Low Level
Aerobatics Display

As the RAAF's elite formation aerobatic display team, the Roulettes perform breathtaking displays, using only hand-eye coordination to fly at speeds of up to 590 kilometres per hour. The six Roulettes may experience up to 4.5G (or 4.5 times the normal force of gravity) during a display in their PC-9/A aircraft. When the Roulettes are not showcasing their skills, they teach qualified RAAF pilots to become flying instructors at RAAF Base East Sale in Victoria.

The aircraft that will be flown today is the RAAF's advanced trainer, the Pilatus PC-9/A.

Pilatus PC-9/A of No. 2FTS, Pearce, W.A.

Role:	Two-seat advanced trainer; forward air control and aerobatics.
Crew:	One or two pilots.
Engine:	Pratt and Whitney PT6A-62 turboprop (950 shaft horsepower, 708 kW).
Wingspan:	10.24 m.
Wing Area:	16.29 m^2.
Weight:	2250kg basic, 2710kg maximum.
Max. Speed:	595 kmh^{-1}.
Cruise Speed:	550 kmh^{-1}.
Rate of climb:	20.8 ms^{-1}.
g limits:	+ 7.0 g to -3.5 g

Source:
http://www.airforce.gov.au/Interact/Air_Force_Roulettes/?RAAF-rfHiMv85HKPcF1XWFcteALXKGiyJTpHL

Questions 1 to 3 relate to the following information.

At take off the Pilatus PC-9/A typically has a total mass of 2500 kg.

Starting from rest the PC-9/A needs 245 m of runway to achieve its take off speed of 43.9 ms^{-1} (158 kmh^{-1}).

Question 1

How long would it take for the PC-9/A to reach its take off speed of 43.9 ms^{-1}?

s

Question 2

What would be the magnitude of the PC-9/A's average acceleration during its take off run?

ms^{-2}

Question 3

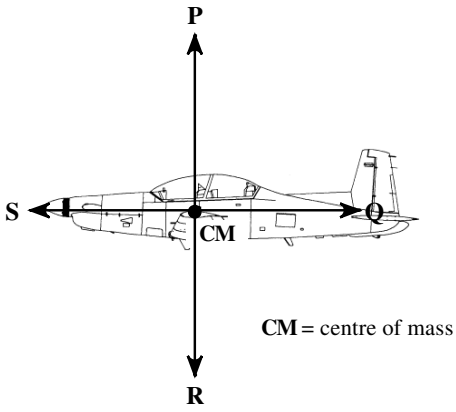
How much work would be done by the engine of the PC-9/A in accelerating it from rest to its take off speed of 43.9 ms^{-1}?

J

Questions 4 and 5 relate to the following information.

Figure 1 shows a PC-9/A some time after it has taken off. It is flying with a steady speed of 54.0 ms^{-1} at a constant height of 500 m.

It has a total mass of 2500 kg and a wing area of 16.29 m^2.



CM = centre of mass

Figure 1

Question 4

On the diagram shown in Figure 1 the forces acting on the aeroplane are labelled **P**, **Q**, **R** and **S**. In the following table which of the choices, **A – D**, correctly matches the force to the appropriate letter.

	Lift	Thrust	Weight	Drag
A.	**S**	**P**	**R**	**Q**
B.	**P**	**S**	**Q**	**R**
C.	**S**	**P**	**Q**	**R**
D.	**P**	**S**	**R**	**Q**

Question 5

For the situation described in Figure 1 the total lift force on the PC-9/A needs to be:

A. Lift = 2500 N. **B.** Lift = 25 kN. **C.** Lift > 2500 N. **D.** Lift > 25 kN.

Questions 6 to 9 relate to the forces that are acting on the pilot and the following additional information.

A short time later the pilot performed the loop shown in Figure 2. The pilot has a mass of 80 kg.

At point **P** the PC-9/A is at the bottom of the loop on an arc of radius, **r**, and flying with a horizontal speed of 450 kmh^{-1}.

At point **Q** the PC-9/A is at the top of the loop, upside down and travelling at an unknown speed along an arc of radius ***r*** metres.

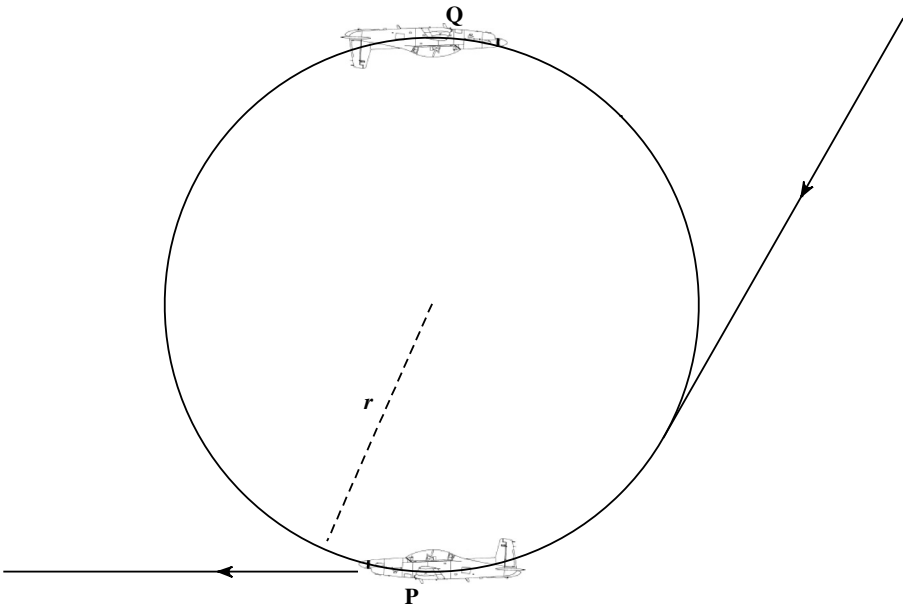
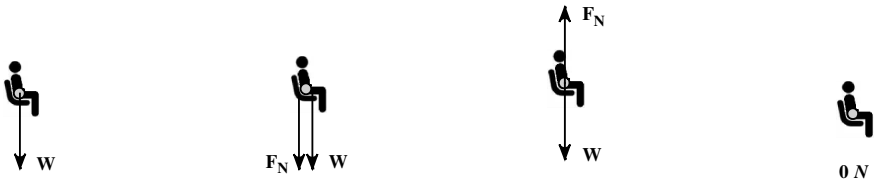


Figure 2

Question 6

Which of the diagrams below, **A – D**, correctly shows the forces acting on the pilot at point '**P**'?



A. **B.** **C.** **D.**

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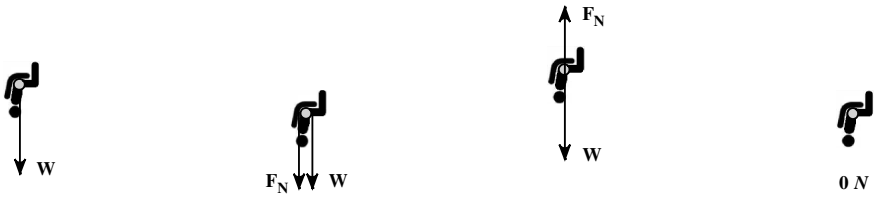
Question 7

Which of the diagrams below, **A – D**, correctly shows the forces acting on the pilot at point '**Q**'?



A. **B.** **C.** **D.**

☐

Question 8

At point '**P**' at the bottom of the loop the pilot experiences a force of 4.00g. If the PC-9/A were flying at a speed of 450 kmh^{-1} at this point, what would be the radius, **r**, of the arc along which it was flying?

m

Question 9

At point '**Q**' at the top of the loop the pilot said that he 'felt that he was weightless'. If the PC-9/A were flying along an arc of radius ***r*** m at point '**Q**', as calculated in Question8, at what speed measured in kilometres per hour would it have been travelling at this instant?

kmh^{-1}

Questions 10 and 11 relate to the following information.

The combined mass of the pilot and the PC-9/A is 2500 kg.

The pilot flew the plane in a horizontal circle as shown by the diagrams in Figures 3a and 3b.

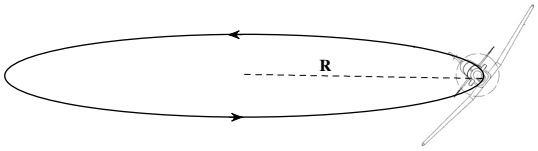


Figure 3a

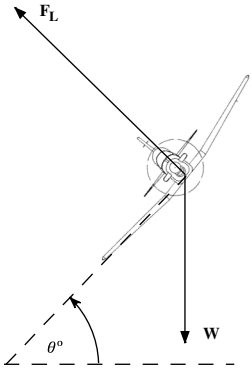


Figure 3b

Whilst flying the PC-9/A in a horizontal circle the pilot kept the airspeed at a *constant* 90.0 ms^{-1}. It took the plane 15.0 seconds for it to complete one full circle.

Question 10

What was the radius, **R**, of the horizontal circle that the PC-9/A flew around?

m

(2 marks)

Question 11

If the angle, θ^o, at which the PC-9/A was banked whilst flying around the horizontal circle, was 60.0^o, how much lift did the PC-9/A's wing produce?

N

(2 marks)

1.	velocity; acceleration	$v = \Delta x/\Delta t$; $a = \Delta v/\Delta t$
2.	equations for constant acceleration	$x = ut + \frac{1}{2}at^2$,
		$x = vt - \frac{1}{2}at^2$,

		$x = ½ (u + v)t$ $v = u + at,$ $v^2 = u^2 + 2ax$
3.	Newton's 2nd Law	$F = ma$
4.	Gravitational potential energy near the surface of the earth	$U_g = mgh$
5.	Kinetic Energy	$E_k = ½mv^2$
6.	Mechanical work	$W = Fx$
7.	Power	$P = W/\Delta t = \Delta E/\Delta t = Fv$
8.	Acceleration due to gravity	$g = 10\ ms^{-2}$