PRESTON MANOR

# A2 Physics Exam Packs

## Circular Motion

Name:

Form:

| Question | Mark |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |

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

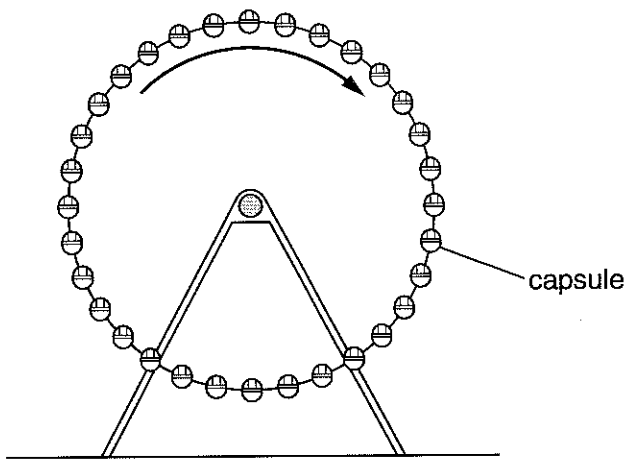



**Fig. 2.1**

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 $0.26\,\text{m}\,\text{s}^{-1}$.

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

time = ...................................................... s **[1]**

**(ii)** Each capsule has a mass of $9.7 \times 10^3$ 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.

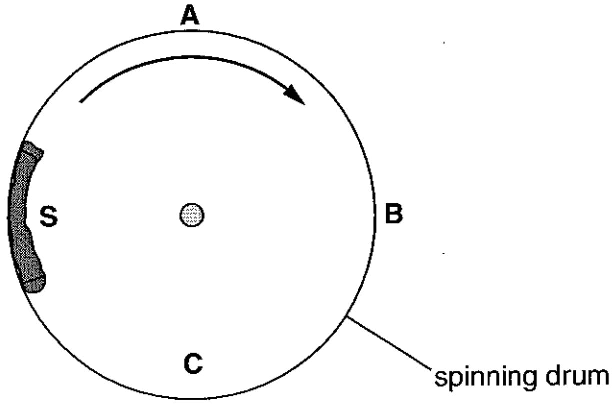



**Fig. 2.2**

**(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 | ($v = 2\pi r/t$ ) $t = 2\pi 60/0.26$ = **1450** s | B1 | Correct answer is 1449.96 hence allow $1.4 \times 10^3$<br>Do not allow a bare $1.5 \times 10^3$ |
| | | ii | (ii) correct substitution into $F = mv^2/r$: eg $F = (9.7\times10^3 \times 0.26^2)/60$<br>F = **10.9** N | C1<br>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**<br>because it supports weight of sock AND provides the required upward resultant (centripetal) force (WTTE)<br><br>2. Least at **A** because sock's weight provides part of the required downward resultant (centripetal) force (WTTE) | **M1**<br>A1<br><br>B1 | This is a mandatory M mark. The second mark cannot be gained unless this is scored.<br>Any indication that candidates think that the centripetal force is a **third** force loses this second and possibly the next mark.<br>They must make correct reference to the resultant force that provides the required centripetal force/acceleration.<br>Allow answers using the equation $F = mv^2/r$<br>such as $N_c - mg$ (at C) = centripetal force OR $mv^2/r$<br>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.<br>All lines looking as though they would meet at the centre judged by eye | B1<br>B1 | At least 4 drawn and care taken<br>Some of the lines must be outside the planet. |
| | b | i | ($mg = GMm/r^2$ and hence) $\mathbf{M = gr^2/G}$<br>correct substitution $M = 24.9\times(7.14 \times 10^7)^2/6.67\times10^{-11}$<br>= $\mathbf{1.9 \times 10^{27}}$ Kg (i.e about $\mathbf{2\times10^{27}}$) | C1 **M1**<br>A1 | Equation needs to be rearranged as shown for C1 mark |
| | | ii | correct substitution into $V=(4/3)\pi r^3 = (4/3)\pi(7.14\times10^7)^3$ {= $1.52 \times 10^{24}$ m$^3$}<br>density = mass/volume = $1.9 \times10^{27}/1.52 \times 10^{24}$ = **1250** kg m$^{-3}$ | C1<br>A1 | If m= $2 \times 10^{27}$ kg is used<br>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.

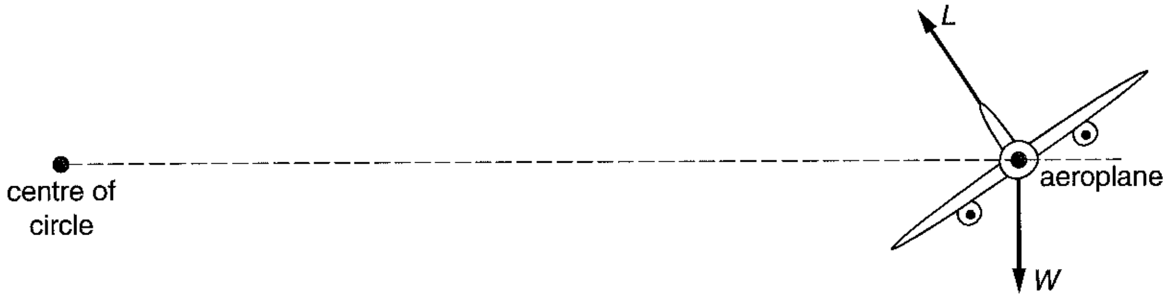



**Fig. 2.1**

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

..................................................................................................................................

..................................................................................................................................

..................................................................................................................................

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

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

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

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

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

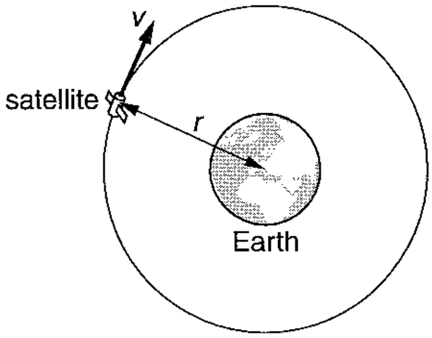



**Fig. 2.2**

| Question | Expected Answers | Marks | Additional guidance |
|---|---|---|---|
| **2** (a) (i) | Horizontal <u>component</u> of **L** provides the centripetal force (WTTE)<br>Vertical <u>component</u> of **L** balances the weight (WTTE) | B1<br>B1 | |
| (a) (ii) | $F = mv^2/r$ correct rearranged into $v = \sqrt{(Fr/m)}$<br>$v = \sqrt{(1.8\times10^6 \times 2000/1.2\times10^5)}$ = **173** m $s^{-1}$ (or 170) | C1<br>A1 | Allow correct substitution of values into $F = mv^2/r$ for C1 mark |
| (b) | $mv^2/r = GMm/r^2$<br>$T = 2\pi r/v$<br>Correct manipulation of equations to give $T^2 = \dfrac{4\pi^2 r^3}{GM}$ | B1<br>M1<br>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) | **Equatorial** orbit (WTTE) (<u>QWC mark</u>)<br>Period is 24h/1day/same as Earth **OR** moves from West to East (WTTE) | B1<br>B1 | QWC <u>equatorial</u> or <u>equator</u> must be spelled correctly |
| (c) (ii) | Correct rearrangement of $T^2 = (4\pi^2 r^3/GM)$ to give $r^3 = T^2GM/4\pi^2$<br>correct sub. $r^3 = \{6.67\times10^{-11} \times 6.0 \times 10^{24} \times (8.64\times10^4)^2\}/4\pi^2 = 7.57\times10^{22}$<br>r = $\mathbf{4.23 \times 10^7}$ **m** (or 4.2 or $4.3 \times 10^7$ ) | C1<br>C1<br>A1 | (1 day = $8.64 \times10^4$s is given on the data sheet).<br>For those who use $g = GM/r^2$ with g = 9.81 award 1 mark for r= $6.4 \times 10^6$ m. |
| | Total | 12 | |

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

**(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 1500 m. 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 = ................................................. m s$^{-1}$ **[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 (WTTE) | 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 m $s^{-2}$ | B1 | **Allow** 1N = 1 kg m $s^{-2}$ |
| (b)(i) | Use of $v = u + at$ OR $a = (v - u) / t \Rightarrow a = (55 - 0) / 2.2$<br>$a = 25$ (m $s^{-2}$) | C1<br>A1 | |
| (b)(ii) | Use of $s = ut + ½ at^2$ e.g. s = 0 + ½ x 25 x $2.2^2$<br>$s = 60.5$ (m) | C1<br>A1 | **Allow** other valid solutions e.g. using $v^2 = u^2 + 2as$ |
| (b)(iii) | $F = ma = 3.2 \times 10^4 \times 25 = 8.0 \times 10^5$ (N) | A1 | **Allow** ecf from (b)(i) |
| (c)(i) | <u>towards the centre of the circle</u>. | B1 | Do not allow a bare "perpendicular to the velocity"<br>Do not allow "in the same direction as the acceleration." |
| (c)(ii) | use $F = mv^2/r$ e.g. $F = (3.2 \times 10^4 \times 120^2)/870$<br>$F = 5.3 \times 10^5$ (529655) (N) | C1<br>A1 | If 55 is used instead of 120 for the velocity F = $1.1 \times 10^5$ $ms^{-1}$ and scores 1 mark |
| (d)(i) | At top of the circle<br>when the weight provides/equals the required centripetal force | M1<br>A1 | **Allow** "when the resultant force = weight" |
| (d)(ii) | realisation that acc = $g$ (OR 9.81) AND (hence) $v^2/r = g$<br>$\{v = \sqrt{(gr)} = \sqrt{(9.81 \times 1500)}\} \Rightarrow v = 120$ (m $s^{-1}$) (121.3) | M1<br>A1 | **Accept** 121.24 as this corresponds to 9.8,<br>do **not** allow 122.5 since this assumes $g = 10$ $ms^{-2}$ |
| | **Total** | **14** | |

**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 $3700\,\mathrm{m\,s^{-1}}$.

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

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 $2.0 \times 10^{7}\,\mathrm{m}$. Calculate the speed of the satellite in this orbit.

speed = ................................................ $\mathrm{m\,s^{-1}}$ **[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<br>acceleration is in direction of force OR is towards the centre/perp. to velocity | B1<br>B1 | Allow a (resultant) force is acting (hence there is an acceleration)) |
| **(b)** | centripetal force OR $mv^2/r = GMm/r^2$ OR $v^2/r = GM/r^2$<br>$v^2 = GM/r \Rightarrow r = GM/v^2$<br>$r = 6.67 \times 10^{-11} \times 6 \times 10^{24} / 3700^2$<br>$r =$ **$2.92 \times 10^7$** m | C1<br>C1<br>C1<br>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)** | $v^2r$ = constant OR $v^2 = GM/r$ OR $v = \sqrt{\{(6.67\times10^{-11}\times6 \times 10^{24})/2\times10^7\}}$<br>new $v = \sqrt{(3700^2 \times 2.94/2)}$ = **4500** m $s^{-1}$ (4473) | C1<br>A1 | |
| | **Total** | **10** | |

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.

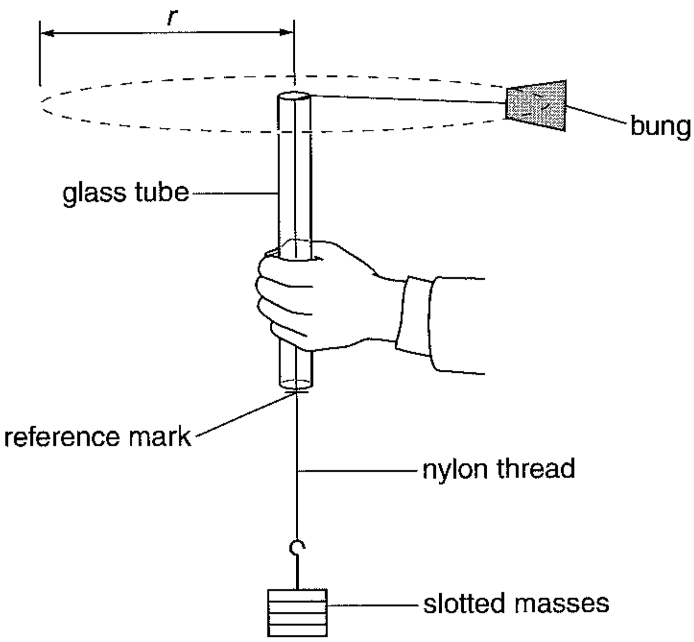



**Fig. 3.1**

**(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]**

**(b) (i)** Two students carry out an experiment using the apparatus in Fig. 3.1 to investigate the relationship between the force $F$ acting on the bung and its speed $v$ for a constant radius. Describe how they obtain the values of $F$ and $v$.

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

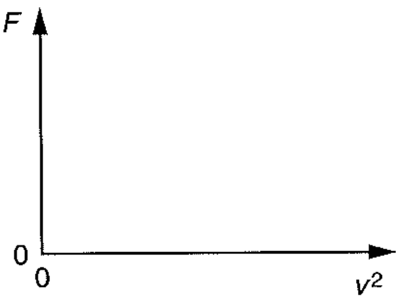
..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

.......................................................................................................................................... **[5]**

**(ii)** **1** Sketch, on Fig. 3.2, the expected graph of $F$ against $v^2$.




**[1]**

**Fig. 3.2**

**2** Explain how the graph can be used to determine the mass $m$ of the bung.

..........................................................................................................................................

..........................................................................................................................................

..........................................................................................................................................

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

**[Total: 11]**

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

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 $7.7\,\mathrm{N\,kg^{-1}}$. The radius of the Earth is 6400 km.

**(a)** Calculate

**(i)** the orbital speed of the satellite

orbital speed = ................................................ $\mathrm{m\,s^{-1}}$ **[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 $56\,\mathrm{m\,s^{-1}}$. 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 $86\,\text{m}\,\text{s}^{-1}$. This is achieved by flying the jet with its wings at 35° 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.

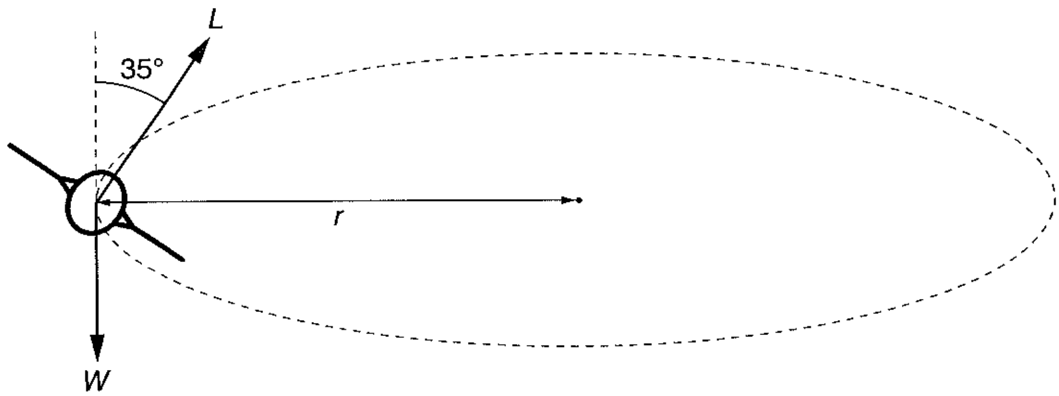



**Fig. 2.2**

**(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.

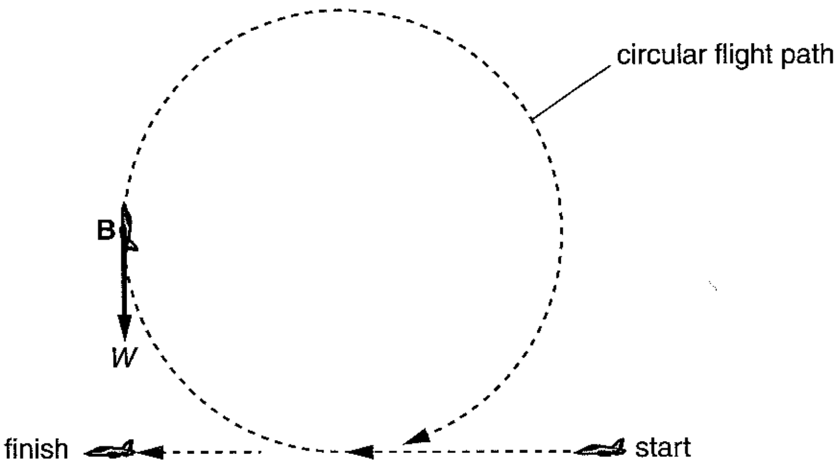



**Fig. 2.3**

**(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.

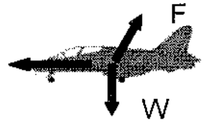
...................................................................................................................................

...................................................................................................................................

...................................................................................................................................

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

**[Total: 14]**

| Question | | | Answer | Mark | Guidance |
|---|---|---|---|---|---|
| 2 | (a) | (i)<br>(ii) |  Correct direction and labelling for W <u>and</u> T | B1 | **Both** forces must be correct to score this mark. |
| | | (iii) | Straight line for F<br>Correct direction **not** horizontal or vertical | B1 | **Allow:** Freehand sketch of *F* must lie between 15° and 75° to the horizontal to score this mark. |
| | (b) | (i) | $a = T/m$<br>$a = 28 \times 10^3 / 6200$ (= 4.516)<br>$v^2 = u^2 + 2as$<br>$56^2 = 0 + 2 \times 4.516s$ (any subject)<br><br>$s = 350$ (m) | C1<br><br>C1<br><br>A1 | Must substitute to score this mark.<br><br>Answer to 3 sf = 347 (m).<br>**Allow:** max 2 marks if v is not squared but correct formula was quoted. [Expect $s = 6.2$ (m)]<br><br>**Allow:** $Fs = ½ mv^2$ [C1]<br>$28 \times 10^3\ s = ½ \times 6200 \times 56^2$ [C1] (any subject)<br>$s = 350$ (m) [A1]<br><br>**Allow:** $Ft = mv$<br>$t = 12.4$ (s) [C1]<br>$s = ½\ vt = ½ \times 56 \times 12.4$ [C1]<br>$s = 350$ (m) [A1] |
| | | (ii) | Air resistance/drag/friction acts on aircraft <u>decreasing</u> **either** the net forward force **or** the acceleration<br><br>Fs = ΔKE so reduced force must act over a longer distance to produce enough kinetic energy for take-off<br>OR<br>$v^2 = (u^2) + 2as$ so reduced acceleration means longer distance to reach take-off speed. | M1<br><br>A1 | **Not:** 'slowing the aircraft down'.<br><br>**Allow** word equation.<br>**Note:** This mark cannot be given if the previous (M1) mark has not been scored. |
| | (c) | (i) | $L \cos 35^\circ = 6200 \times 9.81$<br>$L = \dfrac{6200 \times 9.81}{\cos 35^\circ}$ OR $L = 7.42 \times 10^4$<br>$L = 7.4 \times 10^4$ (N) | <br>M1<br>A0 | **Allow:** Use of 9.8<br><br>**Note:** 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) | $L\sin 35^\circ = mv^2/r$<br>$r = \dfrac{6200 \times 86^2}{7.4 \times 10^4 \sin 35^\circ}$<br>$r$ = 1100 (m) | C1<br>C1<br>A1 | Possible ecf from (c)(i).<br>Correct answer to 3 sf = 1.08 x $10^3$ (m).<br>**Allow:** 1 mark for using cos 35° instead of sin 35°. Expect gives an answer of 760 (m).<br>**Allow:** 2 marks for correct working using v = 56 (m $s^{-1}$) Expect an answer of $r$ = 460 (m).<br>No marks for using tan 35° or for omitting a trig function. |
| | (d) | (i)1 | Indication at 'top' of circle (by eye) | B1 | |
| | | (i)2 | 0 (N) | B1 | |
| | | (ii) | P is not the resultant force<br>**OR**<br>Resultant force must be towards centre of circle so *P* must have a component acting vertically upwards, equal in magnitude to *W* (AW) | B1 | **Allow:** (Horizontal) component of *P* provides centripetal acceleration and vertical component of *P* is equal to weight. (AW) |
| | | | Total | 14 | |