



**A2 Physics Exam Packs**

**Circular Motion**

Name:

Form:

Question	Mark

- 2 (a) Fig. 2.1 shows the London Eye.

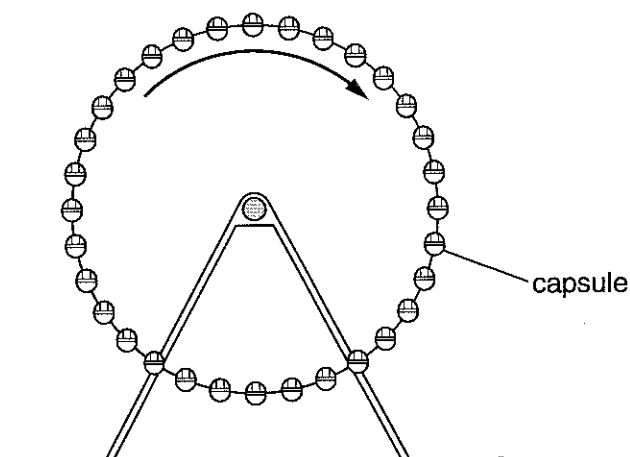


Fig. 2.1

It has 32 capsules equally spaced around the edge of a large vertical wheel of radius 60 m. The wheel rotates about a horizontal axis such that each capsule has a constant speed of  $0.26 \text{ ms}^{-1}$ .

- (i) Calculate the time taken for the wheel to make one complete rotation.

time = ..... s [1]

- (ii) Each capsule has a mass of  $9.7 \times 10^3 \text{ kg}$ . Calculate the centripetal force which must act on the capsule to make it rotate with the wheel.

centripetal force = ..... N [2]

- (b) Fig. 2.2 shows the drum of a spin-dryer as it rotates. A dry sock **S** is shown on the inside surface of the side of the rotating drum.

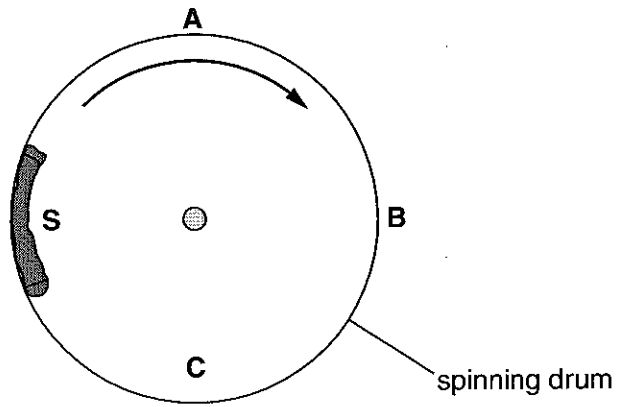


Fig. 2.2

- (i) Draw arrows on Fig. 2.2 to show the direction of the centripetal force acting on **S** when it is at points **A**, **B** and **C**. [1]
- (ii) State and explain at which position, **A**, **B** or **C** the normal contact force between the sock and the drum will be

1 the greatest

.....

.....

.....

..... [2]

2 the least.

.....

.....

..... [1]

[Total: 7]

Question	Expected Answers	Marks	Additional guidance		
2	a	i	$(v = 2\pi r/t)$ $t = 2\pi 60/0.26 = \mathbf{1450}$ s	B1	Correct answer is 1449.96 hence allow 1.4 X 10 <sup>3</sup> Do not allow a bare 1.5 x 10 <sup>3</sup>
		ii	(ii) correct substitution into $F = mv^2/r$ : eg $F = (9.7 \times 10^3 \times 0.26^2)/60$ $F = \mathbf{10.9}$ N	C1 A1	Allow 11 N
	b	i	THREE correct arrows at A, B and C all pointing towards the centre (judged by eye)	B1	Ignore starting point of arrow
		ii	1. Greatest reaction force is at C because it supports weight of sock AND provides the required upward resultant (centripetal) force (WTTE) 2. Least at A because sock's weight provides part of the required downward resultant (centripetal) force (WTTE)	M1 A1 B1	This is a mandatory M mark. The second mark cannot be gained unless this is scored. Any indication that candidates think that the centripetal force is a third force loses this second and possibly the next mark. They must make correct reference to the resultant force that provides the required centripetal force/acceleration. Allow answers using the equation $F = mv^2/r$ such as $N_c - mg$ (at C) = centripetal force OR $mv^2/r$ OR $mg + N_A$ (at A) = centripetal force OR $mv^2/r$
		Total		7	

Question	Expected Answers	Marks	Additional guidance		
3	a		arrows (at least one) indicating direction is towards the planet. All lines looking as though they would meet at the centre judged by eye	B1 B1	At least 4 drawn and care taken Some of the lines must be outside the planet.
	b	i	( $mg = GMm/r^2$ and hence) $M = gr^2/G$ correct substitution $M = 24.9 \times (7.14 \times 10^7)^2 / 6.67 \times 10^{-11}$ $= \mathbf{1.9 \times 10^{27}}$ Kg (ie about $2 \times 10^{27}$ )	C1 M1 A1	Equation needs to be rearranged as shown for C1 mark
		ii	correct substitution into $V = (4/3)\pi r^3 = (4/3)\pi (7.14 \times 10^7)^3$ {= $1.52 \times 10^{24}$ m <sup>3</sup> } density = mass/volume = $1.9 \times 10^{27} / 1.52 \times 10^{24} = \mathbf{1250}$ Kg m <sup>-3</sup>	C1 A1	If $m = 2 \times 10^{27}$ Kg is used $d = 1312$ scores 2 marks
		Total		7	

- 2 (a) Fig. 2.1 shows an aeroplane flying in a horizontal circle at constant speed. The weight of the aeroplane is  $W$  and  $L$  is the lift force acting at right angles to the wings.

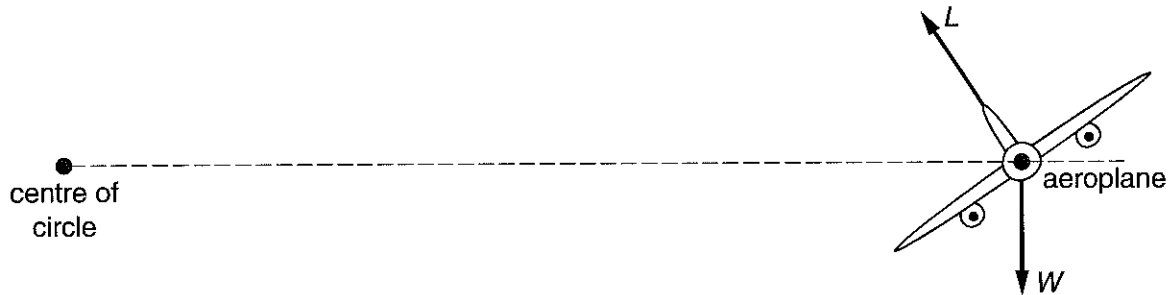


Fig. 2.1

- (i) Explain how the lift force  $L$  maintains the aeroplane flying in a **horizontal** circle.

.....

.....

.....

..... [2]

- (ii) The aeroplane of mass  $1.2 \times 10^5 \text{ kg}$  is flying in a horizontal circle of radius 2.0 km.

The centripetal force acting on the aeroplane is  $1.8 \times 10^6 \text{ N}$ . Calculate the speed of the aeroplane.

speed = .....  $\text{ms}^{-1}$  [2]

- (b) Fig. 2.2 shows a satellite orbiting the Earth at a constant speed  $v$ . The radius of the orbit is  $r$ .

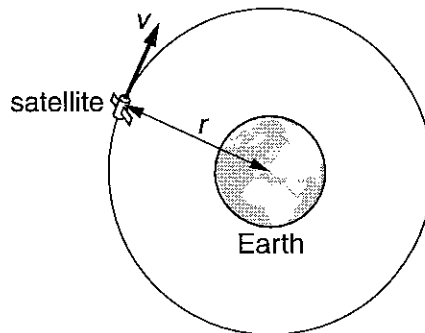


Fig. 2.2

Question	Expected Answers	Marks	Additional guidance
2 (a) (i)	Horizontal component of L provides the centripetal force (WTTE) Vertical component of L balances the weight (WTTE)	B1 B1	
(a) (ii)	$F = mv^2/r$ correct rearranged into $v = \sqrt{(Fr/m)}$ $v = \sqrt{(1.8 \times 10^6 \times 2000 / 1.2 \times 10^5)} = 173 \text{ m s}^{-1}$ (or 170)	C1 A1	Allow correct substitution of values into $F = mv^2/r$ for C1 mark
(b)	$mv^2/r = GMm/r^2$ $T = 2\pi r/v$ Correct manipulation of equations to give $T^2 = \frac{4\pi^2 r^3}{GM}$	B1 M1 A1	Do not allow a bare $v^2 = GM/r$ for the first mark – we need to see where this has come from.
(c) (i)	<b>Equatorial orbit (WTTE) (QWC mark)</b> Period is 24h/1day/same as Earth <b>OR</b> moves from West to East (WTTE)	B1 B1	QWC equatorial or <u>equator</u> must be spelled correctly
(c) (ii)	Correct rearrangement of $T^2 = (4\pi^2 r^3/GM)$ to give $r^3 = T^2 GM/4\pi^2$ correct sub. $r^3 = \{6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times (8.64 \times 10^4)^2\} / 4\pi^2 = 7.57 \times 10^{22}$ $r = 4.23 \times 10^7 \text{ m}$ (or 4.2 or 4.3 x 10 <sup>7</sup> )	C1 C1 A1	(1 day = 8.64 x 10 <sup>4</sup> s is given on the data sheet). For those who use $g = GM/r^2$ with $g = 9.81$ award 1 mark for $r = 6.4 \times 10^6 \text{ m}$ .
	Total	12	

(c) The jet plane describes a **horizontal** circle of radius 870m flying at a constant speed of  $120\text{ms}^{-1}$ .

(i) State the direction of the resultant horizontal force acting on the plane.

..... [1]

(ii) Calculate the magnitude of this horizontal force.

force = .....N [2]

(d) By changing the velocity of the plane it can be made to fly in a **vertical** circle of radius 1500m. At a particular point in the vertical circle, the contact force between the pilot and his seat may be zero and the pilot experiences "weightlessness".

(i) State and explain at what point in the circle this weightlessness may occur.

.....  
.....  
.....  
..... [2]

(ii) Calculate the speed of the plane at which weightlessness occurs.

speed = .....  $\text{ms}^{-1}$  [2]

[Total: 14]

Q1	Expected Answers	Marks	Additional guidance
(a)(i)	A body will remain at rest or continue to move with constant velocity unless acted upon by a force (W/TTE)	B1	Do not allow speed unless "speed in a straight line" is stated. Allow "uniform motion"
(a)(ii)	The force which gives a mass of 1 kg an acceleration of $1 \text{ m s}^{-2}$	B1	Allow $1\text{N} = 1 \text{ kg m s}^{-2}$
(b)(i)	Use of $v = u + at$ OR $a = (v - u) / t \Rightarrow a = (55 - 0) / 2.2$ $a = 25 \text{ (m s}^{-2}\text{)}$	C1 A1	
(b)(ii)	Use of $s = ut + \frac{1}{2}at^2$ e.g. $s = 0 + \frac{1}{2} \times 25 \times 2.2^2$ $s = 60.5 \text{ (m)}$	C1 A1	Allow other valid solutions e.g. using $v^2 = u^2 + 2as$
(b)(iii)	$F = ma = 3.2 \times 10^4 \times 25 = 8.0 \times 10^5 \text{ (N)}$	A1	Allow ecf from (b)(i)
(c)(i)	towards the centre of the circle.	B1	Do not allow a bare "perpendicular to the velocity" Do not allow "in the same direction as the acceleration."
(c)(ii)	use $F = mv^2/r$ e.g. $F = (3.2 \times 10^4 \times 120^2) / 870$ $F = 5.3 \times 10^5 \text{ (529655) (N)}$	C1 A1	If 55 is used instead of 120 for the velocity $F = 1.1 \times 10^5 \text{ ms}^{-1}$ and scores 1 mark
(d)(i)	At top of the circle when the weight provides/equals the required centripetal force	M1 A1	Allow "when the resultant force = weight"
(d)(ii)	realisation that $\text{acc} = g$ (OR 9.81) AND (hence) $v^2/r = g$ { $v = \sqrt{gr}$ } $= \sqrt{(9.81 \times 1500)}$ $\Rightarrow v = 120 \text{ (m s}^{-1}\text{)}$ (121.3)	M1 A1	Accept 121.24 as this corresponds to 9.8, do not allow 122.5 since this assumes $g = 10 \text{ ms}^{-2}$
<b>Total</b>		<b>14</b>	



- 2 (a) (i) State, in terms of force, the conditions necessary for an object to move in a circular path at constant speed.

.....  
..... [1]

- (ii) Explain why this object is accelerating. State the direction of the acceleration.

.....  
..... [2]

- (b) A satellite moves in a circular orbit around the Earth at a constant speed of  $3700 \text{ m s}^{-1}$ .

The mass  $M$  of the Earth is  $6.0 \times 10^{24} \text{ kg}$ .

Calculate the radius of this orbit.

radius = ..... m [4]

- (c) In order to move the satellite in (b) into a new smaller orbit, a decelerating force is applied for a brief period of time.

- (i) Suggest how the decelerating force could be applied.

.....  
..... [1]

- (ii) The radius of this new orbit is  $2.0 \times 10^7 \text{ m}$ . Calculate the speed of the satellite in this orbit.

speed = .....  $\text{m s}^{-1}$  [2]

[Total: 10]

Question	Expected Answers	Marks	Additional guidance
2 (a)(i)	resultant OR net OR overall force acts (on object) perpendicular to the velocity OR towards the centre of the circle	B1	Ignore any reference to "centripetal force"
(a)(ii)	velocity OR direction is always changing acceleration is in direction of force OR is towards the centre/perp. to velocity	B1 B1	Allow a (resultant) force is acting (hence there is an acceleration))
(b)	centripetal force OR $mv^2/r = GMm/r^2$ OR $v^2/r = GM/r^2$ $v^2 = GM/r \Rightarrow r = GM/v^2$ $r = 6.67 \times 10^{-11} \times 6 \times 10^{24} / 3700^2$ $r = \mathbf{2.92 \times 10^7 \text{ m}}$	C1 C1 C1 A1	
(c)(i)	Any mass ejected in the same direction as the satellite (WTTE)	B1	Idea of rocket motor pushing against direction of motion of satellite.
(c)(ii)	$v^2 r = \text{constant}$ OR $v^2 = GM/r$ OR $v = \sqrt{\{(6.67 \times 10^{-11} \times 6 \times 10^{24}) / 2 \times 10^7\}}$ new $v = \sqrt{\{3700^2 \times 2.94 / 2\}} = \mathbf{4500 \text{ m s}^{-1}}$ (44/3)	C1 A1	
	<b>Total</b>	<b>10</b>	

- 3 Fig. 3.1 shows apparatus used to investigate circular motion. The bung is attached by a continuous nylon thread to a weight carrier supporting a number of slotted masses which may be varied. The thread passes through a vertical glass tube. The bung can be made to move in a nearly horizontal circle at a steady high speed by a suitable movement of the hand holding the glass tube. A constant radius  $r$  of rotation can be maintained by the use of a reference mark on the thread.

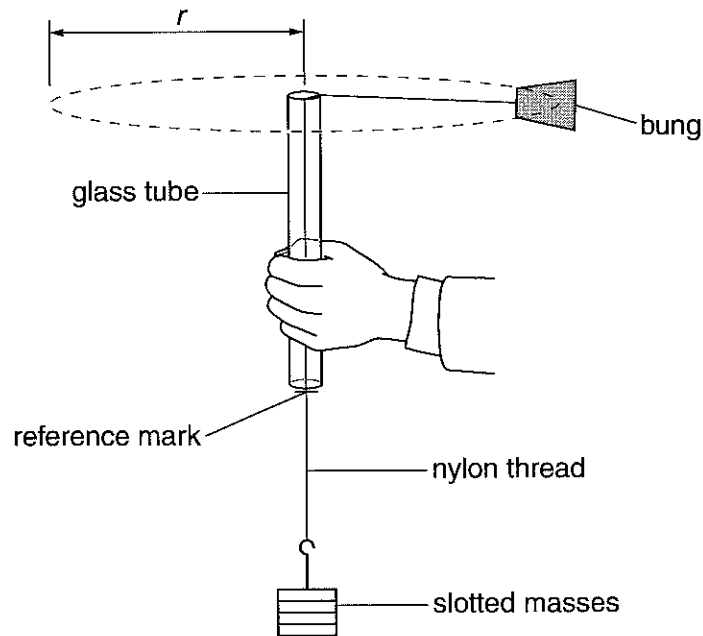


Fig. 3.1

- (a) (i) Draw an arrow labelled  $F$  on Fig. 3.1 to indicate the direction of the resultant force on the bung. [1]
- (ii) Explain how the speed of the bung remains constant even though there is a resultant force  $F$  acting on it.

.....

.....

.....

.....

..... [2]



Question	Answer	Marks	Guidance
3			
(a)	(i) Arrow (labelled $F$ ) directed towards centre of circle	B1	<b>Allow:</b> arrow drawn parallel to the string
	(ii) Resultant force ( $F$ ) acts at $90^\circ$ to motion / velocity of bung so no work done is done by $F$ (hence no change in speed)	B1 B1	<b>Allow:</b> No component of $F$ acts in the direction of motion (B1) hence there is no acceleration in the direction of motion (AW) (B1)
(b)	(i) Student <u>tries</u> to rotate bung at <u>constant</u> radius / <u>tries</u> to keep reference mark at end of tube (AW) Force $F$ is calculated using $F = Mg$ , where $M$ is mass of slotted masses Measure time $t$ for $n$ revolutions of the bung (hence calculate $T$ for 1 revolution). Measure radius $r$ when <u>stationary</u> Calculate $v$ using $2\pi r n / t$ (or $2\pi r / T$ ).	B1 B1 B1 B1 B1	<b>Not:</b> bald 'constant radius' <b>Not:</b> $F = \text{weight}$ <b>Not:</b> 'take time for 1 revolution'
	(ii)	B1	
	1 Straight line of positive gradient <u>passing through the origin</u>	B1	
	2 $F = \frac{m}{r} v^2$ hence gradient = $\frac{m}{r}$ Mass = <u>gradient</u> (of graph) $\times$ radius (of orbit)	B1 B1	Cannot award this mark if graph is curved Can score this mark if graph is curved
	<b>Total</b>	<b>11</b>	

- 2 A satellite orbits the Earth in a circular path 800 km above the Earth's **surface**. At the orbit of the satellite the gravitational field strength is  $7.7 \text{ N kg}^{-1}$ . The radius of the Earth is 6400 km.

(a) Calculate

- (i) the orbital speed of the satellite

orbital speed = .....  $\text{ms}^{-1}$  [3]

- (ii) the period of the orbit of the satellite.

period = ..... s [2]

- 2 (a) Fig. 2.1 shows a jet aircraft preparing for take-off along a horizontal runway. The engine of the jet is running but the brakes are applied. The jet is not yet moving.



Fig. 2.1

On Fig. 2.1 draw an arrow to show each of the following forces acting on the jet:

- (i) the weight of the jet (label this **W**)
  - (ii) the force produced by the engine (label this **T**)
  - (iii) the **total** force exerted by the runway on the jet (label this **F**). [2]
- (b) The brakes are released. The maximum force produced by the engine is 28 kN. The take-off speed of the jet is  $56 \text{ m s}^{-1}$ . The mass of the jet is 6200 kg.
- (i) Calculate the minimum distance the jet travels from rest to the point where it takes off.

distance = ..... m [3]

- (ii) Explain why the runway needs to be longer than the distance calculated in (i).

.....

.....

.....

.....

..... [2]

- (c) The jet is to be used in a flying display in which the pilot will be required to fly the jet in a **horizontal** circle of radius  $r$ , at a constant speed of  $86 \text{ m s}^{-1}$ . This is achieved by flying the jet with its wings at  $35^\circ$  to the horizontal. With the jet flying in this way, the two forces acting on the jet are the lift  $L$  and the weight  $W$ , as shown in Fig. 2.2. Air resistance has negligible effect on the motion of the jet during this manoeuvre.

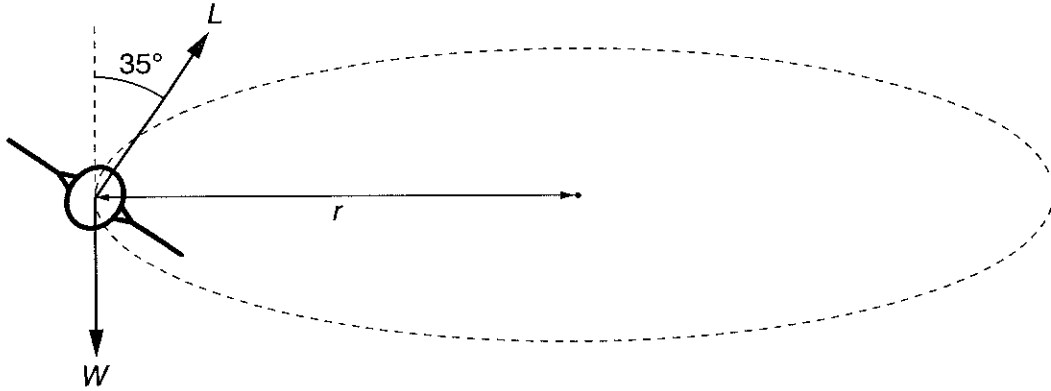


Fig. 2.2

- (i) Show that the magnitude of the force  $L$  is about 74 kN.

[1]

- (ii) Calculate the radius  $r$ .

radius = ..... m [3]



- (d) In a more complex manoeuvre (loop the loop), the pilot is required to fly in a vertical circle at a constant speed as shown in Fig. 2.3.

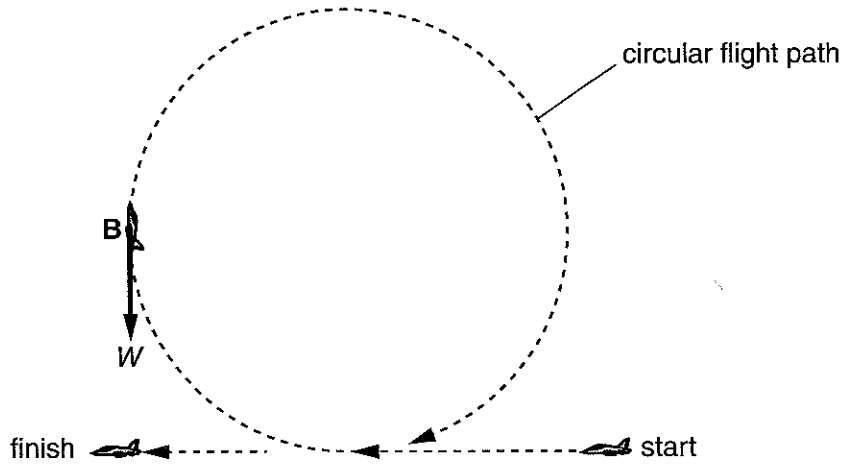


Fig. 2.3

- (i) For a certain speed, the pilot can experience a sensation of weightlessness at a particular point along the circular path.

- 1 On Fig. 2.3, mark with a cross labelled **A**, the point where the pilot experiences the sensation of weightlessness. [1]
- 2 State the magnitude of the vertical component of the contact force exerted by the seat on the pilot at **A**.

force = ..... N [1]

- (ii) In this manoeuvre it is convenient to analyse the motion of the jet in terms of two forces:
- a constant weight  $W$
  - a variable force  $P$ .

$P$  is the resultant of the engine thrust, the lift from the wings and air resistance.

At the point **B** in Fig. 2.3 the jet is flying vertically upwards.

Explain why the force  $P$  is not directed towards the centre of the circular path.


.....

.....

.....

..... [1]

[Total: 14]

Question	Answer	Mark	Guidance
2			
(a)	(i)  Correct direction and labelling for W and T (ii) Correct direction <b>not</b> horizontal or vertical (iii) Straight line for F	B1	<b>Both</b> forces must be correct to score this mark.
(b)	(i) $a = T/m$ $a = 28 \times 10^3 / 6200 (= 4.516)$ $v^2 = u^2 + 2as$ $56^2 = 0 + 2 \times 4.516s$ (any subject) $s = 350$ (m)	C1 C1 A1	Must substitute to score this mark. Answer to 3 sf = 347 (m). <b>Allow:</b> max 2 marks if v is not squared but correct formula was quoted. [Expect $s = 6.2$ (m)] <b>Allow:</b> $Fs = \frac{1}{2}mv^2$ [C1] $28 \times 10^3 s = \frac{1}{2} \times 6200 \times 56^2$ [C1] (any subject) $s = 350$ (m) [A1] <b>Allow:</b> $Ft = mv$ [C1] $t = 12.4$ (s) [C1] $s = \frac{1}{2}vt = \frac{1}{2} \times 56 \times 12.4$ [C1] $s = 350$ (m) [A1]
(c)	(i) Air resistance/drag/friction acts on aircraft <u>decreasing either</u> the net forward force <b>or</b> the acceleration  Fs = ΔKE so reduced force must act over a longer distance to produce enough kinetic energy for take-off OR $v^2 = (u^2) + 2as$ so reduced acceleration means longer distance to reach take-off speed.	M1 A1	<b>Not:</b> 'slowing the aircraft down'. <b>Allow</b> word equation. <b>Note:</b> This mark cannot be given if the previous (M1) mark has not been scored.
(j)	$L \cos 35^\circ = 6200 \times 9.81$ $L = \frac{6200 \times 9.81}{\cos 35^\circ}$ OR $L = 7.42 \times 10^4$ $L = 7.4 \times 10^4$ (N)	M1 A0	<b>Allow:</b> Use of 9.8  <b>Note:</b> There is no mark for the answer as it is given in the question. Marks in 'Show' questions are for the working.

Question	Answer	Mark	Guidance
(ii)	$L \sin 35^\circ = mv^2 / r$ $r = \frac{6200 \times 86^2}{7.4 \times 10^4 \sin 35^\circ}$ $r = 1100 \text{ (m)}$	C1  C1  A1	<p>Possible ecf from (c)(i).</p> <p>Correct answer to 3 sf = 1.08 x 10<sup>3</sup> (m).  <b>Allow:</b> 1 mark for using cos 35° instead of sin 35°. Expect gives an answer of 760 (m).  <b>Allow:</b> 2 marks for correct working using <math>v = 56 \text{ (m s}^{-1}\text{)}</math>. Expect an answer of <math>r = 460 \text{ (m)}</math>.            No marks for using tan 35° or for omitting a trig function.</p>
(d)	(i)1 Indication at 'top' of circle (by eye)	B1	
	(i)2 0 (N)	B1	
	(ii) P is not the resultant force <b>OR</b> Resultant force must be towards centre of circle so $P$ must have a component acting vertically upwards, equal in magnitude to $W$ (AW)	B1	<b>Allow:</b> (Horizontal) component of $P$ provides centripetal acceleration and vertical component of $P$ is equal to weight. (AW)
	<b>Total</b>	14	