1 **(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.

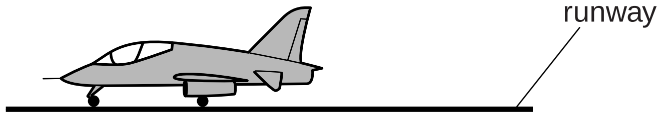

Fig. 2.1

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 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 m 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.

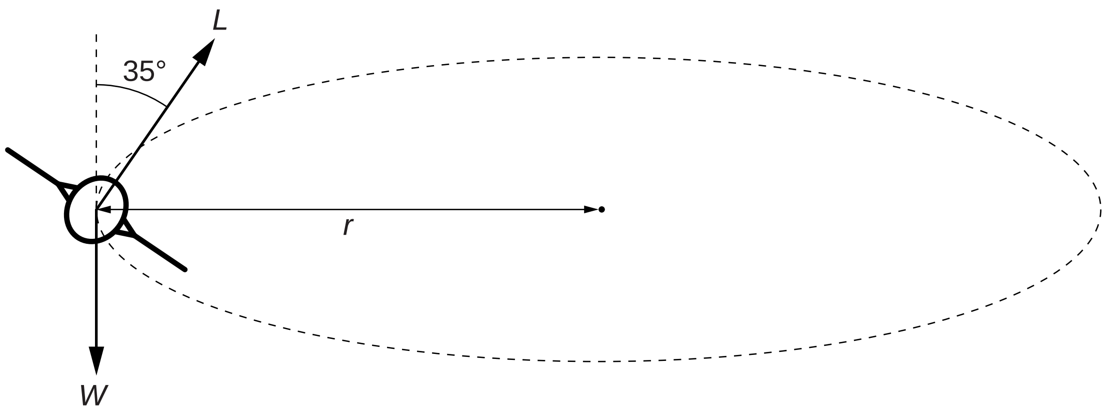

Fig. 2.2

(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.

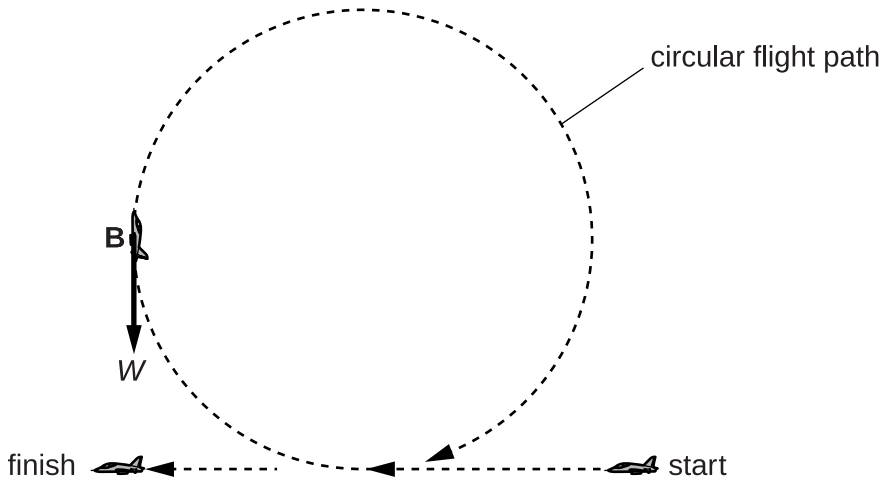

Fig. 2.3

(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]

2 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.

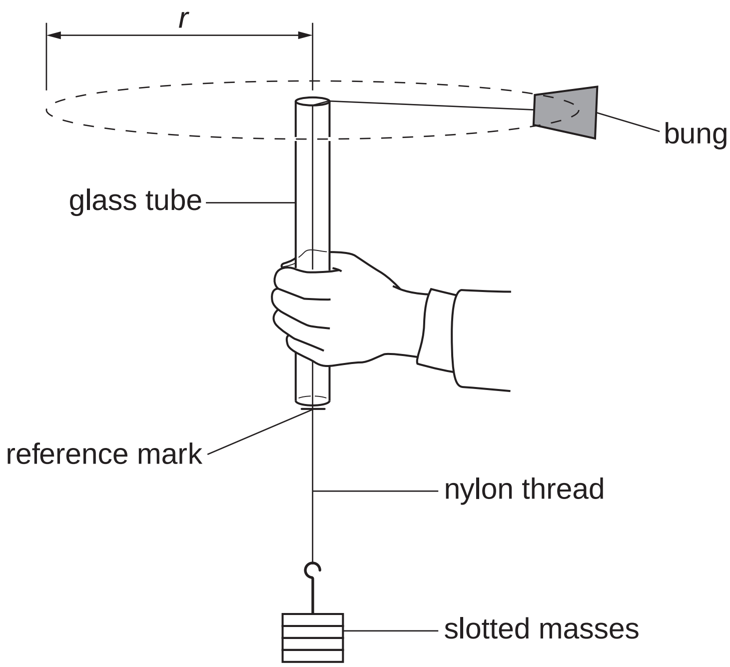

Fig. 3.1

(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]

3 **(a)** **(i)** State Newton's first law of motion.

....

....

.... **[1]**

(ii) Define the *newton*.

....

.... **[1]**

(b) A jet plane on the deck of an aircraft carrier is accelerated before take-off using a catapult. The mass of the plane is 3.2×10^4 kg and it is accelerated from rest to a velocity of $55\,\text{m}\,\text{s}^{-1}$ in a time of 2.2 s. Calculate

(i) the mean acceleration of the plane

mean acceleration = ... $\text{m}\,\text{s}^{-2}$ **[2]**

(ii) the distance over which the acceleration takes place

distance = ... m **[2]**

(iii) the mean force producing the acceleration.

mean force = ...N **[1]**

(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]

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

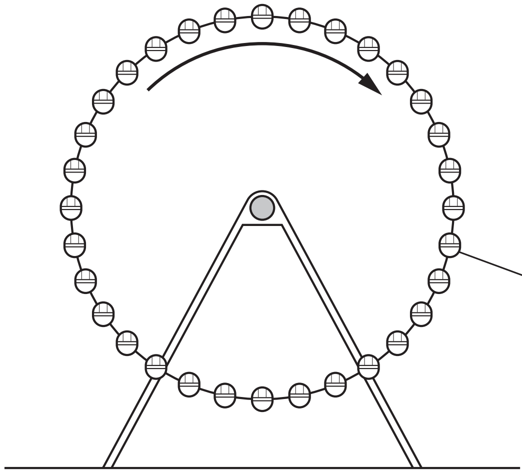

Fig. 2.1

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 $m s^{-1}$.

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

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

(ii) Each capsule has a mass of 9.7×10^3 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.

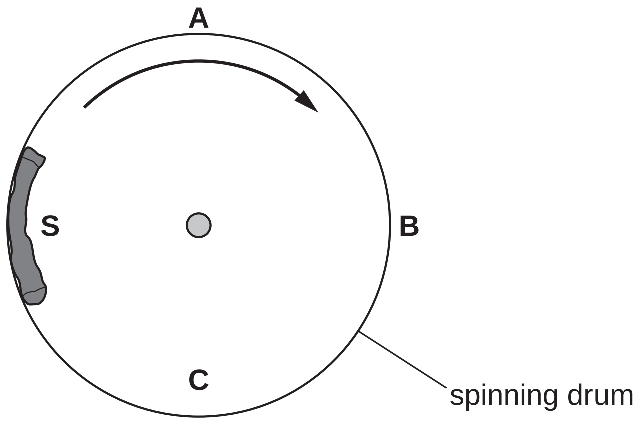

Fig. 2.2

(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]