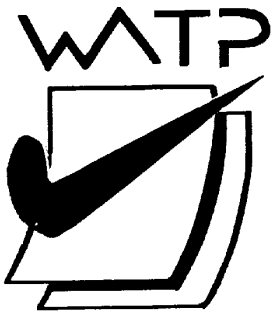


PHYSICS UNIT 3 2022

MARKING GUIDE

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.

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	11	11	50	54	30
Section Two: Extended answer	6	6	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 11 Information Handbook 2022.* 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)**

Suggested working time for this section is 50 minutes.

Question 1 **(3 marks)**

A generator consists of 150 turns of an armature of dimensions 15.0 cm by 25.0 cm. It is spun at a frequency of 50.0 Hz in a uniform magnetic field of 0.500 T. Calculate the EMF_{RMS} produced by the generator.

Description	Total
$EMF_{RMS} = \frac{2\pi Banf}{\sqrt{2}}$	1
$= \frac{2\pi(0.500)(15.0 \times 10^{-2})(25.0 \times 10^{-2})(150)(50)}{\sqrt{2}}$	1
= 625 V	1
Total	**3**

Question 2 **(6 marks)**

(a) Determine the magnitude of the induced current flowing in the loop ABCD. (3 marks)

Element	Description	Marks
Use of emf formula including resistance of section AB	$\varepsilon = vBL = IR$ $I = \frac{vBL}{R}$	1
Substitute correct values to calculate current	$I = \frac{2.50 \times 10^{-2} \times 8.55 \times 10^{-1} \times 0.50}{1.30 \times 10^{-2}}$	1
Calculates correct current	$I = 0.822$ A	1
	Total	**3**

(b) Identify the direction of the induced current **through the resistor (section AB)** and indicate with an arrow on the diagram. (1 mark)

Element	Description	Marks
Draws correct arrow on diagram	Arrow pointing down from A to B ↓	1
	Total	**1**

(c) With reference to Faraday's law and the flux within the loop ABCD, explain why the current in the loop is constant. (2 marks)

Description	Marks
The velocity of the loop of wire is constant, hence experiences a constant (negative) change in flux within the coil.	1
Since current and emf are proportional to the rate of change of flux, the induced current is constant. Note: Must refer to the law.	1
Total	**2**

Question 3 **(3 marks)**

Element	Description	Marks
Sum torques about the edge of the bench.	$\Sigma\tau = 0$ or $\tau_{cw} = \tau_{acw}$	1
Substitutes correct distance from edge and uses correct values	$W_d \times x = W_t \times r_t$ $0.290 \times 9.8 \times x = 0.370 \times 9.8 \times (37 - 54/2)$	1
Calculates correct unknown distance	$x = 12.8\ \text{cm}$	1
	Total	**3**

Question 4 **(7 marks)**

(a) Explain, making reference to relevant equations, why a car would be able to complete path A at a faster speed compared to path B.

(4 marks)

Description	Total
Path A (hitting the apex) creates a larger radius of curvature	1
As the required centripetal force is provided by friction F_F which equals mv^2 / r	1
And given m and F_F is constant, v^2 is proportional to r	1
Hence, as r increases, v_2 can increase proportionately.	1
Total	**4**

(b) Calculate the radius of curvature of a path for a 1305 kg car completing a turn at 90.0 km h^{-1} with a maximum centripetal force of 35.6 kN.

(4 marks)

Description	Total
v = 90 / 3.6 = 25.0 m s^{-1}	1
$\Sigma F = F_C = \frac{mv^2}{r} = F_F \quad r = \frac{mv^2}{F_C}$	1

$r = \frac{1305(25.0)^2}{35.6 \times 10^3}$	
r = 22.9 m	1
Total	**3**

Question 5 **(4 marks)**

Element	Description	Marks
Derives expression for net force on boxes, using $2F$	$\Sigma F_{\text{boxes}} = 2F - W_1 - W_2 = ma$ $F = \frac{ma + W_1 + W_2}{2}$	1
Correctly identifies the period when $2F > W$	Force F will be greatest when net force is upward, and acceleration is upwards. This occurs during 0 – 0.6 seconds	1
Calculates acceleration	$a = \frac{v - u}{t} = \frac{1.2}{0.6} = 2.0 \text{ m s}^{-2}$	1
Calculates F	$F = \frac{350 \times 2.0 + (225 + 125) \times 9.8}{2} = 2.07 \times 10^3 \text{ N}$	1
	Total	**4**

Question 6 **(4 marks)**

(a) Calculate the orbital speed of the satellite in m s^{-1}. (2 marks)

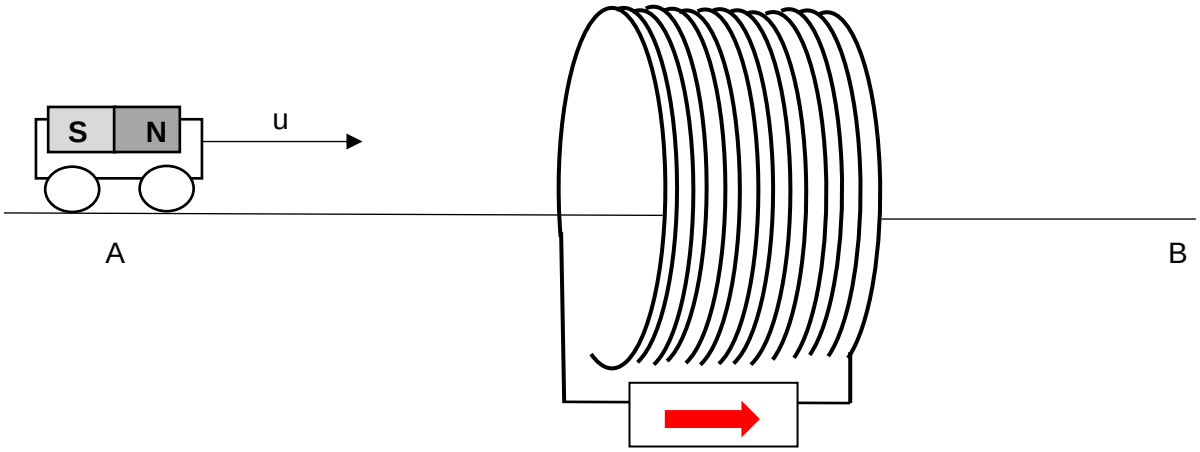
Element	Description	Marks
Derives rule for v^2 from Newton's universal law	$v^2 = \frac{GM}{R} = \frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{(6.37 \times 10^6 + 3.88 \times 10^5)}$	1
Calculates velocity in km/s	$\therefore v = 7676 \text{ m/s}$	1
	Total	**2**

(b) Calculate the magnitude of the acceleration experienced by the satellite in orbit. (2 marks)

Element	Description	Marks
Uses centripetal acceleration formula for a_c substitutes correct values	$a_c = \frac{v^2}{r} = \frac{(7.68 \times 10^3)^2}{6.75 \times 10^6}$	1
Calculates g correctly	$a_c = g = 8.72 \text{ m/s}^2$	1
	Total	**2**

Question 7 **(5 marks)**

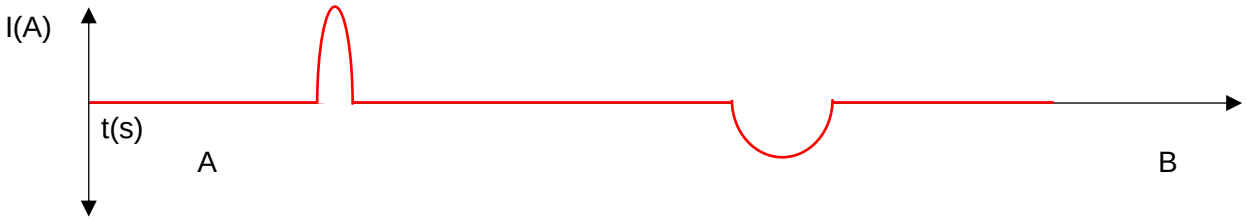
A permanent magnet is placed on a cart and rolled through a long solenoid (coil of insulated wire) with an initial speed 'u'. The solenoid is connected to a resistor as shown below.



(a) As the North pole of the magnet approaches the solenoid, state the direction of the induced current through the Resistor by drawing an arrow in the resistor above.
(1 mark)

Description	Total
Right.	1
Total	**1**

(b) On the axis below, sketch a labelled current-time graph flowing throw the resistor as the magnet travels from point A to point B. (2 marks)



Description	Total
Flat lines for three regions: before entering, inside solenoid, after exiting	1
Two peaks in opposing directions, initial peak is higher in amplitude	1
Total	**2**

(c) Explain why, when the magnet is travelling within the solenoid, there is no current flowing through the resistor.

(2 marks)

Description	Total
When travelling in the solenoid, each pole of the magnet produces an induced emf in the coils near it but in opposite directions.	1
Meaning the net induced EMF across the solenoid is zero, hence zero current is induced.	1
Total	**2**

Question 8 **(4 marks)**

A Calcium ion (Ca^{2+}) travelling in an easterly direction at 0.445% of the speed of light in a magnetic field experiences a force of 2.20×10^{-14} N to the south. Find the magnitude and direction of magnetic field influencing the Calcium ion. Ignore any relativistic effects.

Element	Description	Marks
uses formula for force on charged particle to calculate magnetic field B	$F = qvB$ $B = \frac{F}{qv}$	1
substitutes correct values of velocity v and charge q	$q = 2 \times 1.6 \times 10^{-19} = 3.2 \times 10^{-19}$ $v = \frac{0.445}{100} \times 3 \times 10^{8} = 1.335 \times 10^{6}\ \text{m/s}$	1
calculates B field	$B = \frac{2.20 \times 10^{-14}}{3.2 \times 10^{-19} \times 1.335 \times 10^{6}} = 0.0515\ \text{T}$	1
identifies direction of B	vertically upwards (or out of page)	1
	Total	**4**

Question 9 **(5 marks)**

(a) Calculate the magnitude of the force exerted by particle X on particle Y. (3 marks)

Element	Description	Marks
uses Coulomb's law and incorporates Electric constant	$F = \frac{1}{4\pi(8.85 \times 10^{-12})} \frac{q_X . q_Y}{r^2}$	1
substitutes values of charge and distance (converts to m)	$F = (8.992 \times 10^{9}) \frac{7.48 \times 10^{-6} \times -6.12 \times 10^{-9}}{(5.30 \times 10^{-3})^2}$	1
calculates magnitude of force	$F = 14.7\ \text{N}$	1
	Total	**3**

(b) What is the magnitude of the electric field strength at X due to particle Y. (2 marks)

Element	Description	Marks
uses definition of electric field strength, divides by q_x	$E = \frac{F}{q_x} = -\frac{14.7}{7.48 \times 10^{-6}}$	1
calculates magnitude of electric field	$E = 1.96 \times 10^{6}\ \text{N/C}$	1
	Total	**2**

Question 10 **(7 marks)**

(a) Demonstrate, with a suitable calculation, that the mechanic is unable to loosen the nut by simply standing on the end of the wrench. (2 marks)

Element	Description	Marks
Uses torque equation to calculate torque of mechanic	$\tau = F.r = (67.0 \times 9.8) \times 0.450$	1
Compares torque to required torque	$\tau = 295 \text{ Nm} < 775 \text{ Nm}$ Hence there is insufficient torque	1
	Total	**2**

(b) Unable to loosen the nut, the mechanic slides a long metal tube onto the end of the wrench such that the total arm length is now 1.25 m (still in a horizontal position).

(i) Explain how this will make loosening the nut easier. (2 marks)

Description	Marks
Since torque $\tau = F.r$ making the radius longer will increase the torque applied	1
And thus reduce the required force required to achieve a specific torque.	1
Total	**2**

(ii) When the mechanic stands on the wrench, starting horizontally, through what angle will the nut rotate before stopping? Assume the mechanic doesn't slip. (3 marks)

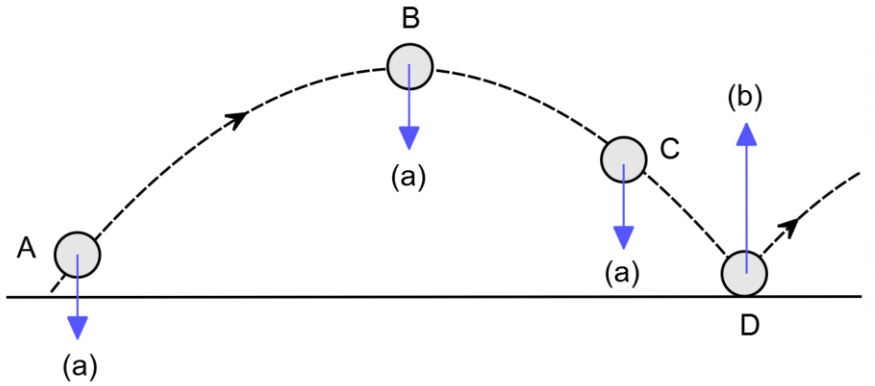
Element	Description	Marks
writes expression for torque when rotated by angle θ using correct trig function	$\tau = r \times W_{\perp}$ $\tau = r \times mg\cos\theta$	1
substitutes correct values and uses required torque of 775 Nm	$775 = 1.25 \times 67 \times 9.8 \times \cos\theta$	1
correctly calculates angle	$\theta = 19.2°$	1
	Total	**3**

Marker's note: If used

$\tau = r \times mg \sin\theta$

And arrived at an answer of $\theta = 70.8°$ (Max 2 marks)

Question 11 **(6 marks)**



(a) On the diagram, draw a vector representing the net acceleration of the soccer ball at points A, B and C. Ignore friction and air resistance. (2 marks)

Description	Marks
all vertically downwards 1 mark each	1
all should be same magnitude	
Total	**3**

(b) On the diagram, draw a vector representing the net force on the soccer ball at point D. Ignore friction and air resistance. (2 marks)

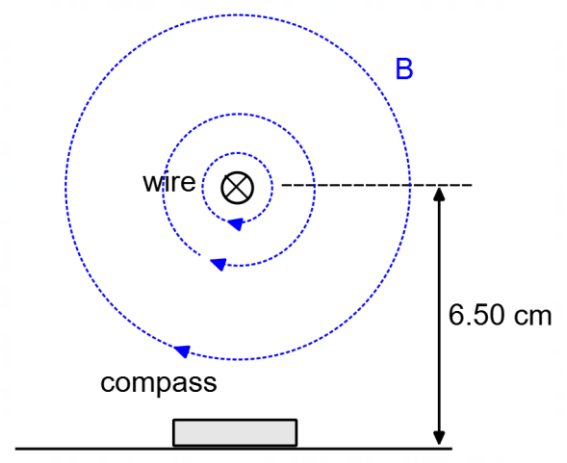
Description	Marks
vertically upwards	1
It should be greater than g in magnitude	
Total	**1**

(c) Assuming that the path of the soccer ball shown on the diagram above involves air resistance, arrange the magnitudes of the **net acceleration** on the ball at positions A, B and C (a_A, a_B, a_C), in the boxes below. (2 marks)

Description	Marks
$a_A > a_B > a_C$ or $A > B > C$	
all 3 correct	2
Total	**2**

Question 12 **(19 marks)**

(a) On the SIDE VIEW, draw the shape of the magnetic field near the wire due to the current in the wire, drawing at least 3 field lines. (3 marks)

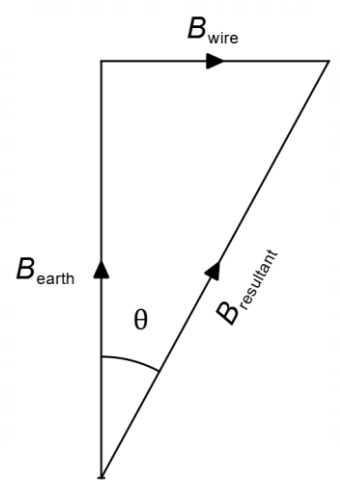


Description	Marks
At least 3 clockwise circles drawn.	1
Correct direction of magnetic field	1
Increased separation between circles, further away	1
Total	**3**

(b) Explain why the compass changes direction when the current is turned on. (2 marks)

Description	Marks
Due to the current in the wire a magnetic field will surround the wire and, at the compass, will point West.	1
This westerly component combines with the earths (northerly) magnetic field and the compass aligns with the resulting magnetic field.	1
Total	**2**

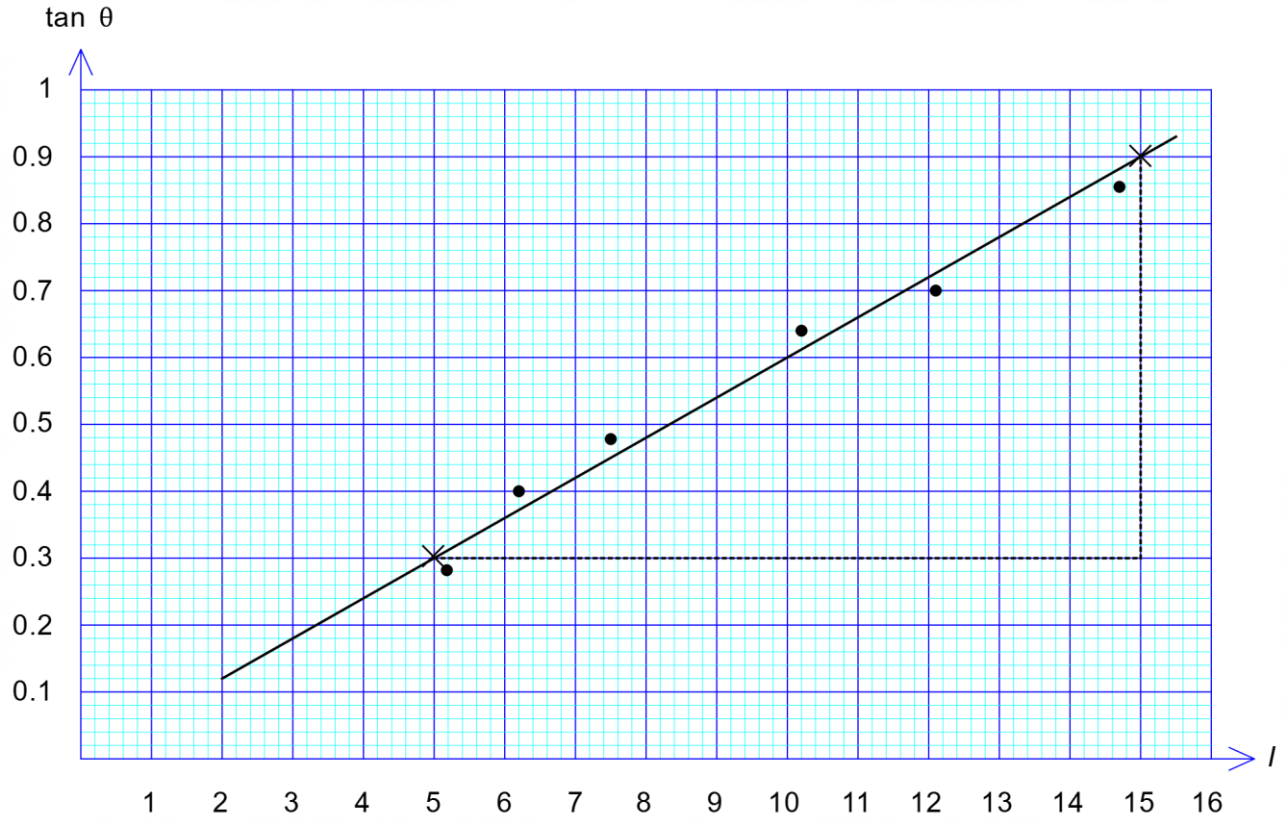
(c) The student decided to construct a graph of $\tan\theta$ versus I. Using a vector diagram and a relevant formula, show that the gradient m of the line of best fit of the graph is given by the following expression, where B_e is the horizontal component of the earth's magnetic field near the wire. (4 marks)

Element	Description	Marks
use of vector diagram		1
uses trigonometry to relate B_w to B_e and uses formula for magnetic field strength near wire	$\tan\theta = \frac{B_w}{B_e} = \frac{\frac{\mu_0}{2\pi}.\frac{I}{r}}{B_e}$	1
simplifies to isolate gradient	$\tan\theta = \left(\frac{\mu_0}{2\pi r B_e}\right) I$	1
expresses gradient	$m = \frac{\mu_0}{2\pi r B_e}$	1
	Total	**4**

This equation derivation **MUST** start with a correct vector diagram

(d) Using the values in the table above complete the graph of $\tan\theta$ versus I and draw a line of best fit on the graph. (3)

Plots points accurately 1
LOBF accurately drawn (1) Linear (1)



(e) Calculate the gradient of the graph, showing your construction of the gradient on the graph. The units are given below. (4 marks)

Element	Description	Marks
marks construction lines for gradient calc.		1
Construction lines contain a large range to reduce error	Domain min is 5	1
Points required for gradient calc are indicated	lines on graph marked at for e.g. (5, 0.3) and (15, 0.9)	1
calculates gradient	$m = \frac{0.9 - 0.3}{15 - 5} = 0.06$	1
	Total	**4**

(f) Using your gradient, determine an estimate for the strength of the horizontal component of the earth's magnetic field close to the wire. (3 marks)

Element	Description	Marks
Rearranges given expression for gradient to find B_e	$B_e = \frac{\mu_0}{2\pi r\, m}$	1
Substitutes constant μ_0, m and r into expression	$B_e = \frac{4\pi \times 10^{-7}}{2\pi \times 0.065 \times 0.06}$	1
Calculates correct B_e within range	$B_e = 51\ \mu\text{T} \quad [50 - 60\ \mu\text{T}]$	1
	Total	**3**

Question 13 (14 marks)

During the Apollo 11 mission, the *Columbia* service module remained in orbit around the moon while the *Eagle* lunar module descended to the lunar surface with Buzz Aldrin and Neil Armstrong. The Columbia positioned itself at an orbital altitude of 112 km above the Moon's surface.

(a) Show the derivation of Kepler's 3rd Law.

(4 marks)

Description	Total
$\Sigma F = F_g = \frac{Gm_1m_2}{r^2} = F_c = \frac{mv^2}{r}$ $v^2 = \sqrt{\frac{GM}{r}}$, $v = \frac{2\pi r}{T}$, $v^2 = \frac{4\pi^2 r^2}{T^2}$ Note: many various pathways to derive	1-2
$\frac{4\pi^2 r}{T^2} = \frac{Gm_2}{r^2}$	1
$\frac{r^3}{T^2} = \frac{Gm_2}{4\pi^2}$	1
Total	4

(b) Hence, calculate the orbital period of the Columbia service module.

(2 marks)

Description	Total
$T^2 = \frac{4\pi^2 r^3}{Gm_2}$ $= \frac{4\pi^2(1.74\times10^6+112\times10^3)^3}{(6.67\times10^{-11})(7.35\times10^{23})}$	1
= 7150 s	1
Total	**2**

(c) Calculate the orbital speed of the Columbia service module.

(2 marks)

Description	Total
$v = \frac{2\pi r}{T} = \frac{2\pi(1.74\times10^6+112\times10^3)}{7150}$	1
= 1630 m s^{-1}	1
Total	**2**

Question 13 (continued)

When the Eagle lunar module, of mass 7810 kg approached the lunar surface, it fired thrusters in the final 50.0 m of its descent to reduce its approach speed from 15.0 m s^{-1} to rest. This provided an average deceleration of 2.25 m s^{-2} upwards. Ignore any reduction in mass due to exhausting gas.

(d) Calculate the weight of the Eagle lunar module in the final 50.0 m of descent.

(3 marks)

Description		Total
$F_g = \frac{Gm_1m_2}{r^2}$	Some students used g_m from the data sheet. There is no penalty for this	1
$= \frac{(6.67\times10^{-11})(7.35\times10^{23})(7810)}{(1.74\times10^6)^2}$		1
= 12, 600 N		1
	Total	**3**

(e) Hence, calculate the average force that must be applied by the thrusters to produce this average acceleration. If you could not obtain an answer to part (d), use F_g = 1.50 x10^4 N.

(3 marks)

Description	Total
$\Sigma F = ma = T - W$	1
7810(+2.25) = T – 12600	1
T = 30,200 N upwards (32,600 N)	1
Total	**3**

Question 14 **(13 marks)**

(a) the angle to the horizontal the ball strikes the wall at point B. (4 marks)

Element	Description	Marks
calculates horizontal velocity	$u_x = 12.0 \times \cos 30° = 10.39 \text{ m/s}$	1
calculates vertical velocity	$u_y = 12.0 \times \sin 30° = 6.00 \text{ m/s}$	
uses horizontal velocity to calculate time of flight to B	$s_x = 4.00 = 10.39 \times t$ $t = 0.3849 \text{ s}$	1
uses relevant equation to determine vertical speed at B	$v_y = u_y + a_y t = 6.00 + (-9.8) \times 0.3849$ $v_y = 2.228 \text{ m/s}$	1
uses components and trig to determine angle to horizontal	$\tan\theta = \frac{v_y}{u_x} = \frac{2.228}{10.39}$ $\theta = 12.1°$	1
	Total	**4**

(b) the speed of the ball as it leaves the wall at point B. (2 marks)

Element	Description	Marks
uses vertical and horizontal speeds to calculate speed	$v = \sqrt{u_x^2 + v_y^2} = \sqrt{10.39^2 + 2.228^2} = \sqrt{112.92}$	1
calculates correct speed	$v = 10.6 \text{ m/s}$	1
	Total	**2**

(c) the height *H* of the ball at point B. (3 marks)

Element	Description	Marks
Uses $t = 0.3849$ and equation of motion to calculate vertical displacement	$s = ut + \frac{1}{2}at^2$ $s = 6.00 \times 0.3849 + \frac{1}{2}(-9.8) \times (0.3849)^2$ $s = 1.583 \text{ m}$	1 – 2
Adds initial height	Height *H* is $1.583 + 0.90 = 2.48 \text{ m}$	1
	Total	**3**

(d) the horizontal distance *D* the tennis player must position themselves at to hit the ball at C. (4 marks)

EITHER
solves using quadratic approach from point A to C [or B to C]

Element	Description	[alternate]	Marks
uses vertical drop from A to C [or B to C] and writes quadratic equation	$s_A = 0.30 = u_{yA}t + \frac{1}{2}at^2$ $0.30 = 6.00.t - 4.9t^2$ $0 = -4.9t^2 + 6.00t - 0.30$	$s_B = -1.28 = u_{yB}t + \frac{1}{2}at^2$ $-1.28 = 2.23.t - 4.9t^2$ $0 = -4.9t^2 + 2.23t + 1.28$	1
uses quadratic and finds time from A to C [or B to C]	$t = \frac{-6.00 \pm \sqrt{30.1}}{-9.8}$ $t = \cancel{0.0522}, 1.17 \text{ s}$	$t = \frac{-2.23 \pm \sqrt{30.1}}{-9.8}$ $t = \cancel{-0.332}, 0.787 \text{ s}$	1
writes horizontal displacement with *D*	$s_x = u_x.t = 10.4 \times 1.17$ $D + 8 = 12.18 \text{ m}$	$s_x = u_x.t = 10.4 \times 0.787$ $D + 4 = 8.18 \text{ m}$	1
calculates *D*	$D = 4.18 \text{ m}$	$D = 4.18 \text{ m}$	1
		Total	**4**

OR
finds intermediate velocity at from point C [or B] to find time and distance

Element	Description	[alternate]	Marks
uses vertical drop from A to C [or B to C] to find speed at C	$v^2 = u^2 + 2as$ $v^2 = 6^2 + 2(-9.8)(0.30)$ $v = -5.488 \text{ m/s}$	$v^2 = u^2 + 2as$ $v^2 = 2.23^2 + 2(-9.8)(-1.28)$ $v = -5.488 \text{ m/s}$	1
calculates time from A to C [or B to C]	$t = \frac{v - u}{a}$ $t = \frac{-5.49 - 6.00}{-9.80} = 1.17 \text{ s}$	$t = \frac{v - u}{a}$ $t = \frac{-5.49 - 2.23}{-9.80} = 0.787 \text{ s}$	1
uses horizontal velocity to write distance from A to C [or B to C]	$s_x = D + 8.00 = u_x.t$ $D + 8.00 = 10.39 \times 1.17$	$s_x = D + 4.00 = u_x.t$ $D + 4.00 = 10.39 \times 0.787$	1
calculates *D*	$D = 4.18 \text{ m}$		1
		Total	**4**

Question 15 (15 marks)

(a) Determine the direction of the current flowing in coil ABCD (as viewed from above) – clockwise or anticlockwise? Circle your answer. (1 mark)

Description	Marks
CLOCKWISE	1
Total	**1**

(b) Determine the maximum torque generated by the coil. (4 marks)

Element	Description	Marks
Use of the torque formula	$\tau = Fr$ $\tau = BILr$	1
Recognises $n = 10$ turns and two sides of the coil	$\tau = 2nBILr$ or $\tau = BIAn$	1
Substitutes correct values	$\tau = 2 \times 10 \times 0.84 \times 2.75 \times 0.120 \times (0.08/2)$	1
Calculates torque	$\tau = 0.222$ Nm	1
	Total	**4**

(c) Explain the function and purpose of the split ring commutator. (2 marks)

Element	Description	Marks
Explanation of function	The commutator acts to reverse the current every half a turn by switching the contacts with the use of a split ring as the coil spins	1
Explanation of purpose	Reversing the current acts to ensure that the torque generated pushes the coil in the same direction as the prior half a spin, thus a smoother rotation	1
	Total	**2**

(d) The student got the motor running but noticed that there was a reduction in the net voltage across the coil as it rotated. Further, the student noticed that this drop in voltage increased as the speed of the motor increased. Account for these observations using relevant physics.

Description	Marks
The wire coil spinning in a magnetic field has an included emf across the coil since the coil experiences a change in flux (according to Faraday's Law)	1
This emf (according to Lenz's law) acts to oppose the applied voltage and thus reduces the net voltage in the coil	1
The size of the induced emf is proportional to rate of change of flux and therefore the voltage-drop increases at higher speeds	1
Total	**3**

Question 16 **(14 marks)**

(a) Show that the tension in the rope is approximately 70 N. (5 marks)

Element	Description	Marks
Sums torques about point P	$\Sigma\tau = 0$ OR $\tau_{\text{cw}} = \tau_{\text{acw}}$	1
Writes the torques generated by pole (p), flag (f), and rope (r)	$W_{p\perp}.r_p + W_{f\perp}.r_f = T_{r\perp}.r_r$	1
Substitutes correct values	$(9.10 \times 9.8 \times \sin 28°) \times 2.10$ $+ (0.755 \times 9.8 \times \sin 28°) \times 4.20$ $= T_{\perp}.(2/3 \times 4.20) \sin 32°$	1
Correctly identifies angle and component of tension in rope	$87.92 + 14.59 = T.\sin 32° \times 2.80$	1
Correctly calculates tension	$T = \dfrac{102.51}{1.484} = 69.1$ N	1
	Total	**5**

(b) Determine the magnitude of the reaction force and the direction relative to the horizontal, of the reaction force of the ground acting on the pivot at point P. Note: if you did not calculate part (a) you may use the value of 70 N for tension in the rope. (5 marks)

Element	Description [alternate using 70 N]	Marks
Sums hor. forces to find R_x (Right positive)	$\Sigma F_x = R_x - T_x = 0 \quad \rightarrow R_x = T_x$ $R_x = 69.1 \times \cos 30° = 59.8$ N [60.62]	1
Sums vert. forces to find R_y (Up positive)	$\Sigma F_y = R_y - W_p - W_f - T_y = 0$ $R_y = 9.8 \times (9.10 + 0.755) + 69.1 \times \sin 30°$ $= 131.1$ N [131.6]	1 – 2
Calculates net force R	$R = \sqrt{59.8^2 + 131.1^2} = 144$ N [144.9]	1
Uses components to find θ relative to horizontal	$\tan\theta = \dfrac{R_y}{R_x} = \dfrac{131.1}{59.8}$ $\theta = 65.5°$ [65.3°]	1
	Total	**5**

(c) Describe and account for how the magnitude of the tension force in the rope changes as the flagpole is raised closer to vertical. (4 marks)

Description	Marks
As the pole is raised, the radial arm for the weight of the flag and pole reduces	1
Thus, the net CW torque produced by the flag and pole reduces	1
Thus, less ACW torque is required for equilibrium	1
Hence, the required tension force is less	1
Total	**4**

Question 17 **(10 marks)**

(a) The generator produces 325 kW RMS of power at 840 V RMS and the 7.80 km transmission line has a resistance of 9.00×10^{-2} ohms per kilometre of line.

(i) What RMS voltage is delivered to the transformer? (4 marks)

Element	Description	Marks
uses voltage and power of generator find current output	$P = VI = 840.I = 325 \times 10^3$ $I = 387\ \text{A}$	1
calculates resistance	$R = 9.00 \times 10^{-2} \times 7.80 = 0.702\ \Omega$	1
calculates power lost in transmission lines	$V_{\text{loss}} = IR = 387 \times .702$ $V_{\text{loss}} = 272\ \text{V}$	1
calculates voltage delivered	$V = 840 - 272 = 568\ \text{V}$	1
	Total	**4**

(ii) The transformer has 1400 windings on the primary side and 400 windings on the secondary side. What RMS voltage is delivered to the houses? (2 marks)

Element	Description	Marks
uses transformer rule to relate windings and voltage	$\frac{N_p}{N_s} = \frac{1400}{400} = \frac{V_p}{V_s} = \frac{568}{V_s}$	1
calculates secondary voltage	$V_s = 162\ \text{V}$	1
	Total	**2**

(b) Residents of the houses are concerned about the significant power loss in the transmission lines from the generator to the transformer. Select a type of transformer that could be installed at the generator which would reduce power loss in the transmission lines. Justify your answer using relevant physics. (4 marks)

Description	Marks
Step-up transformer (circled)	1
A step-up transformer at the generator would reduce the transmission current	1
Since $P_{\text{loss}} \propto I^2$, reducing the current would reduce power loss	1
Reducing the power loss would also reduce voltage drop and increase the voltage delivered to the homes.	1
Total	**4**

Question 18 **(10 marks)**

A 75.0 kg pilot is flying an aircraft around an airport while waiting to land. The pilot is flying the plane in a horizontal circular path of radius 9.00 km as shown. Each revolution about the airport takes 525 seconds to complete.

(a) Determine the magnitude of both the centripetal force and centripetal acceleration on the pilot during this horizontal flight. (4 marks)

Element	Description	Marks
calculates velocity from period and distance	$v = \frac{2\pi r}{T} = \frac{2\pi \times 9000}{530} = 108 \text{ m/s}$	1
substitutes correct values into correct formula	$F_c = mv^2/r$ $F_c = \frac{75.0 \times (107)^2}{9.00 \times 10^3}$	1
calculates centripetal force	$F_c = 96.7 \text{ N}$	1
calculates centripetal accel.	$a_c = \frac{F_c}{m} = \frac{96.7}{75.0} = 1.29 \text{ m s}^{-2}$	1
	Total	**4**

(b) Determine the angle that the plane must bank to achieve this horizontal flight. (2 marks)

Element	Description	Marks
uses trigonometry to relate F_c to W and the angle of bank θ	$\tan\theta = \frac{F_c}{W} = \frac{96.7}{75.0 \times 9.8}$	1
calculates angle θ	$\theta = 7.49°$	1
	Total	**2**

(c) During this descent the plane speeds up to a maximum of 116 m s^{-1} at the bottom. Determine the maximum apparent weight of the pilot during this manoeuvre? (4 marks)

Element	Description	Marks
identifies the bottom of the curve as the max apparent weight and writes force equation	$\Sigma F = R - W = F_c$ $R = F_c + W$	1
writes equation for apparent weight	$R = \frac{mv^2}{r} + mg$	1
substitutes correct values	$R = \frac{75.0 \times (116)^2}{1.30 \times 10^3} + 75.0 \times 9.8$	1
calculates apparent weight	$R = 1.51 \times 10^3 \text{ N}$	1
	Total	**4**

Question 19 **(18 marks)**

(a) Explain how the phenomenon of 'wing effect' increases the range of a discus. Use relevant physics concepts in your explanation. (4 marks)

Description	Marks
The 'wing effect' provides extra lift L for the discus	1
Therefore, the net force is reduced (or the net acceleration a is smaller than g): $\Sigma F_{\text{down}} = mg - L = ma$ $a < g$	1
Thus, the time taken t for the discus to rise, and fall is increased	1
Hence, the distance travelled horizontally ($s_x = u_x.t$) is increased	1
Total	**4**

Marker's notes
Did not accept explanation of increased initial velocity

(b) A certain discus throw has the following parameters: the angle of release is 37.6°, the height of release is 1.66 m, the range of the throw was measured at 69.2 m, and the release speed was 24.0 m s^{-1}. By calculating the expected range (with no air resistance) determine the 'wing effect', as a percentage, for this throw? (6 marks)

Element	Description	Marks
calculates component velocities	$u_x = 24.0 \times \cos 37.6° = 19.01 \text{ m/s}$ $u_y = 24.0 \times \sin 37.6° = 14.64 \text{ m/s}$	1
calculates final vertical speed (uses a sign convention)	$v^2 = u^2 + 2as = 14.64^2 + 2(-9.8)(-1.66)$ $v = -15.72 \text{ m/s}$	1
calculates time of flight	$t = \frac{v-u}{a} = \frac{-15.72 - 14.64}{-9.8} = 3.098 \text{ s}$	1
calculates horizontal distance	$s_x = u_x.t = 19.01 \times 3.098 = 58.90 \text{ m}$	1
compares distances as a ratio	$\frac{69.2}{58.90} = 1.175$	1
expresses 'wing effect'	An increase of 17.5%	1
	Total	**6**

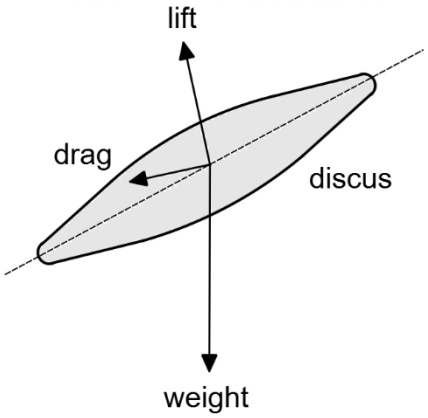
Marker's notes
-1 for calculation errors, including sign convention (cumulative)
-2 for conceptual errors, eg assuming total time is twice that to the peak
No penalty for rounding errors
Reminder to use sign convention consistently and use exact values from previous calculations

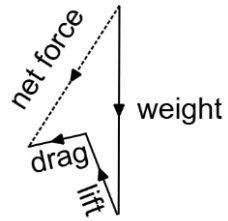
(c) Estimate the maximum tension in the arm of an Olympic female discus thrower during her throw. Give your answer to an appropriate number of significant figures. Clearly state your assumptions. (4 marks)

Element	Description	Marks
extracts data from text (mass and time) makes valid assumption about radius	assumptions: $m = 1.00$ kg (text, par. 3) $t = 1.0$ s, rotations $= 1.5$ (text, par. 5) assume $r = 0.75$ m $0.5\text{ m} < r < 1.25\text{ m}$ (text, fig. 1)	1
estimates release speed (initial speed is zero)	$v_{av} = \frac{d}{t} = \frac{1.5 \times 2\pi \times 0.75}{1.0} = \frac{u+v}{2} = \frac{0+v}{2}$ $\rightarrow v = 14\text{ m/s}\ \ [9.4 - 24]$	1
uses centripetal force to determine tension T	$T = \frac{mv^2}{r} = \frac{1.00 \times 14^2}{0.75} = 266$	1
calculates tension T to max 1 or 2 SF	$T = 270$ N $\quad [71 - 720]$	1
	Total	**4**

Marker's notes
Only 2 marks awarded if velocity was assumed
No marks awarded if assumed discus is rotated vertically
Full marks awarded if angle assumed between 35 and 45 deg and T found from sum of forces

(d) The discus below is travelling upwards and has an angle of attack of 10°. On the discus below draw and label the forces acting on the discus. In the dashed box draw a vector diagram, including the net force. Assume that this discus is uniform. (4 marks)

Element	Description	Marks
Draws lift, weight, and air resistance forces on the discus. The lift force needs to be clearly off perpendicular (as per questions)		1 – 2

Draws correct vector diagram heat-to-tail, including net force		1 – 2
	Total	**4**

Marker's notes
At least lift and weight drawn for first diagram – 1 mark
Vector diagram consistent with first – 1 mark
Did not penalise if shape was more parallelogram as magnitudes and angles not given

Reminder vector diagrams are head to tail, with net vector from tail of first to head of last vector
There is no "throw" force and the direction of motion does not necessarily indicate the net force direction

Question 20 **(18 marks)**

(a) List one economic advantage and one environmental disadvantage of wind turbines. (2 marks)

Element	Description	Marks
Economic advantage	Low operating costs	1
Environmental disadvantage	Winds are not always constant/sufficient OR Visual and/or noise impact	1
	Total	**2**

Marker's notes
Any reasonable answers not given in text accepted

(b) The peak current flowing in a 1.5 MW turbine is 105 A, the strength of the magnetic field is 2.25 T, the coils consist of 315 turns of wire and are formed in a 30.0 cm by 42.0 cm rectangle. Using this information, show that the average power of this turbine is approximately 1.5 MW. (5 marks)

Element	Description	Marks
calculates the induced emf in the coil	$\varepsilon = 2\pi NBAf$	1
substitutes correct values	$\varepsilon = 2\pi \times 315 \times 2.25 \times (0.300 \times 0.42) \times 50$	1
calculates emf	$\varepsilon = 28055\ \text{V}$	1
uses average power formula from text	$P_{\text{avg}} = \frac{1}{2} V_p I_p$ $P_{\text{avg}} = 0.5 \times 28055 \times 105$	1
calculates power	$P_{\text{avg}} = 1.47 \times 10^6\ \text{W} = 1.47\ \text{MW}$	1
	Total	**5**

Marker's notes
When trying to prove P=1.5 MW, cannot use this value in your calculation

(c) Using Betz's law, calculate the maximum power which can be extracted from a 1.5 MW wind turbine in winds speeds of 40.0 km h^{-1} (the density of air is 1.225 kg m^{-3}). (4 marks)

Element	Description	Marks
identifies correct data	$\rho = 1.225\ \text{kg/m}^3$ $v = 40/3.6 = 11.1\ \text{m/s}$ $d = 78.0\ \text{m}$	1
calculates area of rotors	$A = \pi r^2 = \pi \times 39.0^2 = 4778\ \text{m}^2$	1

substitutes values	$P_B = \frac{8}{27}\rho v^3 A = P_B$ $= \frac{8}{27} \times 1.225 \times (11.1)^3 \times 4778$	1
calculates average power available	$P_B = 2.38 \times 10^6$ W $= 2.38$ MW	1
	Total	**4**

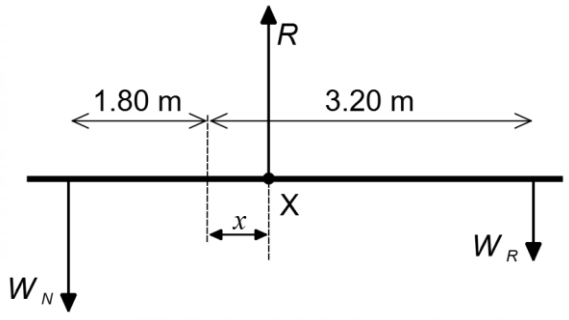
Marker's notes
2 marks awarded if incorrect area used

(d) Using your answer to part (b) and (c) calculate the utility factor of a 1.5 MW wind turbine. (Note: if you didn't calculate part (b) and/or (c) you may use an average power of 1.5 MW and an available power of 2.4 MW). (1 mark)

Element	Description	Marks
uses definition of utility factor	$\frac{P_{\text{avg}}}{P_{\text{B}}} = \frac{1.47}{2.38} = 0.618 \quad [0.625]$	1
	Total	**1**

Marker's notes
No marks awarded if expressed factor as a percentage

(e) A simplified free-body diagram of the forces acting on the nacelle and rotor assembly is shown below. By taking torques about a suitable point, calculate the location of point X in relation to the centre line of the tower. Explain what this means in relation to the stability of the assembly. (6 marks)

Element	Description	Marks
free body diagram		
writes torque equation about point X	$\tau_{\text{CW}} = \tau_{\text{ACW}}$ $W_R(3.20 - x) = W_N(1.80 + x)$	1
uses correct distances and forces in torque equation	$(25.0 \times 10^3 \times 9.8)(3.20 - x)$ $= (42.0 \times 10^3 \times 9.8)(1.80 + x)$	1
ignores reaction force R	Ignores reaction force R	1
solves for x	$7.84 \times 10^5 - 2.45 \times 10^5 x$ $= 7.4088 \times 10^5 + 4.116 \times 10^5 x$	1

	$43120 = 656600x$ $x = 0.0657$ m	
compares x to the width of the tower	point X is only 6.6 cm away from the centreline and well within the tower radius of 1.10 m	1
explains stability	since the CoG is within the base, the top assembly is stable and in equilibrium.	1
	Total	**6**

Marker's notes
Accepted using tower centre as pivot if R calculated from sum of vertical forces