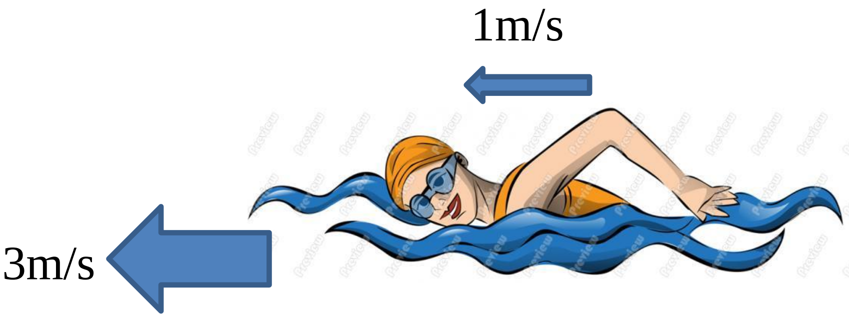
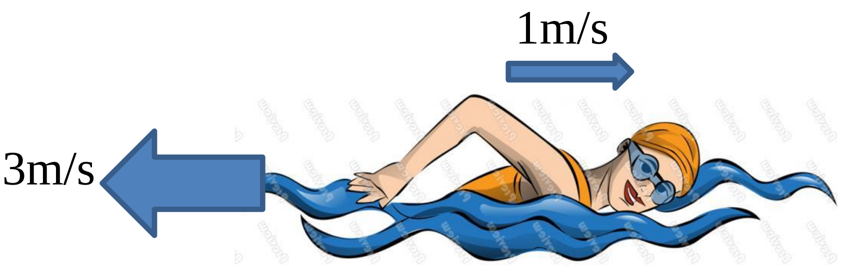
CAN PLANES FLY BACKWARDS?

Firstly, consider this problem of a person who can swim at 1 m/s in a river flowing at 3 m/s.
The river is flowing from **right** to **left** in the pictures below.

CASE A The swimmer is swimming **with** the current.
The result is that the swimmer is travelling at 3 + 1 = 4 m/s

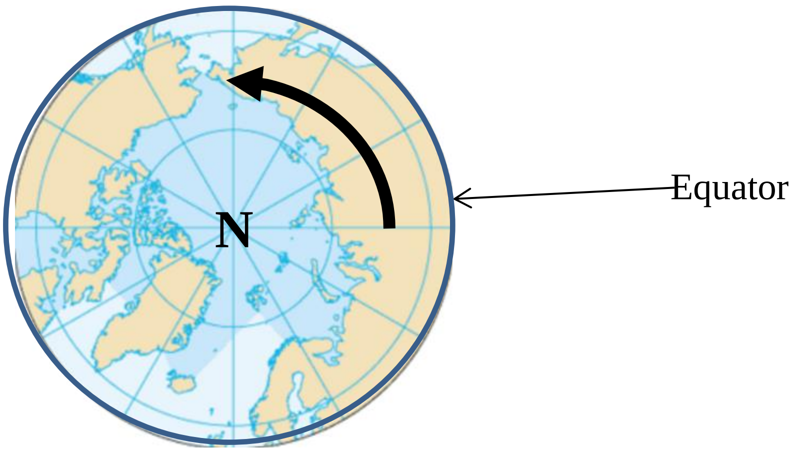


CASE B The swimmer is swimming **against** the current.
Now the swimmer is actually travelling **backwards** at 1 – 3 =–2 m/s



Incidentally, if the river were flowing at 1 m/s and the swimmer was swimming at 1 m/s in the opposite direction, the swimmer would stay in the same place.

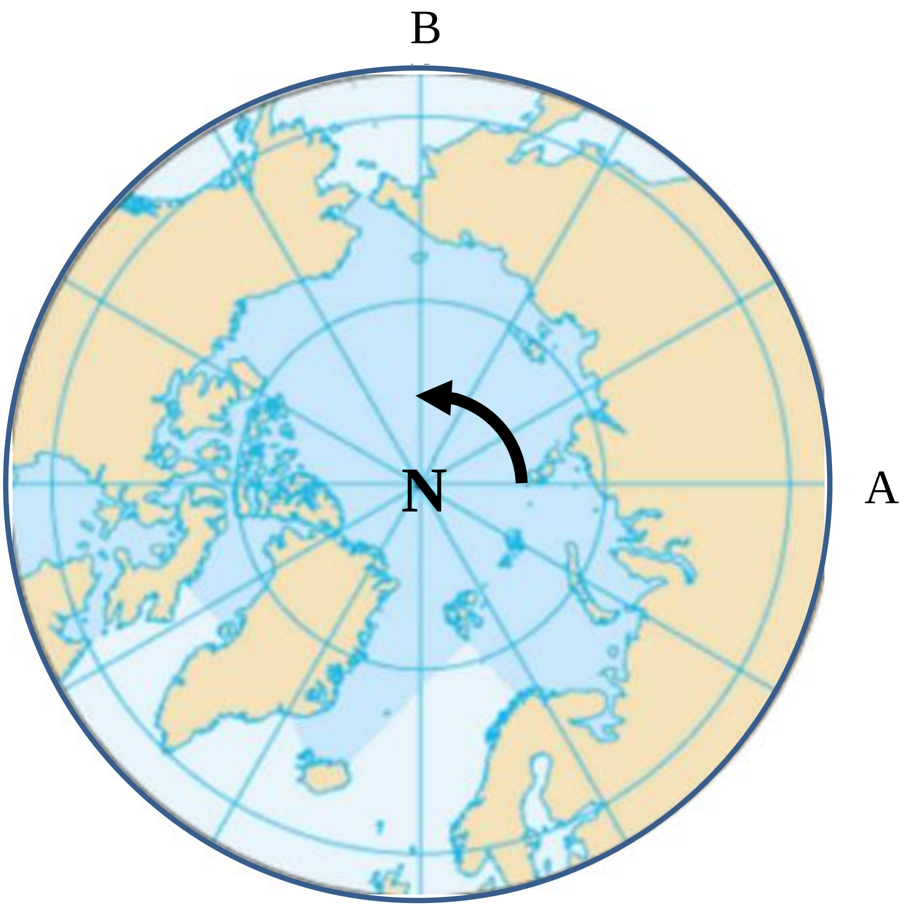
Now consider a view of the Earth from a **stationary position in space**, directly above the North Pole: (the direction of rotation of the earth is marked)



The radius of the Earth at the equator is 6371 Km so the circumference is found by calculating $C = 2\pi r \approx 40030$ Km

The Earth rotates 360^0 in 24 hours so each point on the equator is rotating at a speed of $\frac{40030}{24} \approx 1667.9$ Km/hour

In 6 hours, the point **A** on the equator would rotate 90^0 to the position where **B** is on the diagram below:

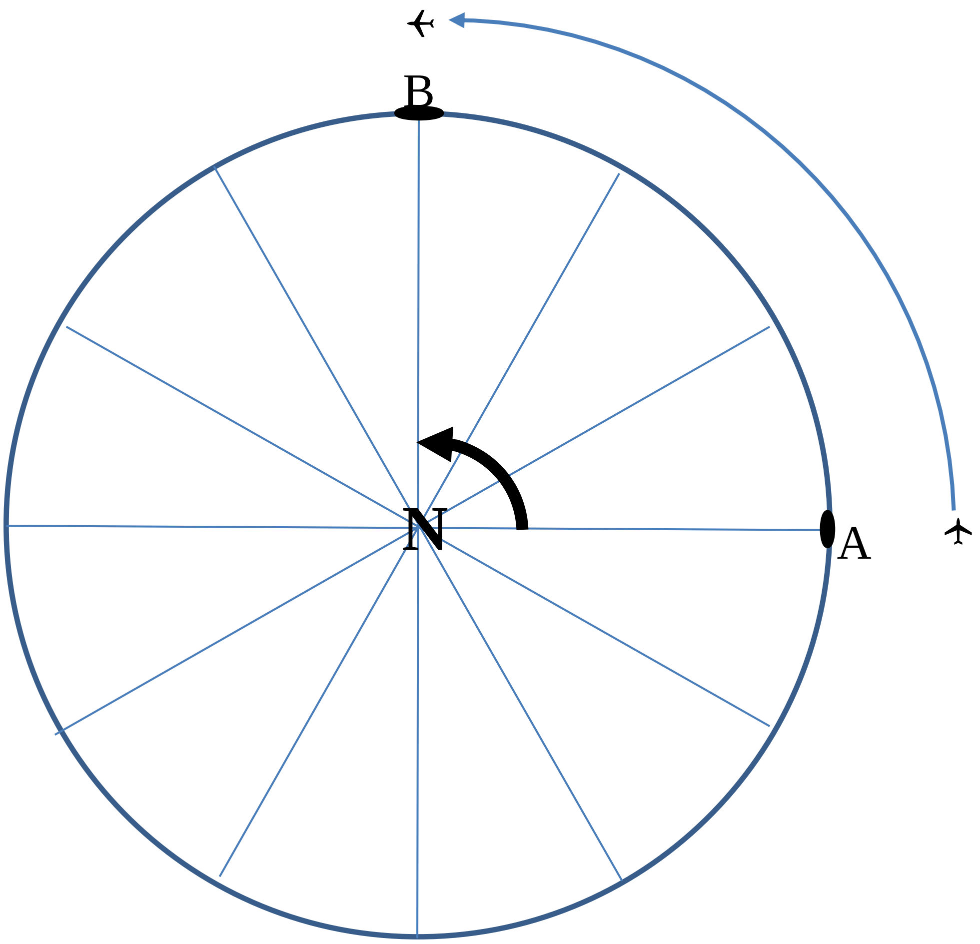


It should be realised that the atmosphere is also rotating with the rotation of the earth.

The earth does not spin independently of the atmosphere or we would have winds of 1667.9 km/h at the surface!

The winds we do have are a result of pressure changes and of course would be negligible compared to this!

Most passenger jet planes travel at about 10 km above the earth and at speeds similar to 1000 km/h. (I will use these numbers for simplicity)
Just to explain a particular idea, I want to imagine that a plane could “hover” like a helicopter.
Imagine a plane hovering 10 km above point A as shown below.

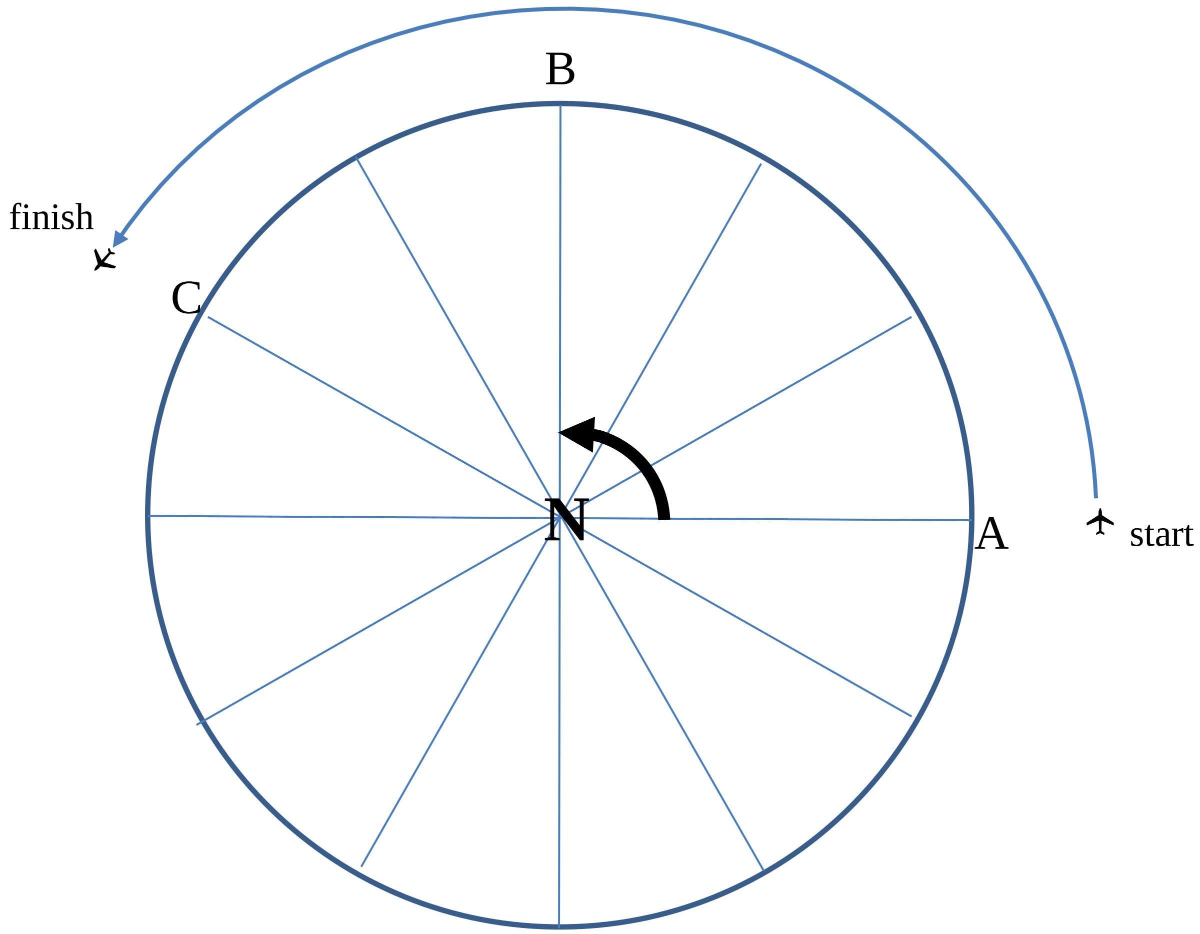


In 6 hours, the earth and its atmosphere would have rotated 90^0 and the hovering plane would be still above the same point on the equator which is now at B.

The radius of the circle in which the plane is travelling is 6371 + 10 so if the plane remained hovering, it would travel a total circumference of $2\times\pi\times6381$ which equals approximately 40093 km.

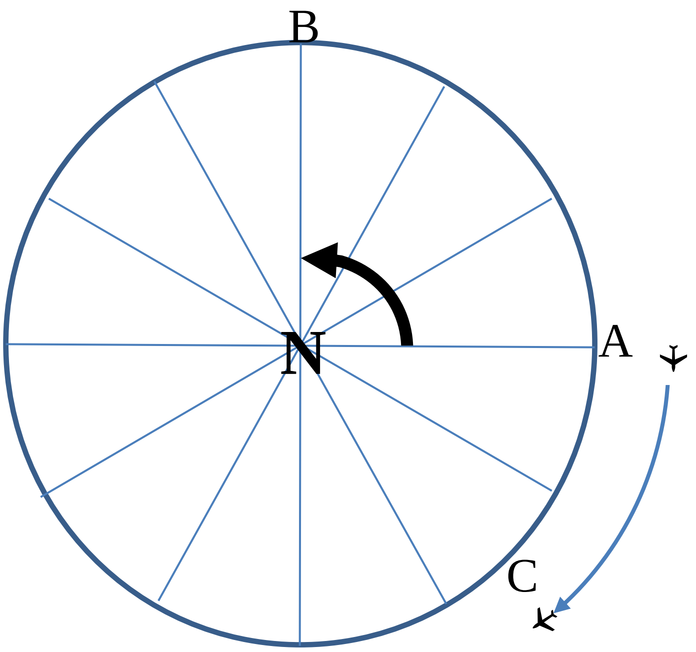
The point A on the equator has moved a ¼ of the equator’s circumference which is approximately 10007.5 km and the plane, which has been hovering above this point, will have moved a ¼ of its own circumference ≈ 10023.25 km.

Now imagine the plane starts from position A on the equator and travels at 1000 km/hour for 6 hours. This of course comes to 6000 km along its own circular path (which is 10 km above the equator).
In that time the earth and atmosphere have also rotated with the plane and the plane has travelled along its path to position C as shown below which comes to 10023.25 + 6000.
Let’s just call this 16023 km
This is similar to the case of the swimmer in the river, swimming <u>with</u> the current.
The actual speed of the plane would be **1000 + 1667.9 = 2667.9 km/h** as viewed from a stationary position in space, directly above the North Pole.

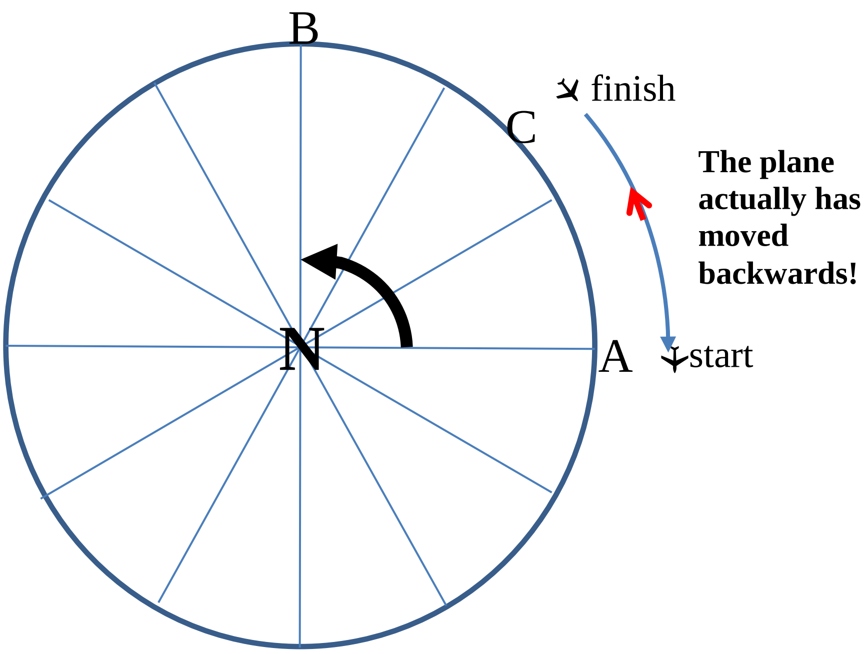


In the 6 hours, the plane will have travelled from position A to position C which is approximately 16,000 km and the starting point on the equator A will have travelled to position B which is approximately 10,000 km.

Now let's consider the plane starting from A and flying 6000 km in the **opposite** direction for 6 hours at 1000 km/h.
If we ignore the earth's rotation, the plane would fly 6000 km and would end up at C as shown below BUT the earth plus its atmosphere and the plane are all rotating anti-clockwise a total of 90^0 in the 6 hour period.



This means that the actual speed of the plane in its clockwise direction is
1000 – 10023 = – 9023 km/h
The actual picture is this:



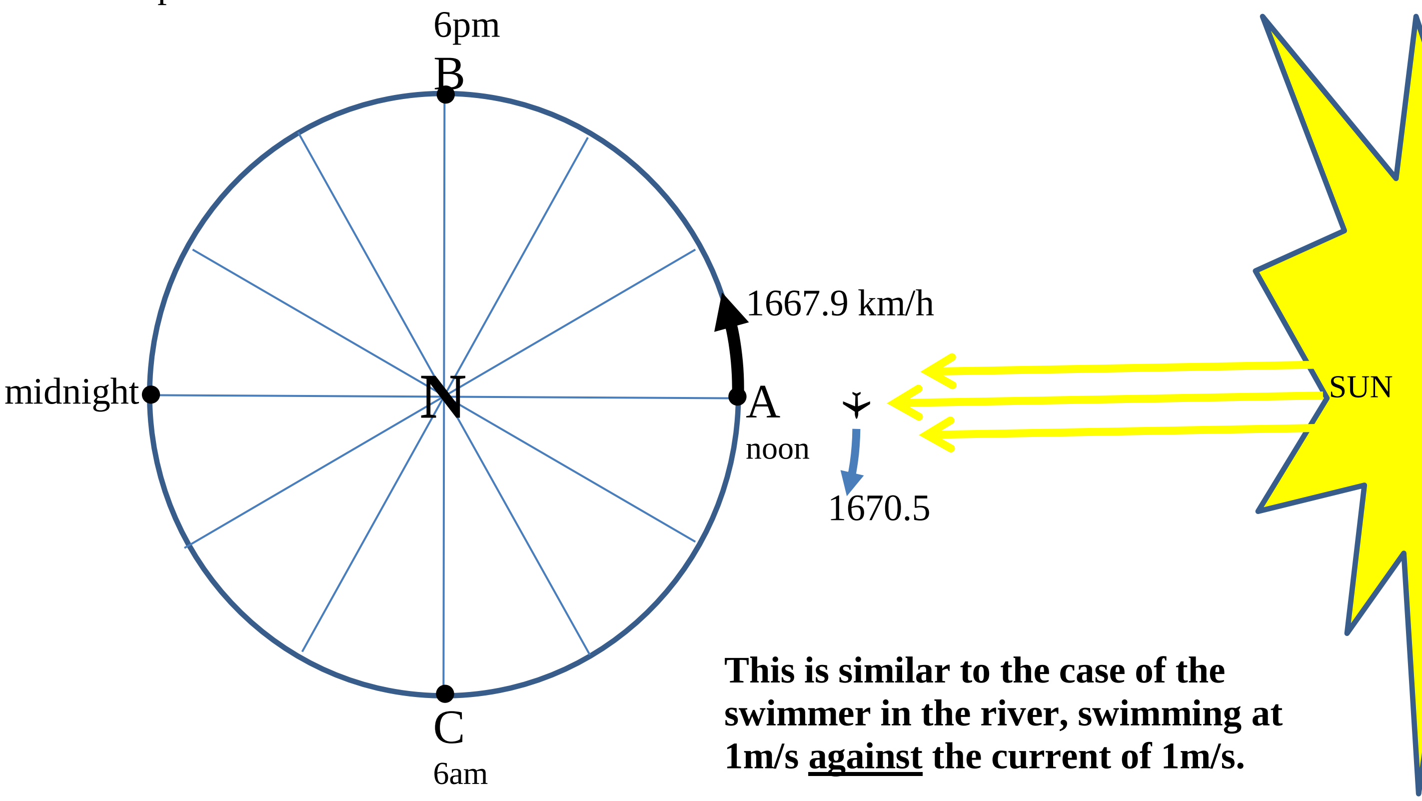
This is similar to the case of the swimmer in the river, swimming <u>against</u> the current.

A very interesting scenario would occur if the plane could travel at the same angular rate that the earth is travelling.

Recall that the radius of the Earth at the equator is **6371 Km** so the circumference is **C = 2πr ≈ 40030 Km**
The Earth rotates 360^0 in 24 hours so each point on the equator is rotating at a speed of $\mathbf{\frac{\underline{40030}}{24} \approx 1667.9}$ **Km/hour**

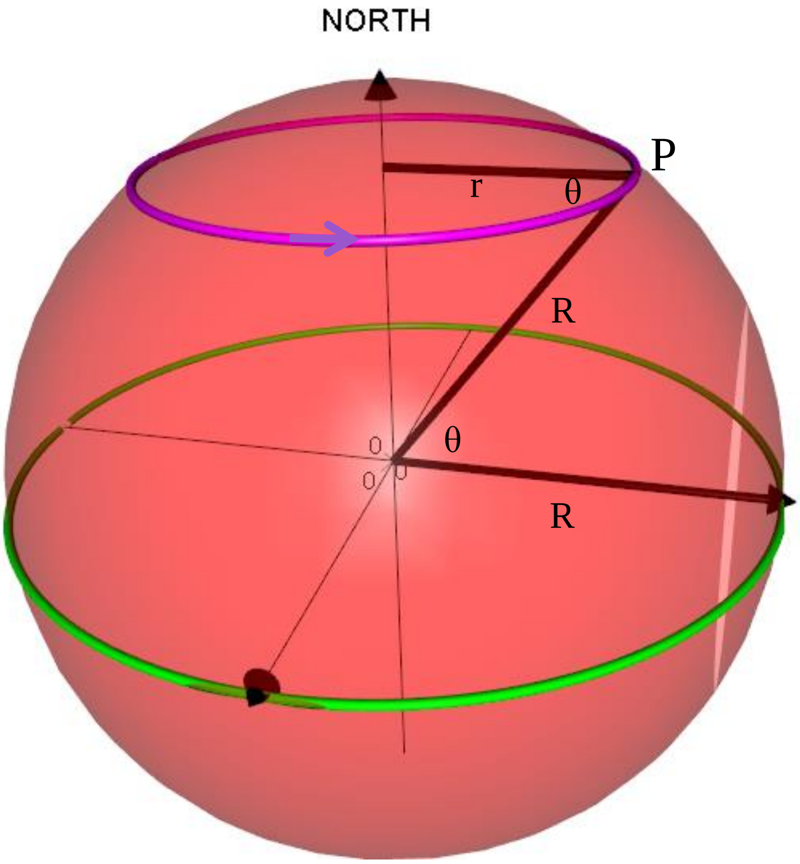
The radius of the circle in which the plane is travelling is **6371 + 10 km** so its circumference is **2×π×6381** which equals approximately **40093 km**.
If the plane could keep up with the earth's rotation then its speed would have to be $\mathbf{\frac{\underline{40093}}{24} \approx 1670.5}$ **km/h**

Suppose it is NOON at point A on the equator and a plane is travelling at **1670.5 km/h** at 10 km above the equator in the opposite direction to the earth's rotation.
In 6 hours the point A will have moved to where B was and it will be 6 pm there.
The point C will have moved to where A was and it will be noon there.
But the plane will still be 10 km above the equator directly above the point C and it will still be NOON since the sun will stay directly above!
The actual speed of the plane as viewed from space would be zero.
It will always be noon at this point but the 'day of the week' will change every time the plane crosses the 'international date line'.



This is similar to the case of the swimmer in the river, swimming at 1m/s <u>against</u> the current of 1m/s.

Another interesting idea is that the speed of rotation of the earth is less than that at the equator at other latitudes. It would be interesting to find an angle of latitude such that a plane could travel along it at 1000 km/h and stay at the same time zone.
Let the radius at the equator = R and the radius of the purple latitude be r.
The circumference of the purple latitude = $\mathbf{2\pi r}$. If it is noon at P on this latitude it would take 24 hours to be noon again the next day.
This means that the speed of point P is $\mathbf{\frac{2\pi r}{24}}$ and if we equate this to **1000 km/h** we can find **r** and consequently find the latitude **θ** using $\mathbf{\cos(\theta) = \frac{r}{R}}$



$\frac{2\pi r}{24} = 1000$
So $r \approx 3819.7$

$\cos(\theta) = \frac{3819.7}{6371}$
$\theta \approx 53^0$

This means at latitude 53^0 North the earth is rotating at 1000 km/h (in an anticlockwise direction, looking down from above North) so a plane travelling at 1000 km/h clockwise would be able to stay at, say, Noon as long as it is flying.