Time

21

By studying this lesson you will be able to,
- understand the reason for the difference in time in two different places on earth at the same instant, depending on their locations,
- calculate the standard time at a given location using time zones, and
- identify the International Date Line and understand the change of date associated with it.

21.1   Introduction

Given below is a news item published in a newspaper.

News

The next ODI between England and Sri Lanka begins at 2.30 p.m. England time at Lord's Cricket Ground and will be telecasted live. You will be able to watch this match from 8.00 p.m. onwards Sri Lankan time.

| England	Sri lanka
2.30 p.m.	**8.00 p.m.**

According to the above news item, the time in Sri Lanka is 8.00 p.m. when the time in England is 2.30 p.m. on the same day.

It is clear that the time can be different in two different places on earth at the same instant.

Let us consider why the time is different at different locations in the world at the same instant.

The earth is a spherical object. Land and oceans cover its surface.

The earth completes one rotation around its axis every 24 hours. This axis is a diameter of the earth. The two end points of the axis are called the North Pole and the South Pole.
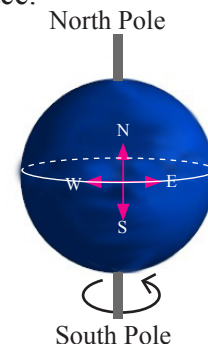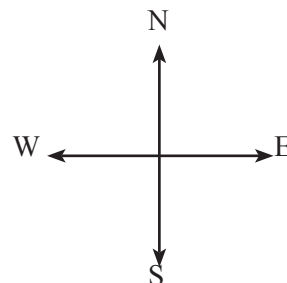
North Pole

South Pole

The direction in which we observe the sunrise is called the East and the opposite direction is called the West. The direction towards the North Pole is called the North and the direction towards the South Pole is called the South.

The hemisphere with the North Pole as its topmost point is called the **Northern Hemisphere**, and the hemisphere with the South Pole as its topmost point is called the **Southern Hemisphere**. The imaginary circle on the surface of the earth which separates these two hemispheres is called the **Equator**.
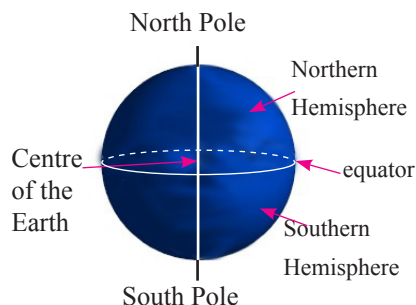
The centre of the Equator is the same as the centre of the earth. The imaginary circles on the earth's surface which are parallel to the Equator are called lines of constant latitude. Latitude is an angle which ranges from $0°$ at the Equator to $90°$ (North or South) at the poles. It is used to specify the location of a place on earth.

When the earth rotates around its axis, the side exposed to the sun receives sunlight and hence experiences daytime while the other side experiences nighttime. Therefore, the time in different places on earth may be different at the same instant.
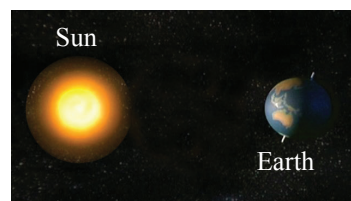
21.2 Longitudes

An imaginary semicircle on the surface of the earth, connecting the North Pole and the South Pole, with the same centre as the centre of the earth is called a line of longitude. Longitude is an angular distance usually measured in degrees which is used to specify the East-West position of a location. Longitudes vary from $0°$ to $+180°$ eastward and from $0°$ to $-180°$ westward from the $0°$ line of longitude which passes through Greenwich, England.
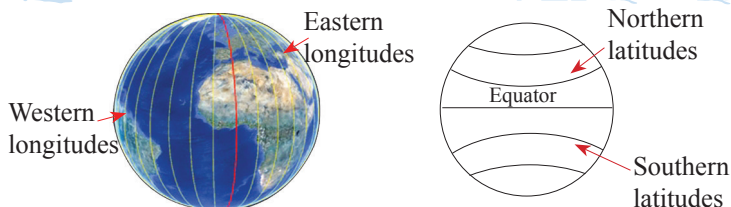
Eastern longitudes

Western longitudes

Northern latitudes

Equator

Southern latitudes

Note

The line of longitude which passes through Greenwich, England is called the **Greenwich Meridian**. The longitude along this line is $0°$.

The longitudes between $0°$ and $+180°$, east of the Greenwich Meridian are called **eastern longitudes** and the longitudes between $0°$ and $-180°$, west of the Greenwich Meridian are called **western longitudes**.

The hemisphere with the eastern longitudes and the hemisphere with the western longitudes are called the **Eastern Hemisphere** and the **Western Hemisphere** respectively.

Western hemisphere

Eastern hemisphere

$0°$
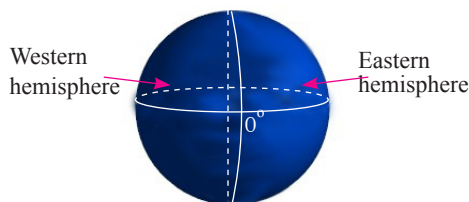
For example, the longitude $23°$ due east of longitude $0°$ is written as $23°E$ and the longitude $105°$ due west of longitude $0°$ is written as $105°W$.

The time taken by the earth to make one complete rotation $(360°)$ around its axis $\Big\} =$ 1 day

$=$ 24 hours

$=$ 24 × 60 minutes

The time to rotate $1°$ $= \dfrac{24 \times 60}{360}$ minutes

$=$ 4 minutes

The time at any location situated on a particular line of longitude is the same.

The time difference between two locations which are $1°$ of longitude apart from each other is 4 minutes. For example, the time difference between the lines of longitude $20°E$ and $21°E$ is 4 minutes.

One rotation of the earth around its axis means a movement of $360°$. The earth takes 24 hours for it.

∴ the number of degrees the earth rotates in an hour $= \dfrac{360°}{24}$

$= 15°$

Note

The time difference between 1° of longitude is 4 minutes. It takes 1 hour for the earth to rotate 15°. Therefore, the earth is divided into 24 times zones where each time zone is bounded by two lines of longitude 15° apart.

When comparing the time in the Eastern Hemisphere with the Greenwich Meridian Time, the time increases by 4 minutes per degree of longitude, because the sun rises earlier in the east due to the rotation of the earth from west to east. Similarly, the time in the Western Hemisphere decreases by 4 minutes per degree of longitude, from the Greenwich Meridian Line towards the west.

21.3 Local time

The time at different locations in the world is calculated based on the longitude of the location and the time along the Greenwich Meridian. This is called the **local time** of that location.

Assume that Colombo is located at longitude 80°E. Let us find the local time in Colombo when Greenwich time is 6:00.

$$\text{The time difference for } 15° \text{ of longitude } = 1 \text{ hour}$$
$$\text{The time difference for } 80° \text{ of longitude } = \frac{1}{15} \times 80 \text{ hours}$$
$$= 5\frac{1}{3} \text{ hours}$$
$$= 5 \text{ hours and } 20 \text{ minutes}$$

Since Colombo is located east of the Greenwich Meridian, we have to add the above time to Greenwich time.

$$\text{The local time in Colombo } = 06 : 00 + 5 \text{ hours and } 20 \text{ minutes}$$
$$= 11 : 20.$$

If Batticaloa is considered to be situated at longitude 81° E, we can obtain the local time in Batticaloa as 11:24 when Greenwich time is 6:00 by using the fact that an increase of 1° of longitude results in an increase in time of 4 minutes, or by calculating the time as above.

21.4 Standard time based on time zones

As we have already observed, the local time can vary from one city to another city even in a small country like Sri Lanka. It is not practical to have different times at different places in the same country when the country is not too large. To avoid this situation, the earth's surface is divided into several time zones. The time of every location within a time zone is considered to be the same at any given moment.

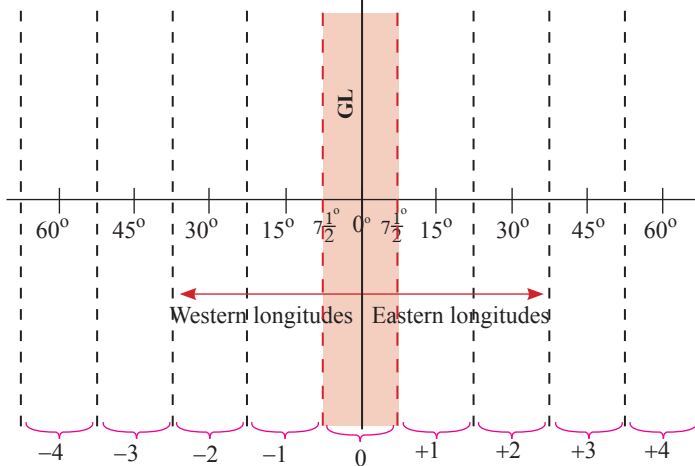The earth's surface is divided into several time zones which stretch from the North Pole to the South Pole as shown in the following figure. It is convenient to mark lines of longitude as parallel lines in figures.

- By taking the Greenwich Meridian as the centre line, the region between $7\frac{1}{2}^{\circ}$ W and $7\frac{1}{2}^{\circ}$ E is named the 0 time zone.

- The 11 regions between lines of longitude placed 15° apart, from $7\frac{1}{2}^{\circ}$ E to $172\frac{1}{2}^{\circ}$ E are named the +1 time zone, +2 time zone, +3 time zone, ... , + 11 time zone respectively and the region between $172\frac{1}{2}^{\circ}$ E and 180° E is named the +12 time zone.

- The 11 regions between the lines of longitude placed 15° apart from $7\frac{1}{2}^{\circ}$ W to $172\frac{1}{2}^{\circ}$ W, are named the -1 time zone, -2 time zone, -3 time zone, ... , -11 time zone respectively and the region between $172\frac{1}{2}^{\circ}$ W and 180° W is named the -12 time zone.
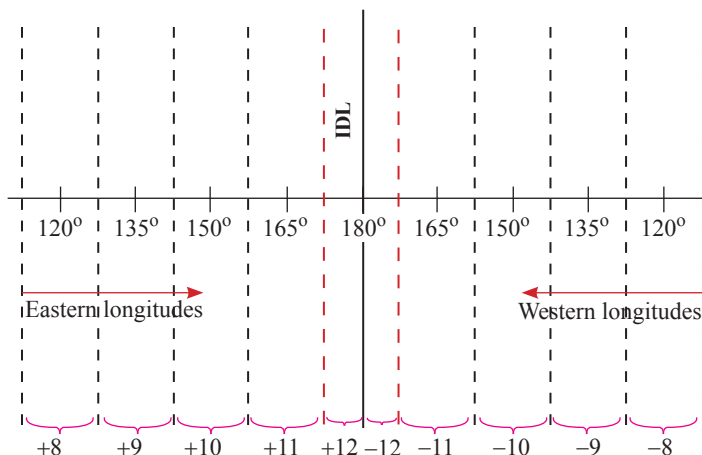

For Free Distribution

Except for a few special situations,

- at a given moment, every place in a particular time zone has the same time.

- the time in a time zone which is adjacent to another time zone west of it, is one hour ahead of the time in the adjacent time zone. The time in a time zone adjacent to another time zone east of it is one hour behind the time in the adjacent time zone.

- The time in Greenwich city at any particular moment is known as the **Greenwich Mean Time** (GMT) of that moment.

- If the GMT of a particular moment is known, the time at any location in the world can easily be calculated. GMT is often used to express global time.

- • When the time in Greenwich is 11.30 a.m. on Sunday the time in the time zone +12 is 11.30 p.m. on Sunday and the time in the –12 time zone is 11.30 p.m. on Saturday (previous day). Hence the time difference between the two zones +12 and –12 is 24 hours.

- ## International Date Line

180ᵒW and 180ᵒE are the same longitude. Since the time in the zones +12 and –12 differ by 24 hours, the International Date Line (IDL) is drawn such that it avoids most of the countries so that the date in two locations of the same country will not be different.
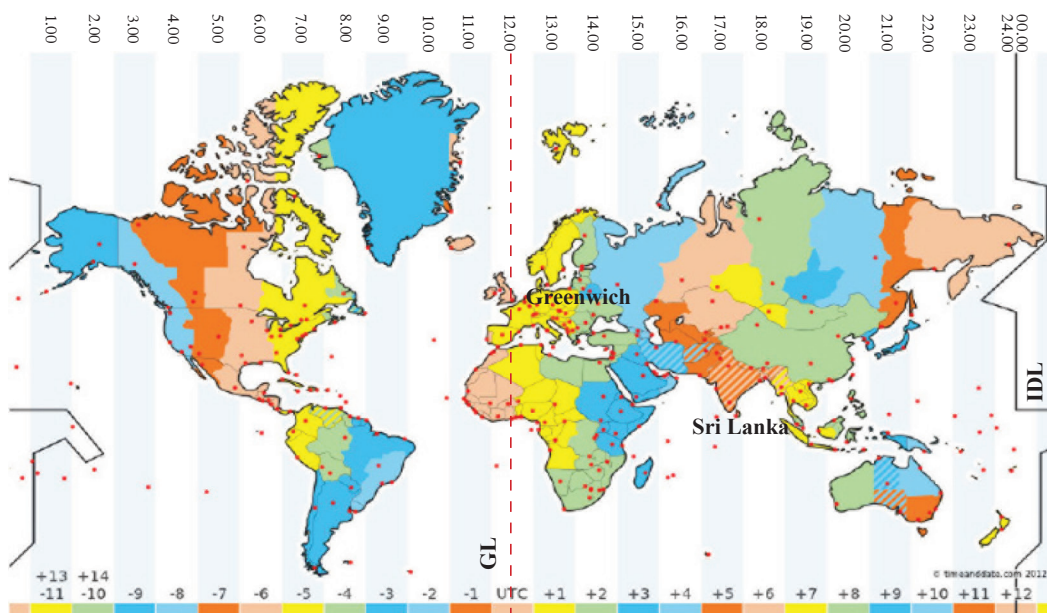
A person who travels from the east to the west across the International Date Line gains an additional day since the current day changes into the previous day across the IDL.

Moreover, a person who travels from the west to the east across the IDL loses a day since the current day changes to the next day across the IDL.

Large countries such as the USA and Australia fall into several time zones. The time in the city of Los Angeles in the USA is 4 hours behind the time in Washington DC which is located to its east.

The difference between the time in the city of Greenwich and the time at any other place, which depends on which time zone the place is located in, is mentioned in the world map given above.

Since India, the largest country situated close to Sri Lanka belongs to both the time zones +5 and +6, the difference between Greenwich time and the time at any place in India is taken to be $5\frac{1}{2}$ hours. That is, the Indian Standard Time is $5\frac{1}{2}$ hours ahead of the GMT. Although Sri Lanka belongs to the time zone +5, Sri Lanka also considers the Indian Standard Time as the Sri Lanka Standard Time due to the ease of maintaining international connections.

Example 1

Find the time in Sri Lanka when Greenwich time is 3.24 p.m. on Monday.

Method I

$$\text{Greenwich time} = 15 : 24$$

$$\text{The time zone to which Sri Lanka belongs} = +5\frac{1}{2}$$

$$\text{Time difference between Greenwich and Sri Lanka} = \left(+5\frac{1}{2}\right) - (0)$$

$$= \left(+5\frac{1}{2}\right)$$

$$\therefore \text{ the time in Sri Lanka} = 15 : 24 + 5 \text{ hours and 30 minutes}$$

$$= 20 : 54 \text{ (same day)}$$
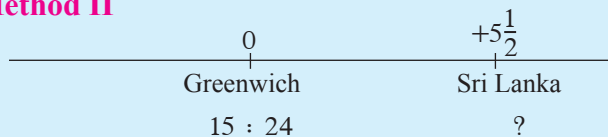
The time in Sri Lanka is 20:54 or 8.54 p.m. on Monday.

Method II

$$+5\tfrac{1}{2}$$

0		$+5\tfrac{1}{2}$
Greenwich		Sri Lanka
15 : 24		?

The time in Sri Lanka $= 15 : 24 + 5$ hours and 30 minutes

$$= 20 : 54$$

The time zone of some of the key cities in the world and the time in those cities when Greenwich time is 12:00 is shown in Table 21.1.

Country/ City	Time Zone	Time in that country	Country/ City	Time Zone	Time in that country
England (London)	0	12:00	Australia (Sydney)	+10	22:00
Bangladesh (Daka)	+6	18:00	Japan (Osaka)	+9	21:00
Thailand (Bangkok)	+7	19:00	Italy (Rome)	+1	13:00
India (Bombay)	+5 1/2	17:30	West indies (Trinidad)	−4	08:00
USA (Los Angeles)	− 8	04:00	Philippines (Manila)	+8	20:00
Sri Lanka (Colombo)	+5 1/2	17:30	Nepal (Thimphu)	+6	18:00
Pakistan (Karachi)	+ 5	17:00	Kuwait (Kuwait)	+ 3	15:00
Malaysia (Kuala Lum-pur)	+ 8	20:00	Norway (Oslo)	+1	13:00

table 21.1

If the time and date of a place A in a particular time zone is known, let us consider how to find the time and date of another place B in a different time zone.

If the time at A according to the 24 hour clock is t and the time difference between A and B is n hours,

Step 1:   Time at $A = t$

Step 2: $n = \dfrac{\text{Time zone of } B}{\text{(as a directed number)}} - \dfrac{\text{Time zone of } A}{\text{(as a directed number)}}$

Step 3: $T = t + n$

Note

- If T is less than or equal to +24, the time at B is T according to the 24 hour clock, on the same day.
- If T is greater than or equal to +24, the time at B is $T - 24$ according to the 24 hour clock, on the same day.
- If T is 0 or negative, the time at B is $24 + T$ according to the 24 hour clock, on the previous day.

Example 2

Find the time in Trinidad, West Indies, when Greenwich time is 3.24 p.m. on Monday.

Method I

$$\text{Greenwich time} = 15 : 24.$$

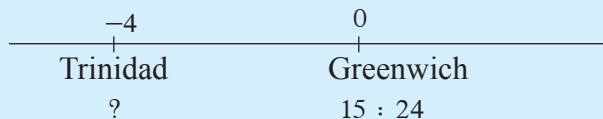$$\text{The time zone to which Trinidad belongs} = -4$$

$$\text{Time difference between Greenwich and Trinidad} = (-4) - 0$$
$$= (-4)$$

$$\therefore \text{ the time in Trinidad} = 15 : 24 - 4 \text{ hours}$$
$$= 11 : 24$$

The time in Trinidad is 11:24 on Monday or 11.24 a.m.

Method II

```
        −4              0
    ────┼───────────────┼────
     Trinidad       Greenwich
        ?            15 : 24
```

$$\text{The time in Trinidad} = 15 : 24 - 4 \text{ hours}$$
$$= 11 : 24$$

Example 3

Calculate the time in Chile when the time in Sri Lanka is 1.15 a.m. on 2017-08-15.

The time in Sri Lanka = 01:15

The Chile time zone = −5

Years	Month	Date	Hours	Minutes
2017	8	15	1	15
−			10	30
2017	8	14	14	45

Method I

The time difference between the two countries $= (-5) - \left(+5\tfrac{1}{2}\right)$

$$= \left(-10\tfrac{1}{2}\right)$$

∴ the time in Chile = 01 : 15 − 10 hours and 30 minutes

$$= -9 : 15 \text{ (previous day)}$$
$$= 24 + (-9 : 15)$$
$$= 24 : 00 - 9 : 15$$
$$= 14 : 45$$

Therefore, the time in Chile is 14:45 or 2.45 p.m. on 2017-08-14.

Method II

−5	0	$+5\tfrac{1}{2}$
Chile	Greenwich	Sri Lanka
14 : 45	19 : 45	01 : 15
2017 - 08 - 14	2017 - 08 - 14	2017 - 08 - 15

Example 4

Calculate the time in Sydney when the time in Sri Lanka is 9.15 p.m. on 2017-08-15.

The time in Sri Lanka = 21 : 15

The Sydney time zone = +10

Years	Month	Date	Hours	Minutes
2017	8	15	21	15
+			4	30
2017	8	16	1	45

Method I

The time difference between Sydney and Sri Lanka $= (+10) - \left(+5\tfrac{1}{2}\right)$

$$= \left(+4\ \tfrac{1}{2}\right)$$

∴ the time in Sydney = 21 : 15 + 4 hours and 30 minutes

$$= 25 : 45 \text{ (next day)}$$
$$= 25 : 45 - 24 : 00$$
$$= 01 : 45$$

Therefore, the time in Sydney is 01:45 on 2017-08-16.

$5(x-y)$ $\sqrt{64}$ $1\frac{7}{10}$ $(-1)^1$

Method II

```
      0              +5½            +10
   Greenwich      Sri Lanka       Sydney
                   21 : 15         01 : 45
                 2017 - 08 - 15  2017 - 08 - 16
```

The time in Sydney = 21 : 15 + 4 hours 30 minutes
                     = 01 : 45   on 2017-08-16.

Note

- USA, Australia and countries in Europe receive sunlight for more than 12 hours a day during the summer period. During these times, because the sun rises early in these countries, daytime is increased by advancing the clock forward by an hour.
- This time period (Daylight Saving Time – DST) is applicable to countries in the Northern Hemisphere from mid March to early November and to countries in the Southern Hemisphere from early October to early April.
- During these periods, the clock is turned forward one hour, so 1 hour should be added to the usual time.

Exercise 21.1

(1) Complete the table given below stating the time in each time zone when the time in the 0 time zone is 12 noon.

Time zone	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+11	+12
Time	12:00											

Time zone	−12	−11	−10	−9	−8	−7	−6	−5	−4	−3	−2	−1	0
Time													12:00

(2) Write the time and the date in each time zone when Greenwich time is 18:00 on Friday 2016-08-19.

Time zone	−11	−6	−3	0	+4	+7	+10	+11
Time				18:00				
Date				Friday, 2016-08-19				

(3) When the time in Bangkok in the +7 time zone is 16:00, find;
    (i) the time in Auckland, New Zealand in the +12 time zone.
    (ii) the time in Athens, Greece in the +2 time zone.
    (iii) the time in Trinidad in the –4 time zone.

(4) When the time in Nuuk, Greenland in the –3 time zone is 01:00 on 2016-10-20, find;
    (i) the time and date in Chicago in the –6 time zone.
    (ii) the time and date in Bangkok in the +7 time zone.

(5) When the time in Vancouver, Canada in the –8 time zone is 18:00 on 2016-10-29, find;
    (i) the time and date in Greenwich.
    (ii) the time and date in Abu Dhabi in the +4 time zone.

(6) When the time in Philippines in the +8 time zone is 19:00 on 2016-11-02, find;
    (i) the time and date in a country in the +12 time zone.
    (ii) the time and date in a country in the –12 time zone.
    (iii) the time and date in Honolulu located in the –10 time zone.

(7) When the time in Sri Lanka is 09:30 on 2017-05-02, find the time and date in Los Angeles located in the –8 time zone in the USA.

(8) An aeroplane takes off from Dubai located in the +4 time zone at 13:00. It arrives in Manila in Philippines, located in the +8 time zone at 20:00.
    (i) Find the time in Manila when the aeroplane departs from Dubai.
    (ii) Find the time duration of the flight.
    (iii) What is the time in Dubai when the aeroplane arrives in Manila?

Miscellaneous Exercise

(1) Sri Lanka is located in the $+5\frac{1}{2}$ time zone. Dileepa who departs from the Katunayaka airport at 14:30 Sri Lankan time, travels to Trinidad in West Indies through London.
    (i) He arrives in London after a journey of 6 hours. What is the time shown on his wrist watch which indicates Sri Lankan time?
    (ii) If London is located in the 0 time zone, what is the time in London when the flight reaches there?

(iii) After adjusting the time on his wrist watch according to the time in London, Dileepa departs for West Indies by another flight. If he spends one hour at the London Airport prior to departure, and it takes 3 hours for the journey, what is the time in West Indies in the –4 time zone when he reaches there?

(2) An aeroplane departs from Dawson located in the –8 time zone at 6:00 a.m. on Monday, flies across the IDL and arrives in Tokyo (Japan) in the +9 time zone. If the flight arrives in Tokyo at 4.00 p.m. on Tuesday, find the time taken for the journey.

(3) Singapore is located in the +8 time zone. An aeroplane departs from Singapore at 3.00 p.m. (15:00) on Monday and travels across the IDL to Honolulu located in the –10 time zone. If it takes 12 hours for the journey, find the local time and date when it arrives in Honolulu.

Summary

    The 0° longitude line which passes through Greenwich, England is called the Greenwich Meridian.

    The 0 time zone is a region of 15° of longitude with $7\frac{1}{2}^o$ of longitude lying to the west of the Greenwich Meridian and $7\frac{1}{2}^o$ of longitude lying to its East.

    Sri Lanka is located in the $+5\frac{1}{2}^o$ time zone and therefore the time in Sri Lanka is 5 hours and 30 minutes ahead of Greenwich Mean Time.

    The time in the + time zones is ahead of Greenwich Mean Time and the time in the – time zones is behind Greenwich Mean Time.

    The date changes by one day across the International Date Line.