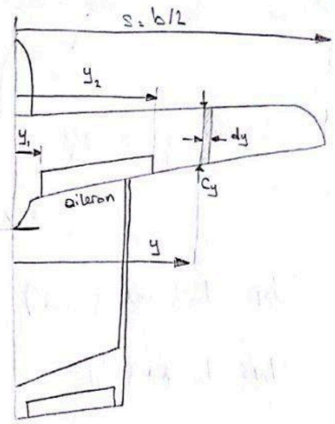
9) Unfortunately, a PhD student has made a mistake when re-programming the autopilot. The inboard control surfaces on the wing have now been linked in as the ailerons and the outboard control surfaces as the flaps. On the assumption that each control surface is independently driven and zeroed correctly, use strip theory to derive an expression for the reduction in roll authority due to this error. Include any assumptions you make in the derivation and comment on the result.

In strip theory, the wing is divided into a number of spanwise elements or strips. The aerodynamic forces in each strip are calculated assuming that it is a part of two-dimensional wing having identical airfoil as that of the given strip.

Strip theory derive for Roll moment:

$\mathring{L}_\xi = \frac{\partial L}{\partial \xi}$ Rolling moment due to aileron ; ξ aileron deflection angle

according to strip theory, due to starboard aileron deflection:



$$L_{right} = -\frac{1}{2}\rho V^2 \int_{y_1}^{y_2} C_{L_y}\Big|_{right} C_y \cdot y \cdot dy$$

C_{L_y} is the local lift coefficient at spanwise coordinate y

$$C_{L_y}\Big|_{right} = a_0 + a_y \alpha + a_{2A}\xi$$

a_y: local lift curve slope at spanwise coordinate y

α: angle of attack

a_{2A}: aileron lift curve slope

$$L_{right} = -\frac{1}{2}\rho V^2 \int_{y_1}^{y_2} (a_0 + a_y \alpha + a_{2A}\xi)\, C_y \cdot y \cdot dy$$

It follows that total rolling moment may be written:

$$\mathring{L}_\xi \cdot \xi = L_{right} + L_{left} = -\rho V^2 (a_{2A}\xi) \int_{y_1}^{y_2} C_y \cdot y\, dy$$

$$\mathring{L}_\xi = -\rho V^2 a_{2A} \int_{y_1}^{y_2} C_y \cdot y\, dy$$

may be written : $L_\xi = \dfrac{\mathring{L}_\xi}{\frac{1}{2}\rho V^2 S b}$; $b = 2s$

$$L_\xi = -\frac{a_{2A}}{S.s} \int_{y_1}^{y_2} C_y . y . dy$$; lets assume C_y approximately constant with y

by doing integration : $L_\xi = -\dfrac{a_{2A}}{S.s} C_y \left[\dfrac{y_2^2}{2} - \dfrac{y_1^2}{2} \right]$

In this error's case, the boundaries of aileron (y_2 and y_1) which represent as the arm of the roll moment, are shorter than in actuall case, and this will lead to less ability of rolling (reduction in roll moment).

10) <u>It turns out the PhD student has also failed to connect the left ruddervator control surface (See Figures Q9 and Q10) to the autopilot which means that only the right ruddervator is functional. Describe the effect this will have on the flight of the Albatross using diagrams and equations where appropriate.</u>

According to this situation, with only right ruddervator functional, the UAV will unable to pitch up and down, since the pitch moment in ruddervator configuration needs the both surfaces to be deflected (left and right) simultaneously upward or downward.
Also, the UAV will unable to yaw left or right, since the yaw moment in ruddervator configuration needs the both surfaces to be deflected in opposite directions to each other. For this configuration to yaw to the right, left ruddervator goes down, right ruddervator goes up, and to yaw to the left, left ruddervator goes up, right ruddervator goes down.
The UAV will be able only to pitch down-yaw to the left, and pitch up-yaw to the right, since to do pitch up/down-yaw motion on this configuration to the left or right, one surface of ruddervator needs to be neutral and the other surface to be deflected up or down.

11) <u>Identify the five sections in the flight where the aircraft is trimmed for a given speed. From this data identify the minimum sink rate for this configuration of the glider. Note this flight was with the 18 metre wingtip configuration and not the 20 metre as shown in Figure Q11. Identify any assumptions and difficulties that you have had in finding this value.</u>

According to UoB_Flight_Data:

1- Approximately at 1740s timing to 45s-50s later, the aircraft has been trimmed at 21-22 IAS (76-79 km/h), pitch between 4-5 degrees, and between altitudes approximately form 1400m to 1350m.
From the data we realize that the **sink rate** approximately is 1.1 m/s.

2- Approximately at 1920s timing to 45s-50s later, the aircraft has been trimmed at 25-24 IAS (90-87 km/h), pitch between 8-9 degrees, and between altitudes approximately form 1300 to 1250.
From the data we realize that the **sink rate** is approximately 1.1 m/s.

3- Approximately at 1977s timing to 45s-50s later, the aircraft has been trimmed at 30-31 IAS (108-112 km/h), pitch between 12-13 degrees, and between altitudes approximately form 1215 to 1170.
From the data we realize that the **sink rate** is approximately 1 m/s

4- Approximately at 2033s timing to 45s-50s later, the aircraft has been trimmed at 35-34 IAS (123-126 km/h), pitch between 15-13 degrees, and between altitudes approximately form 1135 to 1085.
From the data we realize that the **sink rate** is approximately 1.2 m/s.

5- Approximately at 2090s timing to 35-40s later, the aircraft has been trimmed at 40-38 IAS

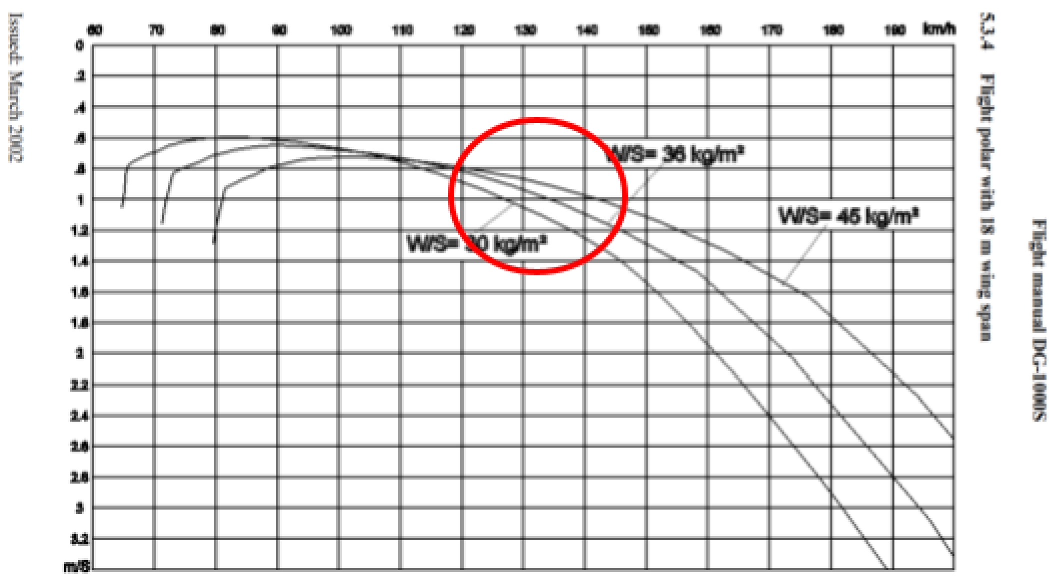
(137-144 km/h), pitch between 16-14 degrees, and between altitudes approximately from 1040 to 980.
From the data we realize that the **sink rate** is approximately 1.4 m/s.

So according to the data and the numbers that we had from the UoB_Flight_Data file, we realize that the average **minimum sink rate** of this configuration is 1.1-1.2 m/s.

NOTE: no difficulties at all on finding the values.

12) <u>Compare the value calculated in question 11 with the flight polar given in the DG1000S flight manual. In addition, what effect do the airbrakes have on the sink rate? How might these be used on the approach to landing?</u>

In compare of Flight Polar of 18m span from **Flight Manual DG-1000S**, and the calculated data in question 11, we realize that the data in question 11 matches and corresponds the Flight Polar.



In general, airbrakes are mounted on the upper surface of the wing.
The purpose of airbrakes are to cause reduction in lift and create more drag, this leads to loss of height and reduce in aircraft's velocity.
The effect of the airbrakes on sink rate is nonlinear, opening the airbrakes to half cause a large increase in sink rate, opening the airbrakes further only increases the sink rate slightly.
The drag produced by the airbrakes varies as the square of the speed.
Hence the airbrakes create 4 times more drag at 100 kts than at 50 kts.

This process can be used during approach to landing, depending on the glide slope (glide angle) of the glider with the runway while approaching, can steepen the glide angle without increasing in speed.

13) <u>Please provide a short description of the five modes of motion that are found in the analysis of a conventional aircraft configuration. These must be in your own words, and please provide a sketch showing where you would expect to find them on the complex plane.</u>

LONGITUDINAL RESPONSE:

1) Short Period mode = High frequency, heavily damped oscillatory motion.
It is just felt as a bump by the pilot, and the pilot doesn't have to take any action to kill this mode.

2) Long Period or Phugoid mode = Lower frequency, lightly damped oscillatory motion.
The Phugoid mode persists for a long time. It can be quite annoying if left to die by itself, so the pilot can easily operate the elevator and kill the it.

Longitudinal characteristic equation:

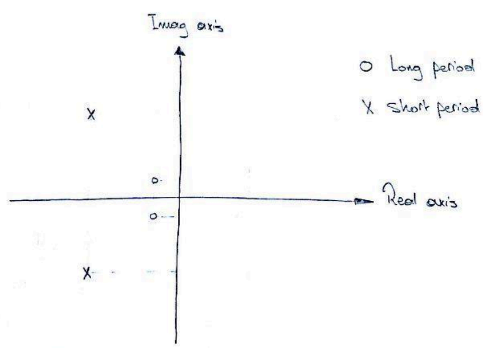
$$A\lambda^4 + B\lambda^3 + C\lambda^2 + D\lambda + E = 0$$

by solving this equation, we have:

$$\lambda_{1,2} = -\eta_1 \pm S_1 i$$

$$\lambda_{3,4} = -\eta_2 \pm S_2 i$$

In order to have damped oscillatory motion, the real part of the complex root need to be negative.



LATERAL-DIRECTIONAL RESPONSE:

1) Roll subsidence mode = Heavily damped roll subsidence mode during which the airplane motion is predominantly rolling about the body axis. This mode is well damped and hardly felt by the pilot.

2) Spiral mode = As encountering a gust that rises one wing relative to the other, the aircraft banks, the nose drops, and the aircraft develops sideslip in the direction of the lower wing. The net result is the aircraft loses altitude, gains airspeed, and banking more and more to the side of the lower wing with an ever-increasing turn rate.

3) Dutch-roll mode = A lateral-directional oscillatory motion following the heavily damped roll subsidence mode. It involves mainly sideslip and yawing motions.

Lateral-Directional characteristic equation :

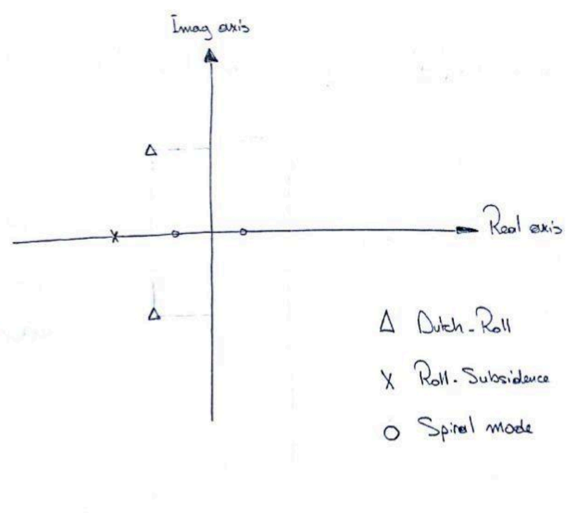
$$A\lambda^5 + B\lambda^4 + C\lambda^3 + D\lambda^2 + E\lambda = 0$$

$\lambda_1 = 0$ (zero)

$\lambda_2 = \pm n_2$

$\lambda_3 = -n_3$

$\lambda_{4,5} = -n_{4,5} \pm s_{4,5}\, i$



14) <u>From the glider flight data, you should be able to identify the phugoid mode. Provide any relevant parameters you can from the response given.</u>

We observe and realize the phugoid mode from glider flight data that at (approximately 2501s timing).
We observe that the pith angle increases and the airplane gains altitude and loses forward speed. Then at a moment the pitch angle goes to zero, and beyond this point, the airplane loses altitude and the pitch angle goes to negative, and the forward speed increases.