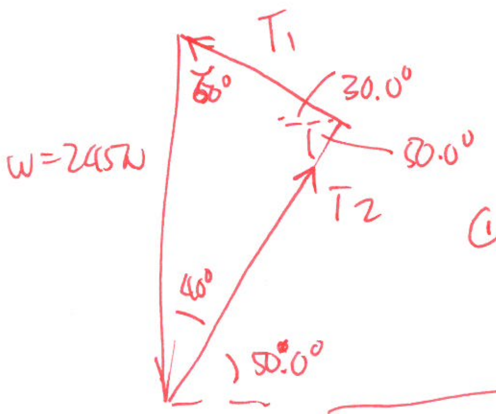
Question 15 **(10 marks)**

A 25.0 kg sign is hung by connecting two wires of negligible mass, as shown in the diagram below.



(a) Calculate the tensions T_1 and T_2 by use of a vector diagram. (4 marks)

W(sign) = mg = 25.0 × 9.80 = 245 N ①

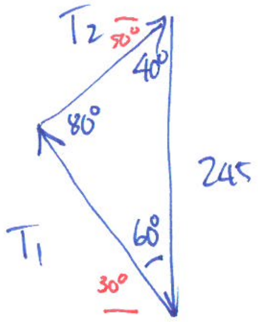


Sine Rule:

$\frac{T_1}{\sin 40^\circ} = \frac{W}{\sin 80^\circ} = \frac{T_2}{\sin 60^\circ}$

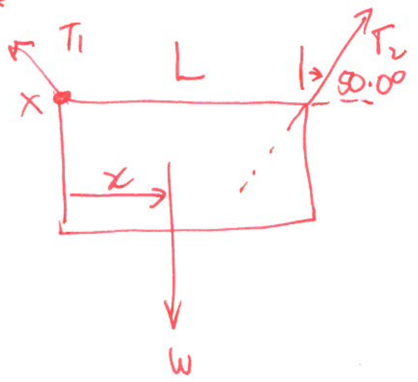
$T_1 = \frac{W \sin 40^\circ}{\sin 80^\circ} = 160\ N$ ①

$T_2 = \frac{W \sin 60^\circ}{\sin 80^\circ} = 215\ N$ ①



T_1: 160 N T_2: 215 N

(b) Given the sign has a horizontal length of L, at what proportion of L as measured from the left side of the sign is the centre of mass? (3 marks)



$\Sigma M_x = 0$ cw +

$w \times x = T_2 \times L \times \sin 50^\circ$

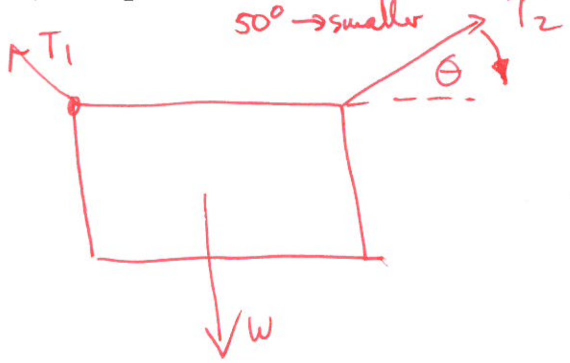
$245 \times x = 215 \times L \times \sin 50^\circ$

$x = 0.672\,L$

Take moments from LHS

Answer: 0.672

(c) As the angle made by T_2 and the horizontal decreases, explain what happens to the value of T_1 and T_2. (3 marks)



Equal when $\theta = 30^\circ$

as θ decreases

T_2 increases

T_1 increases

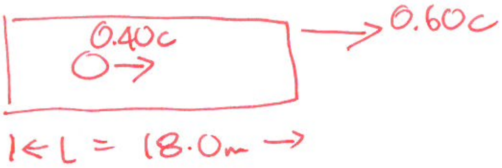
vertical component of T_1 and T_2 must increases to equal w

$\therefore T_1 + T_2$ increase

Question 16 **(12 marks)**

Claire is standing on Earth. She observes Jim passing by in a spaceship at 0.60 c. Jim observes the spaceship to be 18.0 m long. Jim is playing hyperspace pong where he hits a ball towards the front of the spaceship from the back at 0.40 c (according to Jim). The ball has a rest mass of 0.500 kg.

(a) What time does Jim observe the ball take to reach the front of the spaceship? (2 marks)



$t = \frac{s}{v} = \frac{L}{0.40c} = \frac{18.0}{0.40 \times 3.00 \times 10^8}$

$= 1.5 \times 10^{-7}$ sec

$v = \frac{s}{t}$

m = 0.500 kg

some have gone the extra step and used γ ie 1.64×10⁻⁷ ①

Answer: 1.5×10^{-7} s

(b) As the ball completes the journey towards the front of the spaceship, does Jim observe the proper length of the ball's journey or the proper time for the ball's journey or both? Justify your choice. (2 marks)

Yes. In his frame of reference he ① sees the proper length (18.0 m) and the proper time (1.5×10^{-7} sec) for the ball to move from the back to the front. ①

(c) How long is the spaceship as measured by Claire? (2 marks)

L claire

L Jim = 18.0 m

$L_{claire} = 18.0 \times \sqrt{1 - \frac{v^2}{c^2}}$

$= 18.0 \times \sqrt{1 - \frac{0.6^2}{1.0^2}}$

$= 18.0 \times 0.6$

$= 14.4$ m

around wrong way

$18.0 = l \times \sqrt{1 - \frac{v^2}{c^2}}$

$l = 22.5$

① mark only

$\gamma = \sqrt{1 - \frac{v^2}{c^2}} = \sqrt{1 - \frac{0.6^2}{1.0^2}}$

= 0.8

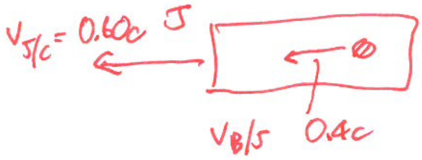
formatting

Answer: 14.4 m

farnothing

Answer: 14.4m m

(d) What is the velocity of the ball as measured by Claire? Give your answer as a fraction of the speed of light. (2 marks)



$$v_B = \frac{v_{J/C} + v_{B/J}}{\left(1 + \frac{v_{J/C} v_{B/J}}{c^2}\right)} = \frac{0.6 + 0.4c}{1 + \frac{0.6 \times 0.4 c^2}{c^2}} = \frac{1.0c}{1 + 0.24} = 0.806c$$

Answer: 0.806 c

(e) Calculate the energy of the ball as measured by Jim. (2 marks)

$$E = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{0.500 \times c^2}{\sqrt{1 - \frac{(0.4c)^2}{c^2}}} = \frac{0.500 \times 9.00 \times 10^{16}}{\sqrt{1 - 0.16}} = 4.91 \times 10^{16} \text{ J}$$

$v = 0.4c$

$m = 0.500$ kg

Answer: 4.91×10^{16} J

(f) Calculate the momentum of the ball as measured by Claire. (2 marks)

$$p = \frac{mv}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

Use (d) value

$m = 0.500$

$v = 0.806c$

$$p = \frac{0.500 \times 0.806 \times 3.00 \times 10^8}{\sqrt{\left(1 - \frac{0.806^2 c^2}{c^2}\right)}} = 2.04 \times 10^8 \text{ kgms}^{-1}$$

If v from (d) is 0.6c

$$p = \frac{0.5 \times 0.6 \times 3.00 \times 10^8}{\sqrt{\left(1 - \frac{0.6^2 c^2}{c^2}\right)}} = 1.13 \times 10^8 \text{ kgms}^{-1}$$

$$\gamma = \sqrt{1 - 0.806^2} = 0.591$$

Answer: 2.04×10^8 kg m s^{-1}

Question 17 **(12 marks)**

A trebuchet is a siege weapon that flings boulders from a great distance. Consider the arrangement of a trebuchet and a castle shown below.

$s_h = 326\,m$

(a) The boulder lands at the same height it was launched from, was fired at 45.0° above the horizontal and was airborne for 8.16 s. Complete the following questions:

i. Calculate the launch velocity of the boulder. (3 marks)

$t = 8.16$ sec
$S_H = 326$ m

$v_H = \frac{S_H}{t} = \frac{326}{8.16} = 39.95... = 40.0\ ms^{-1}$ ①

$u_H = u \cdot \cos 45°$ ①

$u = \frac{40.0}{\cos 45°} = 56.5\ ms^{-1}$ @ 45° to horiz ①

Answer: 56.5 m s^{-1}

ii. Calculate the maximum height the boulder achieved above its launch point. (3 marks)

$u_v = 40.0\ ms^{-1} \uparrow$ ie $= |u_H|$

$g = a_v = -9.80\ ms^{-2} \uparrow$

$t = 8.16 \div 2 = 4.08$ sec

$s_v = u_v t + \frac{1}{2} a_v t^2$

$= 40.0 \times 4.08 + 0.5 \times (-9.80) \times 4.08^2$

$= 81.6$ m

Alternate method:

$v_v^2 = u_v^2 + 2a_v s_v$

$s_v = \frac{v_v^2 - u_v^2}{2g}$

$= \frac{0 - 40.0^2}{2 \times -9.8}$

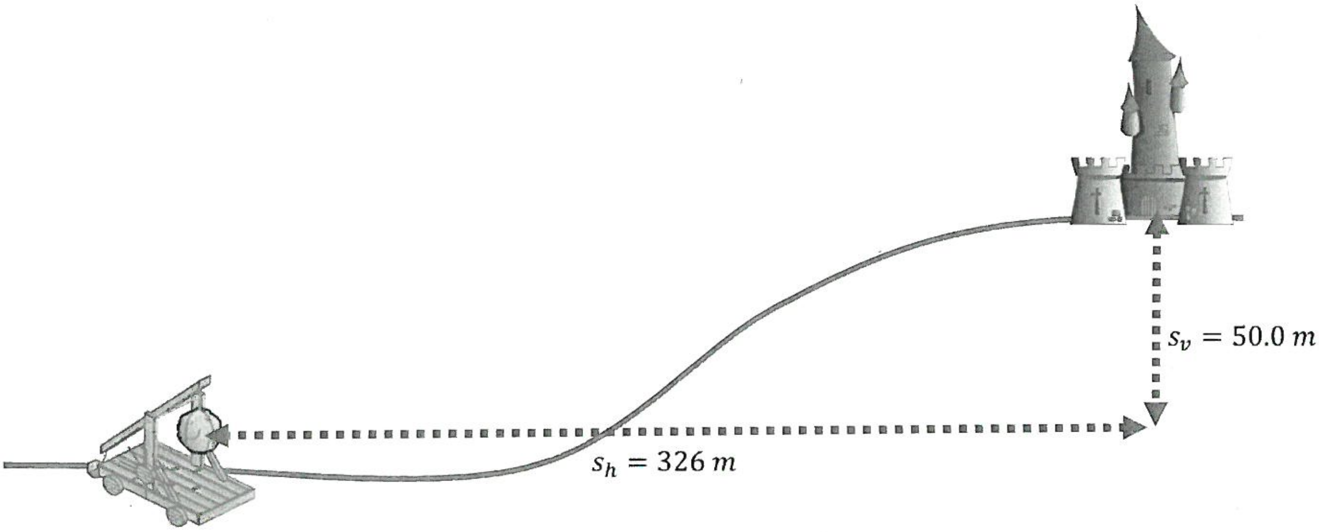
$= 81.4$ m

Errors:
Use of 56.5 ms⁻¹ for uv gives 162 m [2 max]

units wrong

Answer: 81.6 m ~~m s^{-1}~~

Medieval castles were often built at higher elevations to give an advantage to those under siege.



(b) A launched boulder is in the air for 4.80 s. The distances, s_h and s_v above indicate how far the boulder travelled to hit the castle. Determine both the speed and angle above the horizon the boulder was launched at. You may make use of the trigonometric identity $tan\theta = \frac{sin\theta}{cos\theta}$ and air resistance can be ignored. (6 marks)

$t = 4.80\ s$
$s_v = 50.0\ m$
$s_h = 326\ m$
$u_h = \frac{s_h}{t} = \frac{326}{4.80} = 67.9\ ms^{-1}$ ①

$a_v = 9.80\ ms^{-2} \downarrow$
$u_v = ?$
$t = 4.80$
$s_v = 50.0\ m \uparrow$

$s_v = u_v t + \frac{1}{2} a_v t^2$

$50.0 = u_v \times 4.80 + \frac{1}{2} \times -9.80 \times 4.80^2$

$u_v = \frac{50 + 4.90 \times 4.80^2}{4.80}$

$= 33.9\ ms^{-1} \uparrow$ ②

$u = \sqrt{67.9^2 + 33.9^2}$

$= 75.9\ ms^{-1}$ ①

angle $= tan^{-1}\left(\frac{33.9}{67.9}\right)$

$= 26.5^\circ$ ②

To horizon : 63.5° ① ONLY
See Q.

Speed: 75.9 m s^{-1} Angle: 26.5° °

STOP HERE