ATAR Course Examination, 2019

Question/Answer Booklet

PHYSICS

Name:_____

Teacher:_____

Time allowed for this paper

Reading time before commencing work: ten minutes
Working time for paper: three hours

Material required/recommended for this paper

To be provided by the supervisor

This Question/Answer booklet
Formula 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, drawing templates, drawing compass and a protractor

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 examination
Section One Short response	11	11	50	54	30
Section Two Problem-solving	6	6	90	90	50
Section Three Comprehension	2	2	40	36	20
				Total	**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 answers in this Question/Answer Booklet.

3. When calculating or estimating answers, show all your working clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning.

   In calculations, give final answers to three significant figures and include appropriate units where applicable.

   In estimates, 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 to follow any instructions that are specific to a particular question.

5. Supplementary pages for the use of planning/continuing your answer to a question have been provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

6. The Formulae and Data booklet is not to be handed in with your Question/Answer booklet.

See next page

SECTION ONE: Short Response **30% (54 marks)**

This section has **11** questions. Answer **all** questions. Write your answers in the spaces provided.

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.

Supplementary pages for the use of planning/continuing your answer to a question have been provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 50 minutes.

Question 1 **(5 marks)**

Question 2 **(5 marks)**

Question 3 **(5 marks)**

Question 4 **(5 marks)**

Question 5 **(5 marks)**

Question 6 **(4 marks)**

Question 7 **(6 marks)**

Question 8 **(5 marks)**

Question 9 **(4 marks)**

Question 10 **(5 marks)**

Question 11 **(5 marks)**

End of Section One

SECTION TWO: Problem-solving **50% (90 marks)**

This section has **seven** questions. Answer **all** questions. Write your answers in the spaces provided.

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.

Supplementary pages for the use of planning/continuing your answer to a question have been provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 90 minutes.

Question B-1 **(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)

$t = \frac{s}{v} = \frac{18.0}{0.40 \times 3.00 \times 10^8} = 1.50 \times 10^{-7}$ s

(1) (1)

Answer: 1.50×10^{-7} s

Proper time

(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)

He observes proper length

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

See next page

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

↖ she sees contracted length

$l = l_0\sqrt{1 - v^2/c^2} = 18.0\sqrt{1-(0.60)^2} = 14.4\ m$

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)

$u = \dfrac{u' + v}{1 + \dfrac{u'v}{c^2}} = \dfrac{0.4c + 0.6c}{1 + \dfrac{(0.4c)(0.6c)}{c^2}} = \dfrac{1c}{1.24}$

Answer: 0.806 c

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

$E = mc^2 = \dfrac{m_0 c^2}{\sqrt{1 - v^2/c^2}} = \dfrac{(0.500)(3.0\times10^8)^2}{\sqrt{1-(0.40)^2}}$

$= 4.91\times10^{16}\ J$

Answer: 4.91×10^{16} J

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

$p = \dfrac{m_0 v}{\sqrt{1 - v^2/c^2}} = \dfrac{0.5 \times 0.806 \times 3.00\times10^8}{\sqrt{1-(0.806)^2}} = 2.04\times10^8\ kg\,ms^{-1}$

Answer: 2.04×10^8 kg m s^{-1}

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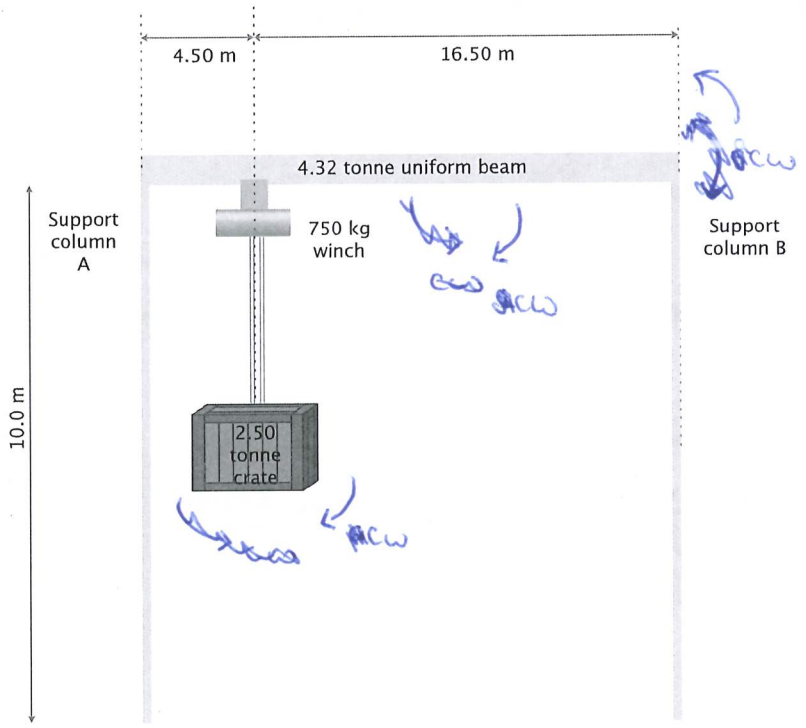
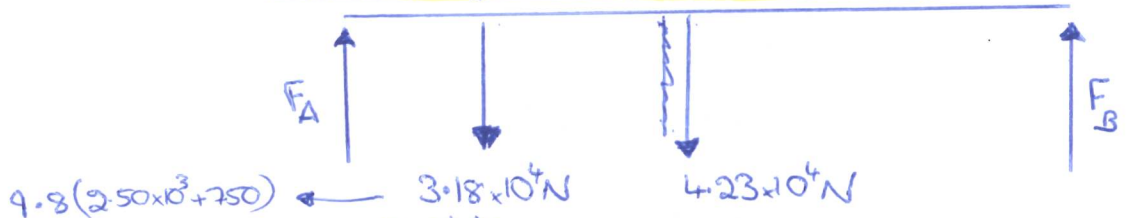
See next page

Question B-2 **(14 marks)**

A gantry crane is being used to lift a 2.50 tonne crate as shown in the diagram below. The gantry consists of a 4.32 tonne, 21.0 m uniform beam that is supported by two 10.0 m support columns A and B. The 2.50 tonne crate is 4.50 m from the center of column A and 16.50 m from column B. There is a 750 kg winch whose center of mass is directly above the center of mass the crate.



(a) In the space below, draw a free body diagram of the beam, clearly labelling all forces acting on it. Include magnitude of downward forces (4 marks)



more space

(b) Calculate the magnitude reaction force provided by each column on the beam. (4 marks)

Pivot at A $\quad \sum \tau_{cw} = \sum \tau_{acw}$

$3.18\times10^4 \times 4.5 + 4.23\times10^4 \times 10.5 = F_B \times 21$

$F_B = 2.80\times10^4$ N up

$\sum F = 0 = 3.18\times10^4 + 4.23\times10^4 \text{N} - 2.80\times10^4 - F_A = 0$

$F_A = 4.61\times10^4$ N up

more space

Reaction force from column A: 4.61×10^4 N

Reaction force from column B: 2.80×10^4 N

See next page

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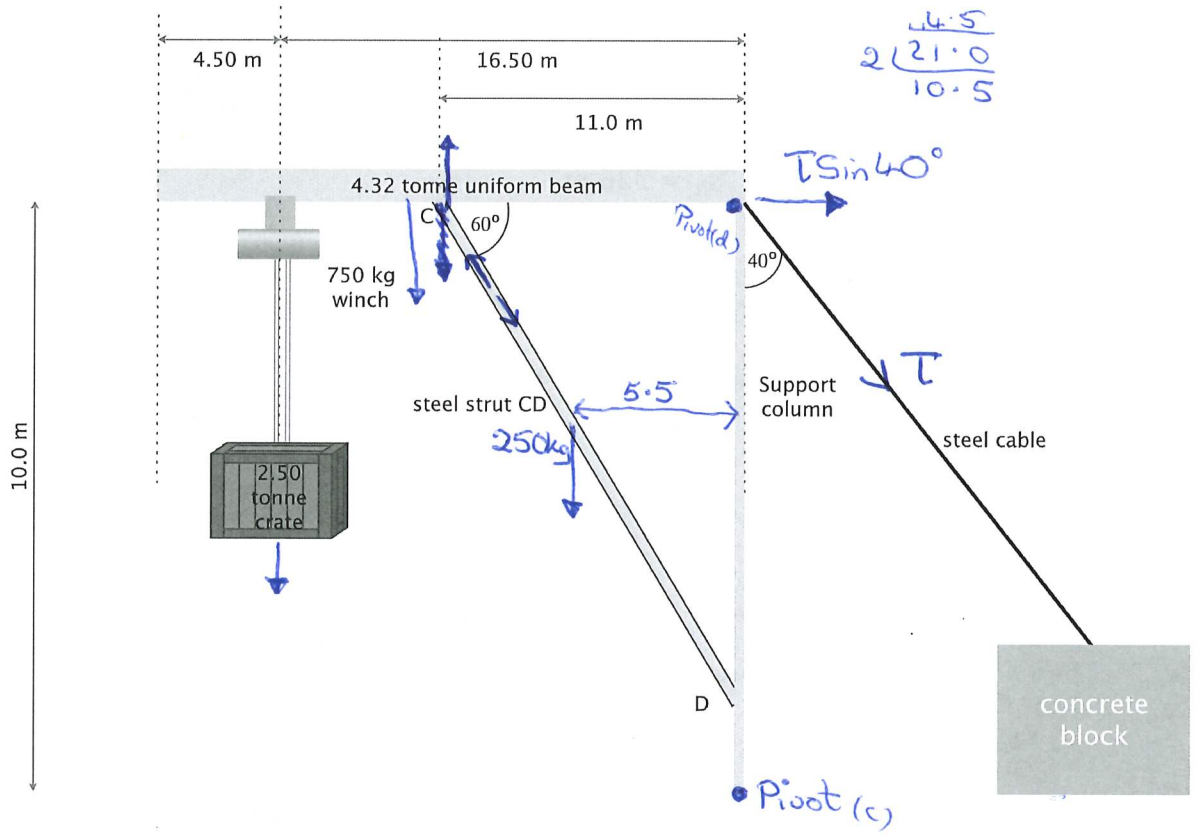
In a variation of the gantry crane, the beam is supported by one column, pivoted at its base and at its point of attachment with the beam, which is held in place by a steel cable attached to a large concrete block. The beam is supported by a 250 kg strut CD which is pivoted at both ends. CD makes an angle of 60° with the beam and is attached 11.0 m from the right hand end of the beam. The cable makes an angle of 40° with the support column.

16.5
4.5
2 | 21.0
10.5



(c) Calculate the tension in the steel cable. (3 marks)

more space

Pivot at base of B

$\sum \tau_{cw} = \sum \tau_{acw}$

$10.0 \times T\sin 40° = (3.18\times10^4 \times 16.5) + (4.23\times10^4 \times 10.5) + (250 \times 9.8 \times 5.5)$

$T = 1.52\times10^5 N$

Answer: 1.52×10^5 N ← more space

(d) Calculate the force of compression in strut CD. (3 marks)

Pivot at top of B

more space

$\sum \tau_{cw} = \sum \tau_{acw}$

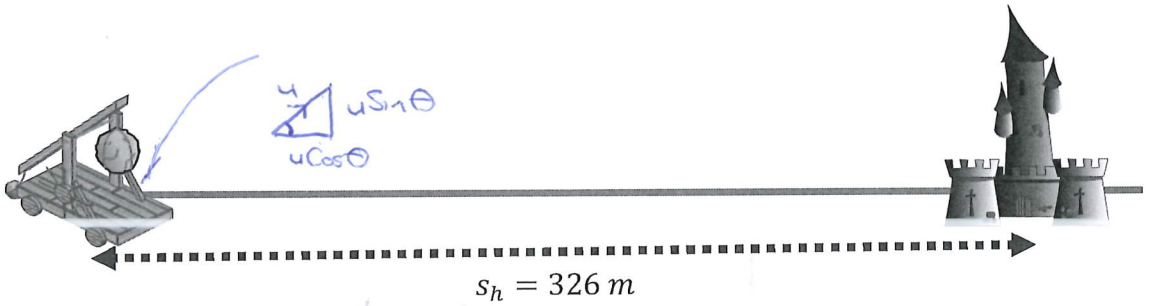
$F_{CD}\sin 60 \times 11 = (3.18\times10^4 \times 16.5) + 4.23\times10^4 \times 0.5$

Answer: 6.78×10^4 N

more space

Question B-3 **(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.



(a) The boulder lands at the same height it was launched from, was fired at 45.0^0 above the horizontal and was airborne for 8.16 s. Complete the following questions:

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

$t = 8.16s$

$u = ?$

$u_v = u\sin\theta = u\sin 45$

$u_h = u\cos\theta$

$s_H = u_H t + \frac{1}{2}at^2 = u_h t$

$326 = (u_h)(8.16)$

$u_h = 39.95 m s^{-1}$

$u = \frac{u_h}{\cos\theta} = \frac{39.95}{\cos 45} = 56.5 m s^{-1}$

Answer: 56.5 m s^{-1}

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

$s_{max} = ?$

$v_v = 0$

$u_v = 56.5\sin 45$

$t = 8.16s \rightarrow$ complete journey

$t = 4.08s$

$s = ut + \frac{1}{2}at^2$

$= (56.5\sin 45)(4.08) + (0.5)(-9.8)(4.08^2)$

$= 163 +$

$= 81.4 m$

$v^2 = u^2 + 2as$

$0 = (56.5\sin 45)^2 - (2)(9.8)s$

$s = \frac{(56.5\sin 45)^2}{(2)(9.8)}$

$= 81.4 m$

Answer: 81.4 m s^{-1}

See next page

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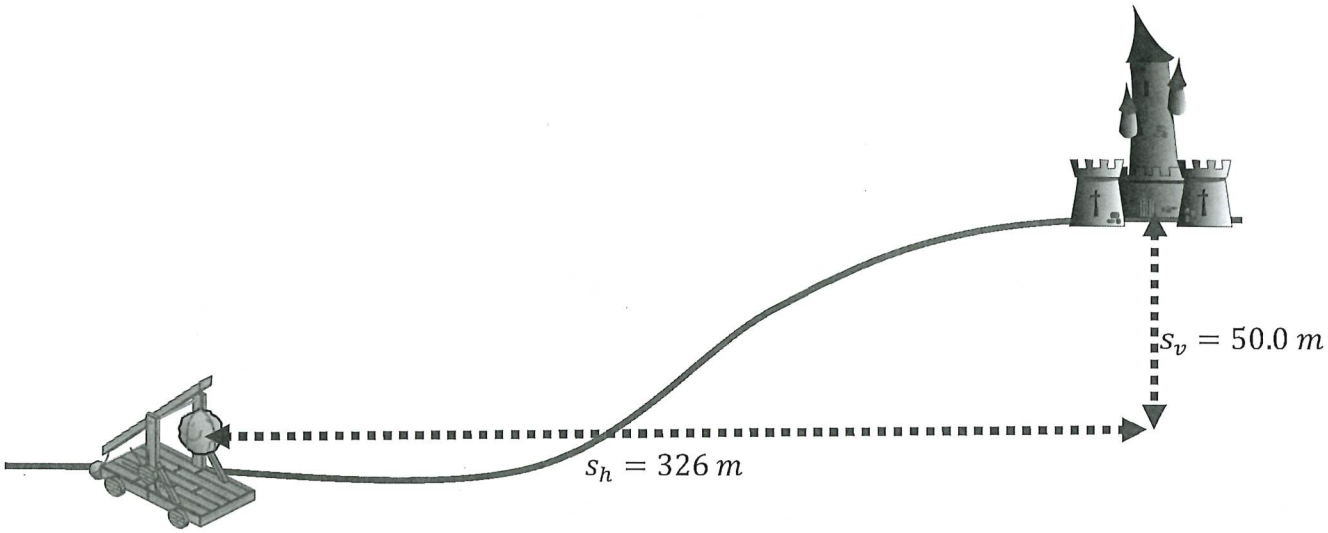
Medieval castles were often built at higher elevations to give an advantage to those under siege.



(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. Air resistance can be ignored. (6 marks)

$s_h = 326m$ $s_v = 50$

$u_h = u\cos\theta$ $u_v = u\sin\theta$

$v_h = ?$ $v_v =$

$a = 0$ $a = -9.8\,ms^{-2}$

$t = 4.80s$ $t = 4.80s$

$s_h = u_h t$

$326 = (u\cos\theta)(4.8)$

$u\cos\theta = \frac{326}{4.8} = 67.92\,ms^{-1}$

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

$50 = (u\sin\theta)(4.80) - (4.9)(4.8^2)$

$u\sin\theta = \frac{50 + (4.9)(4.8^2)}{4.8} = 33.94\,ms^{-1}$

$\frac{u\sin\theta}{u\cos\theta} = \frac{33.94}{67.92} = \tan\theta \Rightarrow \tan^{-1}\theta = 0.4997$

$\theta = 26.6°$

$u\sin\theta = 33.94$

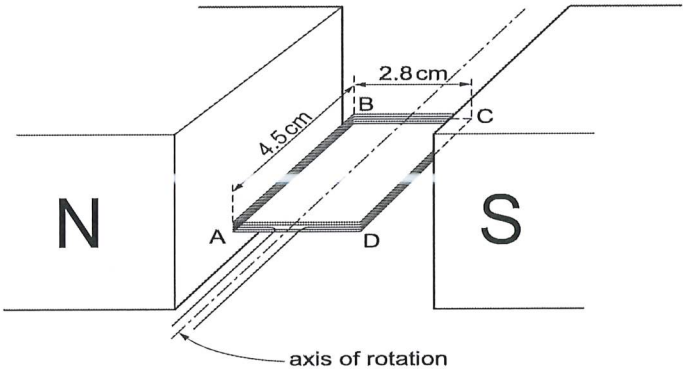
$u = \frac{33.94}{\sin 26.6} = 75.8\,ms^{-1}$

Speed: 75.8 m s^{-1} Angle: 26.6 °

See next page

Question B-4 **(13 marks)**

A small rectangular coil ABCD contains 140 turns of wire. The sides AB and BC of the coil are of lengths 4.5 cm and 2.8 cm respectively, as shown in the figure below.



The coil is held between the poles of a large magnet so that the coil can rotate about an axis through its centre. When the current in the coil is 170 mA and the coil is stationary, the maximum torque produced in the coil is 2.1×10^{-3} N m.

τ_{max}

(b) For the coil in the position shown calculate the magnitude of the force on

(i) side AB of the coil (2 marks)

$F = IlB$

$\tau = F.r \Rightarrow F_{AB} = \frac{2.1 \times 10^{-3}}{1.4} = 0.15\,N$

F_{CD}

$\Rightarrow F_{AB} = 0.075\,N$

Answer 0.075 N

(ii) side BC of the coil (1 marks)

0 N

Answer _____ N

(c) Calculate the strength of the magnetic field experienced by the sides of the coil. (3 marks)

$F = nIlB$

$B = \frac{0.075}{(140)(170 \times 10^{-3})(4.5 \times 10^{-2})}$ (1)

$= 0.0700\,T$ (1)

Answer: _____

See next page

units (1) give units (OR) award marks for units

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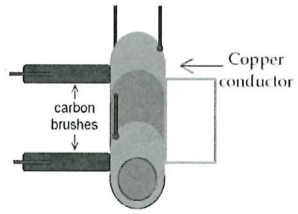
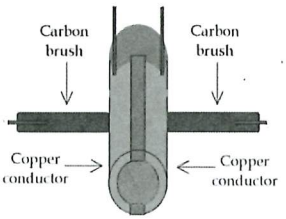
Mech 1 or Mech 2

(c)

(d) The above diagram does not show how the coil is connected to a potential difference. Of the two mechanisms shown below, which mechanism should be used for the coil to rotate as a DC motor. **Name the mechanism** and **explain your choice.** (3 marks)



Mechanism 1



Mechanism 2

(4)
give ~~some~~ marks and expect a better description of Split Ring Comm?

Split ring commutator (1)

Mechanism 2 (1)

It reverses the direction of the current every ½ turn ensuring the motor spins in a constant direction, ~~as~~ (by ensuring the torque maintains a constant direction)

(d)

(e) Once the coil has started rotating as a DC motor, does the maximum torque increase, decrease or remain the same. Explain. (4 marks)

Put in bold

- Decrease
- As the motor spins, a back emf is generated, as
- ~~According to Lenz's Law a current is generated~~ current is generated in a direction to oppose ~~the change~~

Improve answer key

- According to Lenz's Law the direction of the induced current is such as to oppose the change that is producing it - the rotating coil produces its own emf that opposes the applied emf
- Less current drawn by motor
- ~~Less~~ Max torque reduced

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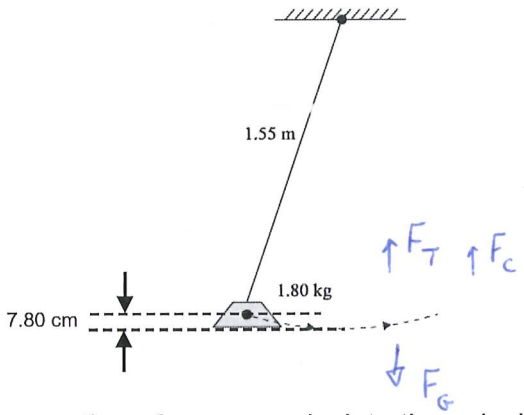
Question B-5 **(15 marks)**

During an experiment, a pendulum is set up, as shown in the diagram. The length of the cord attached to the bob is 1.55 m. The bob has a mass of 1.80 kg and is released from rest from the position shown. At the lowest point of its path, the bob is 7.80 cm beneath its starting point.



(a) By considering conservation of energy, calculate the velocity of the bob at its lowest point. (3 marks)

$E_{KE} = E_{PE}$

$0.5mv^2 = mgh$

$v^2 = (2)(9.8)(7.8 \times 10^{-2})$

$v = 1.24$

0.27644
1.5288

Answer = 1.24 m s^{-1}

more space

(b) Calculate the tension in the cord at the lowest point of its path. (3 marks)

$F_C = F_T + F_G$

↑ +ve
↓ −ve

$\frac{mv^2}{R} = F_T + mg$

$F_T = \frac{mv^2}{r} - mg$

$= \frac{(1.8)(1.24^2)}{1.55} - (1.8)(-9.8) = 19.4\,N$

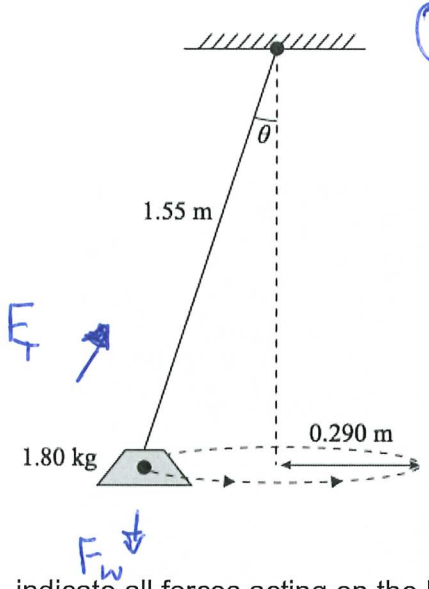
Answer = 19.4 N

diagram

more space

See next page

Later, the experimental setup is modified so that the bob swings in a horizontal circular path, with radius 0.290 m, as a conical pendulum.



(c) On the above diagram, indicate all forces acting on the bob as clearly labelled arrows **and** indicate the direction of the net force on the bob as a dashed arrow (- - - →). (3 marks)

(d) Show that the tension in the cord is now 18.0 N. (3 marks)

$\sin\theta = \frac{0.290}{1.55} \Rightarrow \theta = 10.8°$

$\sum F_{up} = \sum F_{down}$

$F_{T} = F_{grav}$

$T\cos 10.8 = 1.80 \times 9.8$

$T = 18.0\ N$

Answer _____

(e) Calculate the magnitude of the velocity of the bob at the position shown. (3 marks)

$F_c = F_{T\,hor}$

$\frac{mv^2}{r} = 18\cos 10.8$

$v = \sqrt{\frac{(0.29)(18)(\cos 10.8)}{1.8}} = 1.69\ ms^{-1}$

Answer 1.69 m s^{-1}

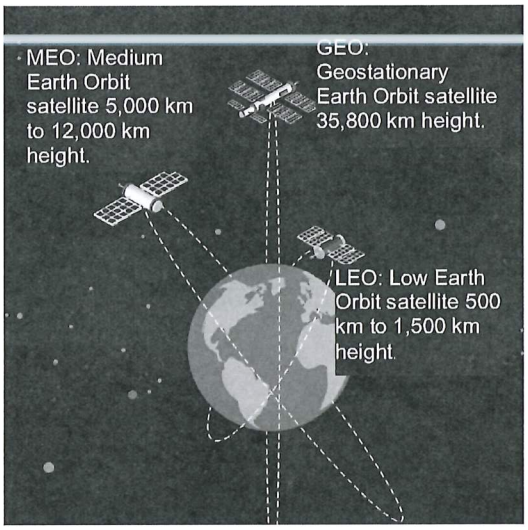
$v^2 = 2.8486$

See next page

Question B-6 **(10 or 13 marks)**

Digital television in Australia can be accessed by using a satellite dish pointed at a satellite in space. The satellite used to transmit the signals appears to stay still relative to the Earth. The satellite, with a mass of 300 kg, is actually travelling around the Earth in a geostationary orbit.

The picture below show the three main types of satellite orbits. Low Earth Orbits (LEO), Medium Earth Orbits (MEO) and Geostationary Earth Orbits (GEO).



(a) In the picture, there is an error with the indicated orbit of a GEO satellite. Indicate this error and explain why the orbit shown must be an error. (2 marks)

• Geostationary satellite must have a 24 hour period and orbit above the equator. The satellite remains above the same position on Earth

(b) Which of these satellites experiences the greatest gravitational force from the Earth? Circle the correct answer from the choices below. Explain your answer in the space provided. (2 marks)

(LEO) MEO GEO All satellites experience the same force

Explanation

Leo has lowest orbit. As $F_G = \frac{Gmm}{r^2}$, $F \propto \frac{1}{r^2}$
=> F_G greatest for smallest radius

See next page

delete?

(c) Which of these satellites is travelling at the greatest speed relative to the Earth? Circle the correct answer from the choices below. Explain your answer in the space provided. (3 marks)

LEO MEO GEO All satellites have the same speed

Explanation

Leo has lowest orbit. According to Kepler's Law

(d) Kepler's Third Law is given on your data sheet. By using relevant equations, in the space below, derive Kepler's Third Law. (3 marks)

$F_G = F_c$ (1)

$\frac{GMm}{r^2} = \frac{mv^2}{r}$

$\frac{GM}{r} = v^2$

(1) $\frac{GM}{r} = \left(\frac{2\pi r}{T}\right)^2 = \frac{4\pi^2 r^3}{T^2} \Rightarrow T^2 = \frac{4\pi^2 r^3}{GM}$ (1)

(e) Using the information in the picture, calculate the minimum period of a LEO satellite. (3 marks)

5×10^5 m

Minimum period = lowest altitude $= 500\times10^3$ m

Orbital radius $= 6.87\times10^6 + 500\times10^3$

$= 7.37\times10^6$ m

different to official soln check

$T = \sqrt{\frac{4\pi^2(7.37\times10^6)^3}{6.67\times10^{-11}\times 5.97\times10^{24}}} = \sqrt{3.969\times10^7} = 6300$

Answer: 6300 seconds

s

See next page

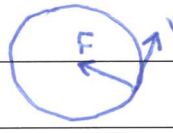
Question B-7 **(14 marks)**

The Large Hadron Collider is the largest synchrotron in the world, with a total circumference of 26.7 km. While capable of accelerating protons up to 6.50 TeV, first operations in 2013 were run at the relatively lower 3.50 TeV. The Large Hadron Collider has multiple stages of particle accelerators, starting with a simple linear accelerator and eventually confining the proton beam in the main ring. Very powerful, expensive magnets, powered and cooled to near absolute zero are required to confine the beam.

(a) Describe how a magnetic field can help keep protons confined within the ring of a synchrotron. (3 marks)

• When a charged particle is moving in a magnetic field it experiences a force which is perpendicular to its direction of travel and ⊥ to the magnetic field (right hand palm rule). This causes the charged particle to moving in a circular path

$F = qvB$



$F_{net} = \frac{mv^2}{r}$

(b) Explain why the protons in the Large Hadron Collider must first be accelerated in a straight line, with a linear accelerator, rather than starting in a ring like in the synchrotron. (2 marks)

The protons must ~~have~~ be moving at ~~a~~ velocity before they experience the force as $F = qvB$

The linear accelerator gives the protons their initial velocity

See next page

(c) What percentage of the energy of the proton beam used in 2013 is due to the rest mass of the proton? (3 marks)

$E_{o\ \text{rest mass}} = m_o c^2 = 1.67\times10^{-27} \times (3.00\times10^8)^2$

$= 1.503\times10^{-10}\ J$

$E_{\text{sync total}} = 3.50\ TeV = 3.50\times10^{12}\times1.60\times10^{-19} = 5.60\times10^{-7}\ J$

$\%\ \text{energy due rest mass} = \frac{1.503\times10^{-10}}{5.60\times10^{-7}}\times100 = 0.0268\%$

(d) In a later experiment the charged particles travelling around the LHC were also protons. Calculate the centripetal force acting on a proton when travelling in a circular path of circumference 26.7 km at one-tenth of the speed of light. Ignore relativistic effects. (3 marks)

$\text{circ} = 2\pi r \Rightarrow r = \frac{26.7\times10^3}{2\pi} = 4.30\times10^3\ m$

$F = \frac{mv^2}{r} = \frac{1.67\times10^{-27}\times(3\times10^7)^2}{4.30\times10^3} = 3.50\times10^{-16}\ N$

Force: 3.50×10^{-16} N

(e) Describe how the Large Hadron Collider is used to make new scientific discoveries. (3 marks)

- LHC collides hadrons together at high speeds
- The energy involved in these collisions forms new particles - that often have a very short life span, so otherwise would not be observed on Earth
- This helps understand/replicate some of the particles/conditions during the early stages of the Big Bang

End of Section Two

SECTION THREE: Comprehension 20% (36 marks)

This section has **two (2)** questions. You must answer **both** questions. Write your answers in the spaces provided.

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.

Additional working space pages at the end of this Question/Answer booklet are for planning or continuing an answer. If you use these pages, indicate at the original answer, the page number it is planned/continued on and write the question number being planned/continued on the additional working space page.

Suggested working time: 40 minutes.

Question 18 **(18 marks)**

Question 19 **(18 marks)**

End of Questions

See next page

Additional Working Space

Question number: _____

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See next page

Additional Working Space

Question number: _____

See next page

Acknowledgements:

Picture of Earth Satellites:

https://assets.pcmag.com/media/in[illegible]-satellite-orbital-heights.jpg?thumb=y

Antihydrogen Antics

Article adapted from: https://www.physicscentral.com/explore/action/antics.cfm

Escape velocity and The Black Hole

Article adapted from Fundamentals of Modern Physics by Peter J Nolan. 2014

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