Level 3 Physics: Demonstrate understanding of mechanical systems – Circular Motion - Answers

In 2013, **AS 91524** replaced **AS 90521.**

The Mess that is NCEA Assessment Schedules….

In AS 90521 there was an Evidence column with the correct answer and Achieved, Merit and Excellence columns explaining the required level of performance to get that grade. Each part of the question (row in the Assessment Schedule) contributed a single grade in either Criteria 1 (Explain stuff) or Criteria 2 (Solve stuff). From 2003 to 2008, the NCEA shaded columns that were not relevant to that question.

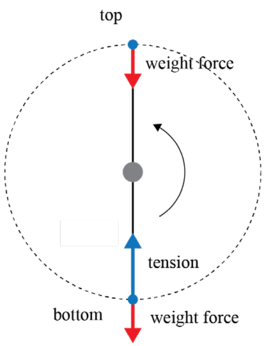
In 91524, from **2013 onwards**, each part of a question contributes to the overall Grade Score Marking of the question and there are no longer separate criteria. There is no shading anymore. There is no spoon. At least their equation editor has stopped displaying random characters over the units.

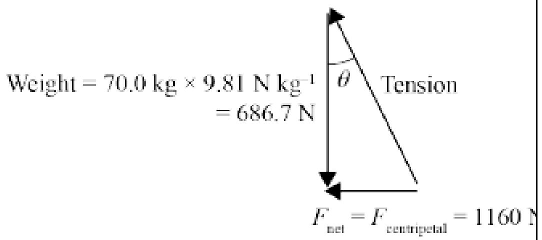
For 2019:

NØ	**N1**	**N2**	**A3**	**A4**	**M5**	**M6**	**E7**	**E8**
0	1A	2A or 1M	3A or 1A +1M or 1E-	4 A or 2A + M or 2M or 1A+1E-	1A + 2M or 1M+1E- or 3A +1M or 2A + 1E-	2A + 2M or 3M or 3A + 1E- or 1A +1M + 1E-	2M+1E- or 2A +1M + 1E- or A + 2M + 1E-	A + 2M +E

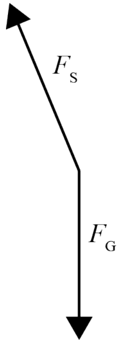
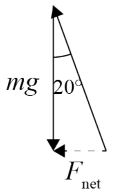
Other combinations are also possible using a=1, m=2 and e=3. However, for M5 and M6, at least one Merit question needs to be correct (maximum 6). For E7 or E8, at least one Excellence needs to be correct (maximum 8). **Note: E- and E only applies to the E7 and E8 decision. <----** It's good that NCEA gets clearer and clearer after 16 years!

Question	Evidence	Achievement	Merit	Excellence
2019(1) (c)	radius of circle = 0.700 m mass = 60.0 kg g = 9.81 ms^{-2} F_c at top at minimum speed = mg = 588.6 N $v=\sqrt{\frac{F_c r}{m}}=\sqrt{\frac{588.6\times 0.7}{60.0}}=2.62\text{ m s}^{-1}$ OR $F_c = F_g$ $\frac{mv^2}{r}=mg$ $v^2 = rg$ $v=2.62\text{ m s}^{-1}$	• F_c at top minimum speed = $F_{gravity}$. OR Attempts to calculate speed correctly but with incorrect F_c.	• Correct working and answer.	

(d)	• The weight force is constant and downward at all points in the motion. • At the bottom, tension is upward and much larger than the weight force, as the tension must overcome the weight force to provide an upward centripetal force. • At the top, the tension will be zero. At the top, the F_c is provided entirely by the weight force, since Chris is travelling with the minimum possible speed.  	• Weight force drawn or described as constant and downward at both top and bottom points. OR Tension force drawn bigger than the downwards weight force at the bottom. OR Equation stated for $F_c = F_T - F_w$ (bottom) OR Equation stated for $F_c = F_w$ (top)	• Tension force drawn or described as larger than weight force at bottom and non-existent at the top. OR Stating that $F_c = F_T - Fw$ (bottom) AND $F_c = F_w$ (top).	• Forces correctly identified and described, with justifications in relation to the centripetal force and minimum speed with diagram included. (E) • Forces correctly identified and described, with justifications in relation to the centripetal force and minimum speed without diagram. (E–)

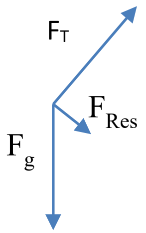
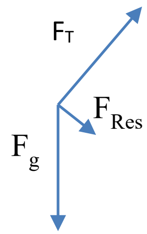
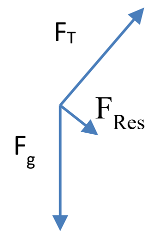
2019(3) (d)	$F_c = \frac{mv^2}{r} = \frac{70.0\text{ kg} \times (2.61\text{ m s}^{-1})^2}{0.411\text{ m}} = 1160\text{ N}$  $F_{tension}{}^2 = 686.7^2 + 1160^2$ $F_{tension} = 1348\text{ N} = 1350\text{ N}$ $\theta = \tan^{-1}\frac{1160\text{ N}}{686.7\text{ N}} = 59.34°$ from vertical *(Accept 1.04 radians as angle also)*	• Calculates $F_{centripetal}$(1160N) OR • Recognises $F_{net} = F_{centripetal}$.	• Correct labelled vector diagram. OR • Calculates the Tension force only correctly. OR • Tension force wrong but θ correct.	• Tension magnitude and angle from vertical. (E) • Tension magnitude and angle calculated with calculator in radians mode (giving the angle as being 1.04 but given degrees as unit. (E–)
2018(1) (a)	$F = \frac{GMm}{r^2}$ $F = \frac{6.67\times10^{-11}\times5.97\times10^{24}\times150.0}{(6.37\times10^6+5.00\times10^5)^2} = 1265.5\text{ N}$ $= 1270\text{ N (3 sf)}$	Correct WORKING (Note, NOT answer as this is a SHOW question).		
(b)	$\frac{GMm}{r^2} = \frac{mv^2}{r}$ $v = \sqrt{\frac{GM}{r}} = 7.613\times10^3\text{ m s}^{-1} = 7.61\times10^3\text{ m s}^{-1}$ (3 sf) Please accept the following answer due to the error in the formula v = 3.82 x 10^{-8} m s^{-1} (Using m as the mass of the satellite.)	Equates gravitational force and centripetal force. (Accept $F_c = F_g$) OR Calculates the velocity using the given formula in the question.	Equates gravitational force and centripetal force. (Accept $F_c = F_g$) AND Calculates the velocity using the given formula in the question.	

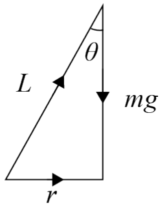
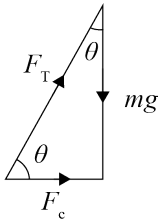
2017(1) (d)	$F_g = \frac{GmM}{r^2}$ $F_c = \frac{mv^2}{r}$ $v = \frac{d}{t} = \frac{2\pi r}{T}$ $\frac{GmM}{r^2} = \frac{mv^2}{r}$ $\frac{GM}{r} = \frac{v^2}{1} = \frac{4\pi^2 r^2}{T^2}$ $M = \frac{4\pi^2 r^3}{GT^2} = \frac{4\times\pi^2\times((351+5220)\times10^3)^3}{6.67\times10^{-11}\times(5.46\times10^3)^2}$ $M = 3.43\times10^{24}$ kg OR $mg = \frac{mv^2}{r}$ $g = a_c$ $a_c = \frac{v^2}{r}$ and $v = \frac{2\pi}{r}$ $a_c = \frac{4\pi^2 r}{t^2} = \frac{4\pi^2 r((351+5220)\times10^3)}{(5.46\times10^3)^2}$ $a_c = 7.38$ m s^{-2} and thus local $g = 7.38$ m s^{-2} $g = \frac{GM}{r^2}$ $M = \frac{gr^2}{G} = \frac{7.38((351+5220)\times10^3)^2}{6.67\times10^{-11}}$ $M = 3.43\times10^{24}$ kg As the spaceship approaches the planet, it loses gravitational potential energy and gains kinetic energy. This causes the linear speed to increase. OR As the spaceship approaches the planet, the gravitational force increases between them. This results in the planet pulling the spaceship closer to the planet. The increase in the gravitational pull from the planet will cause an increase in the linear speed of the spaceship. (The gravitational force on the spaceship has a component in the direction of travel; this will increase the linear speed.)	Combines F_g and F_C. OR States that gravity supplies the centripetal force. OR Uses F_g, F_c and $v = \frac{2\pi r}{T}$ to attempt to make M the subject of the formula. OR Calculates v correctly as 6410 m s^{-1}. OR Candidate recognises that this is an Energy Change situation. OR Candidate recognises that gravitational force is increasing.	Error in the calculation. e.g.: forgot to square T or π or cube r or add orbital radius while substituting. OR Algebraically makes M the subject of the formula correctly. OR calculates local g = 7.38 m s^{-2} OR (Two ideas linked) e.g.: As the spaceship approaches the planet, it loses gravitational potential energy and gains kinetic energy. OR (Two ideas linked) e.g.: As the spaceship approaches the planet, the distance will decrease. This will cause an increase in the size of the gravitational pull on the spaceship. OR The gravitational force on the spaceship has a component in the direction of travel; this will increase the speed.	Correct calculation and correct answer for the mass with unit. (E) OR Complete correct explanation with links. (E). Correct calculation and correct answer for the mass without unit. (E-) OR Complete explanation with links accepted with minor errors (E-) For instance, the candidate has said “speed” and not “linear speed”; both linear and rotational speeds exist here.

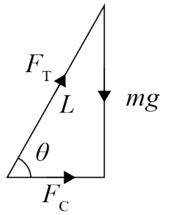
2016(1) (a)	 	• support force • reaction force • normal force • normal reaction force (Do not accept lift or tension force) OR • gravity force • weight force	Correct answer.	
(b)	 $\tan 20 = \frac{F_c}{mg}$ $F_c = mg \tan 20$ $F_c = 960 \times 9.81 \times \tan 20$ $F_c = 3430$ N	Correct diagram. OR Correct calculation and answer. OR Calculates F_c correctly but using **g** = 9.8 m s^{-2} not 9.81 m s^{-2}. (F_c = 3420 N)	Correct diagram AND Correct calculation and answer.	
(c)	At Position A there is no acceleration so the force from the track equals the gravity force. At Position B, the car is moving in a vertical circle. So the car is accelerating upwards, so the force from the track is greater than the gravity force. OR At B the car is moving in a vertical circle, so it is accelerating up, so the force the track exerts at B is bigger than that at A.	Complete answer for Position A *(Accept the force from the track equals the gravity force)* OR Complete answer for Position B *(Accept the force from the track is greater than the gravity force)* OR Partial explanation for both positions.	Complete answer with links between concepts.	

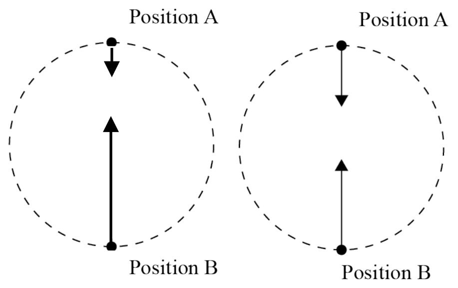
(d)	$a_c = \frac{v^2}{r} = 9.81$ $v^2 = 9.81 \times 5.0$ $v = 7.00 \text{ m s}^{-1}$ $mgH = \frac{1}{2}mv^2 + mg \times 2R$ $H = \frac{\frac{1}{2}v^2 + (g \times 2R)}{g} = \frac{\frac{1}{2}7.00^2 + (9.81 \times 2 \times 5)}{9.81} = 12.5$	Recognises that gravitational potential energy (GPE) at the top is equal to GPE + E_k at the top of the loop. OR Recognises that a_c = 9.81.	Calculates speed OR Calculates *H* correctly but with incorrect speed.	Correct calculation and correct answer. (E) Note: Accept 7.5 m for correct working if *mgR* is used instead of *mg2R* for (E–).
2015(1) (a)	The force is weight / the force of gravity / gravitational force acting towards the centre of the Earth	Gravitational / weight / gravity force acting towards the (centre of the) Earth. *(Accept radial or towards the earth)*		
(b)	$F_g = \frac{GMm}{r^2} = \frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24} \times 300}{(4.22 \times 10^7)^2}$ $= 67.1 \text{ N}$	F_g = 67.1 N		

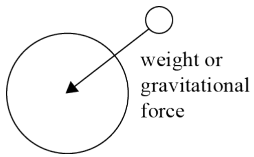
(c)	Gravitational force must be equal to the centripetal force required at that radius so $F_g = F_c$ $\frac{mv^2}{r} = \frac{GMm}{r^2}$, so $v = \sqrt{\frac{GM}{r}}$ $v = \sqrt{\frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{4.22 \times 10^7}}$ m s^{-1} $v = 3070$ m s^{-1} OR $F_g = F_c = 67.1$ N from (b), $F_c = \frac{mv^2}{r}$ so $v = \sqrt{\frac{F_c r}{m}} = \sqrt{\frac{67.1 \times 4.22 \times 10^7}{300}}$ $= 3070$ m s^{-1} OR The satellite is in geostationary orbit, so must take 24 hours (86 400 s) to complete one orbit $v = \frac{2\pi r}{T} = \frac{2\pi \times 4.22 \times 10^7}{24 \times 60 \times 60} = 3070$ m s^{-1}	The gravitational force provides a centripetal force so $F_c = F_g$ (or use of $\frac{mv^2}{r} = \frac{GMm}{r^2}$) OR $v = \sqrt{\frac{GM}{r}}$ OR $v = \sqrt{\frac{F_c r}{m}}$ OR The satellite is in geostationary orbit so must take 24 hours (86400 s) to complete one orbit (or use of $v = \frac{2\pi r}{T}$)	Use of $v = \sqrt{\frac{GM}{r}}$ to prove $v = 3070$ m s^{-1} OR $v = \sqrt{\frac{F_c r}{m}} = \sqrt{\frac{67.1 \times 4.22 \times 10^7}{300}}$ $= 3070$ m s^{-1} *(allow M for follow on error carried forward for F_c from (b))* OR Use of $v = \frac{2\pi r}{T}$ to prove $v = 3070$ m s^{-1}	
(d)	Using $F_c = \frac{mv^2}{r}$ *and* $F_g = \frac{GmM}{r^2}$: $F_g = F_c$ so $\frac{GmM}{r^2} = \frac{mv^2}{r}$ Using $v = \frac{2\pi r}{T}$: $v^2 = \frac{4\pi^2 r^2}{GT^2}$ Combining: $T^2 = \frac{4\pi^2 r^3}{GM}$ so $T^2 = \frac{4\pi^2}{GM} r^3$ To find the mass of the Moon: $M = \frac{4\pi^2 r^3}{GT^2}$ $M = \frac{4\pi^2 \times (1.79 \times 10^6)^3}{6.67 \times 10^{-11} \times (6.78 \times 10^3)^2} = 7.38 \times 10^{22}$ kg	Uses F_g, F_c and $v = \frac{2\pi r}{T}$ to attempt to prove $T^2 \propto r^3$.	Uses F_g, F_c and $v = \frac{2\pi r}{T}$ to prove $T^2 \propto r^3$.	Uses F_g, F_c and $v = \frac{2\pi r}{T}$ to prove $T^2 \propto r^3$. AND Calculates the mass of the moon, correctly, as being 7.38×10^{22} kg

2014(2) (b)	Tension and gravitational force add to make the  restoring force towards the equilibrium. The bob is stationary at point of release. This restoring force makes the bob speed up from as it goes towards the middle. The restoring force decreases and goes to zero as the bob goes to the middle, so the acceleration decreases to zero and the bob has constant speed at the equilibrium position. *Accept F_{res} horizontal*	Gravitational and tension forces identified. Force is towards the equilibrium position. OR Force proportional to displacement OR At equilibrium no force AND at end points maximum force. At release point *v* = 0, and at equilibrium *v* is maximum. OR Speeds up / accelerates as it goes towards the centre. *MAXIMUM 2As* *Accept net /total / restoring force in place of force, but not gravitational force or tension force.*	 OR Idea of direction of tension and gravitational force (either stating the directions or saying they don't cancel, or correct ideas of components) OR (F_{res} towards equilibrium SO that bob speeds up / accelerates. AND Restoring force decreases so acceleration decreases OR At equilibrium no F_{res} so constant speed / no acceleration.) *Accept net force /total force in place of restoring force.*	 OR Idea of direction of tension and gravitational force (either stating the directions or saying they don't cancel, or correct ideas of components).) AND F_{res} towards equilibrium SO that bob speeds up / accelerates. AND Restoring force decreases so acceleration decreases OR At equilibrium no F_{res}, so constant speed/no acceleration. *Accept net force /total force in place of restoring force.*

(c)(i)	  $r = 0.290$ m $L = 1.55$ m $\sin\theta = \frac{r}{L} = \frac{0.290}{1.55}$ $\Rightarrow \theta = 10.78°$ or 0.188 rad $F_g = mg$ $= 1.8 \times 9.81$ $= 17.658$ $F_t = \frac{F_g}{\cos\theta}$ $\frac{1.8 \times 9.81}{\cos 10.78} = 17.975$ N ***ALERT:*** $\theta \; \tan^{-1}\left(\frac{0.29}{1.55}\right) \; 10.59$ *is wrong answer*	Correct angle OR Find F_g = 17.658 and use INCORRECT angle to find F_T	Correct tension force showing working for correct angle. AND evidence of correct trig used. $F_T = \frac{F_g}{\cos\theta}$ AND F_g = 17.658 or evidence of mg used.	

(ii)	$\cos\theta = \frac{F_C}{F_T} = \frac{0.290}{1.55}$ $\Rightarrow F_C = \frac{0.290 \times 17.975}{1.55} = 3.3631$ $F_C = \frac{mv^2}{r} \Rightarrow v = \sqrt{\frac{3.3631 \times 0.290}{1.8}} = 0.7361$ $v = 0.74 \text{ m s}^{-1}$ 	Obtain F_c as number or equation Eg $F_c = F_g\tan\vartheta$ or $F_c = F_T\sin\vartheta$ or $F_c = \sqrt{F_T^2 - F_g^2}$ **OR** Uses $F_c = \frac{mv^2}{r}$ to find v with wrong F. *Follow on error accepted.*	(Evidence of use of trig or Pythagoras in attempt to get F_c AND uses $F_c = \frac{mv^2}{r}$ to find v (E.g. mistakes – doesn't use square root, uses wrong trig or sin in Pythagoras, or re-arrange incorrectly)) OR Correct answer with insufficient working *Follow on error accepted.*	Some working shown ($F_c = \frac{mv^2}{r}$ plus correct trig or pyth) and consistent answer and unit. *Follow on error accepted.*
2013(2) (a)	$F_c = \frac{mv^2}{r} = \frac{0.250 \times 4.00^2}{1.20} = 3.33 \text{ N}$	Correct answer OR correct working (equation and substitution)		
(b)	The total amount of kinetic and gravitational potential energy of the ball is conserved. As the ball goes down the gravitational potential energy is changed into kinetic energy. At the bottom of the circle the ball has the least gravitational energy, so it has the greatest amount of kinetic energy; therefore it must be moving fastest here.	Maximum/high speed linked to maximum/high kinetic energy. Gravitational force/weight has sped the ball up as it goes down Centripetal force/Net force is greater at the bottom, so velocity is higher Gravitational potential energy at the top is converted to kinetic energy. OR Statement of conservation of energy and mentions GPE and KE.	Gravitational potential energy at the top is CHANGED into kinetic energy at the bottom so it goes faster. OR Energy is conserved. At the bottom the gravitational potential energy is the smallest, so the kinetic energy is the largest, therefore it goes faster at this point. There is a tangential force which accelerates the ball as it goes down	

(c)		THREE vectors in correct directions. (Tension in correct directions, larger at the bottom. OR Centripetal force in correct directions, larger at the bottom).	All vectors in correct directions and (tension OR centripetal force) shown as larger at bottom.	All vectors in correct directions AND - tension larger at bottom than top - centripetal force larger at bottom than top - centripetal force at top is larger than tension or gravity - centripetal force at bottom is smaller than tension force at the bottom.
(d)	SHOW THAT QUESTION At the top of the circle, where the speed is least, the centripetal force is the sum of the gravity force and the tension force. The minimum centripetal force is therefore when the tension force is zero and so the centripetal force is provided by the gravity force. $F_g = F_c \rightarrow mg = \frac{mv^2}{r}$ $v = \sqrt{rg} = \sqrt{1.2 \times 9.81}$ $= 3.4310 = 3.43 \text{ m s}^{-1}$ Note: Use of $T = 2\pi\sqrt{\frac{l}{g}}$ No credit. Note: Be cautious of working – F_c=9.81 gives 6.86, which then students divide by 2 to get 3.43. This is not worth M. Check to see if they have achieved points.	Equates Fg to Fc (words, symbols or equations, Fc=9.81×0.25 is sufficient) Tension force is zero Rearranges $F_c = \frac{mv^2}{r}$ to get *v*. Uses equation $v = \sqrt{rg}$ to get correct speed. Note: Accept g = 9.81 or 9.8 or 10	Only force acting is the gravitational force OR gravitational force IS the centripetal force OR tension force=0 therefore centripetal force = gravitational force Some correct working shown (equation OR substitution). Use of $a_c = \frac{v^2}{r}$ okay.	Correct working (equation AND substitution). AND Gravitational force IS the centripetal force. OR tension force = 0, therefore centripetal force = gravitational force. Note: stating $F_c = F_g$ is not the same as F_c IS F_g.

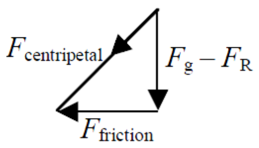
(e)	SHOW THAT QUESTION $E_k(\text{top}) = \frac{1}{2}mv^2$ $= \frac{1}{2} \times 0.25 \times 3.4310^2 = 1.4715\text{ J}$ $E_k(\text{position shown}) = \frac{1}{2}mv^2$ $= \frac{1}{2} \times 0.25 \times 34.00^2 = 2.00\text{ J}$ $\Delta E_k = \Delta E_{p\,grav} = 2.00 - 1.4715 = 0.5285\ J$ $\Delta E_{p\,grav} = mg\Delta h$ $0.5285 = 0.250 \times 9.81 \times \Delta h$ $\Delta h = \frac{0.250 \times 9.81}{0.5285} = 0.2155\text{ m}$ $\cos\theta = \frac{(1.2 - 0.2155)}{1.2}$ $\theta = 34.8740 = 34.9°$	Either E_K calculated (at position shown (2J) or at top (1.41715 J)) Correct E_{Pgrav} at top (from middle of circle = 2.943 J or from bottom of circle 5.886 J) OR Difference in E_{Pgrav} = 0.5285 J	A correct height – (0.2155 from top, or 0.9835 from middle or 2.1835 from bottom). Note: Doesn't have to explain where this is measured from A height using E_{Pgrav} = 2 J (0.815 m) or E_{Pgrav} = 1.47 J (0.599 m) is not acceptable.	Correct working – Some evidence of E_{pgrav} and E_K equations used and trig used.
2011(3) (a)		[1]Correct single force vector with correct label.		
(b)	$F_g = \frac{GMm}{r^2}$ $= \frac{6.67 \times 10^{-11} \times 5.974 \times 10^{24} \times 1.08 \times 10^3}{((0.636 + 2.02) \times 10^7)^2}$ $= 610\text{ N}$	[2]Correct answer consistent with radius of earth not added. OR Correctly substituted equation.	[2]Correct answer.	

(c)	$F = \frac{mv^2}{r}$ $600.2 = \frac{1080v^2}{2.66 \times 10^7}$ $v^2 = 1.498 \times 10^7$ $v = 3\,870 \text{ m s}^{1}$ $v = \frac{2\pi r}{T}$ $3070 = \frac{2\pi \times 2.66 \times 10^7}{T}$ $T = 43\,182 \text{ s}$ $T = \frac{43\,182}{(60 \times 60 \times 24)}$ $T = 0.500 \text{ days}$	[2]Correct velocity.	[2]Correct period in seconds. OR Correct period in hours consistent with incorrectly calculated velocity.	[2]Calculated period compared with 12 hours.
(d)	• Gravitational force must be equal to the Centripetal force required at that radius. • Centripetal acceleration of any object must equal the acceleration due to gravity at that radius, regardless of its mass. $F = \frac{mv^2}{r} = \frac{GMm}{r^2}$ $v^2 = \frac{GM}{r}$ but $v = \frac{2\pi r}{T}$ so $\left(\frac{2\pi r}{T}\right)^2 = \frac{GM}{r}$ $r^3 = \frac{GM}{4\pi^2} \times T^2$	[1]$F_g = F_C$ plus reason why mass has no effect. [2]Correct formula for v^2.	[1]Correct formula for v^2 plus reason why mass has no effect. [2]Correct relationship developed.	[1]Correct relationship developed plus reason why mass has no effect.

(e)	For a satellite to be geostationary, it must orbit in the direction of the Earth's rotation, in the plane of the equator, and with an orbital period of one Earth day.	[1]Satellites must have this orbital period to be geostationary.	[1]Achievement plus either same direction or above the equator.	
2009(1) (a)	**THIS IS A SHOW QUESTION** $L_v = mg = 635 \times 9.81 = 6229.35$ N	[2]Correct working.		
(b)	Resultant = 6229.35 × tan 22.5 = 2580 N to the left or center of circle or inwards	[2]Correct size R = 2580 N **OR** Direction to the left	[2]Correct answer. **Size and direction.** Resultant = 2580.28N Direction to the left	
(c)	$F_c = ma = 635 \times 2.5 = 1587.5$ N $\tan\theta = ma/mg = 0.25$ $\tan\theta = 1587.5/6230 = 2.5/9.81 = 0.25$ $\theta = 14.3°$			[2]Correct answer. $\theta = 14.297°$ *Watch 14.8 – wrong*

(d)	To move in a circle at a constant speed, the plane needs a centripetal force. This must be an unbalanced force that acts at right angles to the velocity of the plane. This can only be provided by the horizontal component of the lift force. There is no other way that the plane can get a horizontal force, none of the other forces that act on the plane do this. (The propeller makes it go forward, friction drags it back, weight pulls it down.)	[1]Gives requirements for circular motion: E.g.: Centripetal force unbalanced force resultant horizontal component of the lift force $F = mv^2/r$	[1]The tilt gives the horizontal component of the lift force which provides the centripetal force or unbalanced force or resultant or mv^2/r **OR** (They do not mention centripetal force but give a correct direction for it.) E.g.: The tilt gives the horizontal component of the lift force which points towards the centre left at right angles to the velocity.	[1]Merit plus Discusses the effect of one other force E.g.: drag/friction weight thrust **OR** The tilt gives the horizontal component of the lift force which provides the centripetal force or unbalanced force or resultant or mv^2/r **AND** The direction of the centripetal force. centre left at right angles to the velocity.
2008(4) (a)	$F = \frac{GMm}{r^2} = \frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24} \times 3.0 \times 10^{-3}}{\left[(6.38 + 0.35) \times 10^6\right]^2}$ $= 2.6 \times 10^{-2}$ N (= 2.63749×10^{-2} N) Watch for 0.029348N **(N)**	[2]Correct radius used (6.73×10^6 m)	[2]Correct answer.	

(b)	For a stable orbit **(1)** centripetal force = gravitational force (**Stability)** (2) $\frac{mv^2}{r} = \frac{GMm}{r^2}$ (**mass**) *m*'s cancel so orbit speed is independent of mass (3) acceleration due to gravity is independent of mass, so the two objects so both (free) fall at same rate towards Earth - so they stay together (**mass**) (4) $v^2 = \frac{GM_{\text{Earth}}}{r}$ or $v^2 \alpha \frac{1}{r}$ so same radius gives same velocity (**Same Velocity**)	[1]Uses: (1) Stability argument OR Explains why speed is constant, e.g. There is no friction. Force of gravity is at right angles to velocity.	[1]Uses: (2) or (3) Mass argument made OR (4) Same velocity argument.	[1]Uses: (4) Same velocity argument AND Mass argument (2) or (3)
2006(2) (a)	The force is the gravitational force and it acts towards the centre of the earth.	[1]Both correct answers		
(b)	$F_g = mg = \frac{GMm}{r^2}$ $\Rightarrow$ $g = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{(7.00 \times 10^6)^2}$ = 8.14012 = 8.14 N kg^{-1}	[1]Answer given to 3 sf plus 5 correct units given. (cannot be 3c unit).	[2]Correct answer.	

(c)	The reaction force of the shuttle on the astronaut gives them the sensation of weight. Because the astronaut and shuttle are falling freely in the gravitational field towards the earth, there is no reaction force of the shuttle on the astronaut and so the astronaut feels no apparent weight.		[1]Idea of astronaut falling freely towards Earth in the gravitational field.	[1]Explanation is clear and accurate and links the fact that the shuttle and astronaut are both accelerating freely towards the earth, and there are no forces between them.
(d)	$F_c = \frac{GMm}{r^2} = \frac{mv^2}{r}$ $v = \frac{d}{t} = \frac{2\pi r}{T}$ $v = 2 \times \pi \times 9.38 \times 10^6 \div 27\ 600 = 2135.37$ $M = \frac{v^2 r}{G}$ $= 2135.37^2 \times 9.38 \times 10^6 \div 6.67 \times 10^{-11}$ $= 6.412439 \times 10^{23}$ $= 6.41 \times 10^{23}$ kg	[1]Recognition that the centripetal force is provided by the gravitational force **OR** Recognition of how to calculate the tangential speed.	[2]Calculation of speed **AND** Recognition that the centripetal force is provided by the gravitational force.	[2]Correct answer.
2005(1) (a)	$F = \frac{mv^2}{r} = \frac{1.0 \times 10^4 \times 0.26^2}{68} =$ 9.94118 N **9.9 N**	Correct answer		
(n)		Recognition that gravity and another force contribute to the centripetal force.	Diagram shows the gravity force and another force combining to give a centripetal force that acts towards the centre of the wheel.	The "other" force is recognised to be friction acting on the person's feet.