Happy Birthday POW! - Keira, Claire, and Samhitha (Aces)

PROBLEM STATEMENT:

How can someone born within the current century (1901-2099) find the day of the week they were born on? Our goal was to develop a method that someone with limited math skills could follow to find the day of the week they were born on.

Parents don't remember what day of the week their child was born on. So, using only information about the number of days in a month, the 2023 October calendar, and a calendar, how can you find what day of the week you were born on?

PROCESS:

In order to solve this problem, we first listed some patterns we noticed and made sure to note down important numbers, such as the number of days in a year/leap year—there are 365 days in a "normal" year and 366 days in a leap year. Leap years occur on years that are a multiple of 4 (every 4 years). February 29 is the extra day in the leap year.

We then noticed that birthdays have day shifts when comparing them by year. When we say "day-shift", we mean how many days forward your birthday will be in the weekly calendar compared to the prior year. We noticed that birthdays shift by 1 day each normal year. This is because 365 divided by 7 gives us a remainder of 1. Therefore, there will be a 1-day shift every normal year. For example, a Monday birthday in 2022 would be on a Tuesday in 2023.

However, leap years are a different scenario. In order to find the day-shift for leap years, we must look at leap years in 2 cases: the first case being if your birthday is before March 1st, and the second case being if your birthday is on or after March 1.

Case 1: If your birthday is before March 1st, there will be a 2-day shift **after** the leap year. This is because it is not affected by Feb 29 since your birthday occurs before Feb 29 happens. However, because of this extra day, the next year will result in a 2-day shift because 366 days will pass between your birthday this year and next year, and 366 divided by 7 gives us a remainder of 2. For example, if you had a February 20 birthday on a Monday in 2023, your birthday would be on a Tuesday in 2024 and on a Thursday in 2025.

Case 2: If your birthday is on or after March 1, there will be a 2-day shift **on** the leap year. This is because Feb 29 happened before your birthday. The year after the leap year will have a normal 1-day shift as you wait 365 days for your next year's birthday. For example, if you have a June 28 birthday on a Wednesday in 2023, your birthday would be on a Friday in 2024 and on a Saturday in 2025.

In order to solve this problem, our group tried to go backward. We were given a list of famous people, their respective birthdays, and the day of the week we were born. We tried to take the day they were born and then tried to find what day their birthday would fall in 2023, as we were given a 2023 October calendar to base calculations off of. We chose Kristi Yamaguchi's birthday (July 12, 1971), who was born on a Monday.

Her birthday is July 12, so we tried to find out what position her birthday is in a 365-day year. In other words, we found out how many days after Jan 1 their birthday would occur. To do this, we used the given chart, which states the number of days in each month:

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
31	28*	31	30	31	30	31	31	30	31	30	31

*29 in leap years

We added the total number of days in each month before their birthday month and added the day they were born. In Yamaguchi's case, we would do 31+28+31+30+31+31+12. This summed up to 194, meaning her birthday is the 194th day of the year.

Then, we found the number of years difference between the birth year and 2023 (our given calendar year). So, we did 2023-1971, which gives us 52 years.

In order to find the day shift from 1971 to 2023, we have to look at it in 2 parts: leap years and normal years. There are 52 years, and leap years occur on every 4th year multiple. So, we can divide 52 by 4 to see how many leap years occur between 1971-2023. 52 / 4 = 13, so there are 13 leap years. These 13 leap years give us 13 extra day shifts, so we can account for the extra shift by adding 13 to 52. This way, the 2-day shifts are counted per leap year. 52 + 13 = 65, which means that from 1971, July 21 shifts 65 days in the weekly calendar.

Next, we divided this day shift by 7 and found the remainder. This is because there are 7 days in a week, so a 7-day shift will give us the same day we started with. Dividing by seven will remove those same day occurrences. 65 / 7 is 9 remainder 2. This means that in the 65-day shift, we land on Monday 9 times. Since there is a remainder of 2, we have to add 2 days to Monday to see what day July 12 is in 2023. 2 days after Monday gives us a Wednesday, which means Yamaguchi's birthday is on a Wednesday in 2023.

But now, we have to find out how to find the day of week in a different year, as that is what our problem is looking for. Realistically, we do not know what day of the week every day was in 2023. Therefore, we had to find a method to find the person's weekday in 2023. We were given a 2023 calendar for October, and we saw that October 1, 2023, fell on a Sunday. We used this day as a benchmark to find the birthday weekday in 2023.

Using the monthly chart that was given, we found that October 1 is the 274th day of the year. Then, we could find the number of days before or after October 1st that their birthday falls on.

For example, July 12 is the 194th day of the year, and it is before October 1st. 274 - 194 = 80. This means that 80 days before 274 is when July 12 occurs. Again, we divided 80 by 7 and found the remainder to find the weekday difference between Sunday and the weekday of July 12. 80/7 gives us a remainder of 3. This remainder gives us the day of the week that July 12th fell on in 2023, which was a Wednesday, which is what we got when we did our initial process.

To find our final solution and procedure, we compiled these steps but rewrote them backwards. We made the procedure such that the user would find the day their birthday is in 2023 first. Then, we tried our procedure for different cases of birthdays to make sure our procedure accounted for all of the different birthday scenarios. We tried birthdays after 2023, and we tried birthdays before and after March 1. We noticed that birthdays before and after March 1 aligned with our procedure and resulted in the correct weekdays. This is because the 2-day shift occurs regardless of the birth date; the only thing that changes is when the shift happens.

However, we noticed that there were two cases where our procedure was not completely accurate. The cases were when the birthday was on a leap year after 2023 and was after February 28, and when the birthday was on a leap year before 2023 and was before February 28.

Case 1: When the birthday was on a leap year after 2023 and after February 28. For example, if we took June 28, 2032 and followed our procedure, we would have the following answers:

June 28 = 179th day of the year
274 - 179 = 95 day difference
95/7 gives us a remainder of 4
Going backwards (June 28 is before October 1), June 28 is a Wednesday in 2023
2032 - 2023 = 9 year difference
9/4 gives us a quotient of 2
9 + 2 = 11 day difference
11/7 gives us a remainder of 4
Going forward (2032 is after 2023), would be a Sunday

However, we must remember that their birthday is after Feb 29 of the year they were born. Since they were born after 2023, we have to add an extra day shift to account for Feb 29 in their birth year. So, when we go forward one day, we get June 28, 2032 to be a Sunday.

Case 2: When the birthday was on a leap year before 2023 and before February 28. For example, if we took January 2nd, 1964 and followed our procedure, we would get the following answers:

January 2 = 2nd day of the year
274 - 2 = 272 day difference
272/7 gives us a remainder of 6
Going backwards (Jan 2 is before October 1), Jan 2 is a Monday in 2023
2023 - 1964 = 59 year difference
59/4 gives us a quotient of 14
59 + 14 = 73 day difference
73/7 gives us a remainder of 3
Going backward (1964 is before 2023) would be a Friday

However, we must go backwards one more time. This is because when we divide by 4, we get the number of leap years, including the birth year. Therefore, when we went backwards on the last step, we counted a second shift for the birth leap year. However, because this birthday was before Feb 29, it does not shift a second time. Therefore, we must go backwards to "remove" this extra shift.

After we found these cases, we made our final procedure and made sure to be as descriptive yet simple as possible to help the user understand exactly what they must do. We realized that going forward and backward may be hard for someone to keep track of. Therefore, we added an extra step to make it so the user only has to go forward, regardless of whether their birthday was before or after October 1.

Since the week calendar has 7 spaces, going backwards by x spaces is the same as going forwards by (7-x) spaces. Therefore, we added extra steps for people that were born before Oct 1, and they would subtract their remainders from 7 before shifting.

In the end, we have a procedure that finds the weekday a person was born on for any birthday from 1901 to 2099.

SOLUTION:

Our solution is as follows:

Please keep track of your answers from each step:

A. Know your birthday, birth month, and birth year, and write that down.

B. Now find what position day of the year your birthday is during 2023, using this table:

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
31	28*	31	30	31	30	31	31	30	31	30	31

*29 in leap years

To do this, add up the number of days in each month of a non-leap year before your birth month, then add the day of the month you were born to that number.

C. Using the process above, we know that October 1st is the 274th day of the year. We know that this day is a Sunday, so we will use this date to base our calculations on. Perform the following equation, which finds how many days from October 1st your birthday is

Part B answer – 274

D. Make sure the answer from Part C is kept positive. **Divide your answer from Part C by 7** and keep the remainder.
   a. If your birthday is before October 1, subtract your remainder from 7.
   b. If your birthday is after October 1, leave the remainder as is.

E. Each day of the week corresponds to a number. This is shown in the following chart:

Day of the week	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Corresponding number	0	1	2	3	4	5	6

F. Based on the chart, use Part D to find the day of the week that your birthday was in 2023. Go forward with your answer to Part D, starting at 0 (Sunday).

G. Do **2023 – your birth year**, make sure to make it positive and save that number

H. **Divide that answer by 4** and find the quotient; ignore the remainder.

I. Take the number from part G, and add your answer from part H to it. Add 1 to this answer only if your birthday satisfies the following conditions:
   a. If your birthday was on a leap year after 2023 and it is after February 28.
   b. If your birthday was on a leap year before 2023 and is on or before February 28.

J. Take that number, **divide by 7** and find the remainder.

K. Now remember what day you had in part F.
    a. If you were born before October 1st, 2023, subtract the remainder from 7 and keep the number
    b. If you were born after October 1st, 2023 keep the remainder as is

    Go forward by the number you have now.

L. That day of the week is the day you were born!

SOLUTION SUMMARY:

Our solution begins by asking for the date of birth of the person, as the day, month, and year will all be used in finding the solution. We next find what day, out of 365, the person's birthday falls on in order to figure out how many days backwards or forwards we needed to go to find what day of the week they were born on in 2023. We already know that October first is the 274th day of the year, and it is a Sunday, so by subtracting it from part B, we find how many days apart the two days are. A week is seven days, and a week repeats, meaning that if we divide the difference by 7 and find the remainder, we will find the shift of weekdays between the person's birthday and October first. This only works for positive numbers, so for negative numbers we need to first make it positive, and then do the same. If the person's birthday was before October first, subtract the remainder from 7, and if the person's birthday was after October first, leave the remainder as is. The number found is the difference in week days between the birthday and October 1st, 2023. We assign each day of the week a number (Sunday is 0, Monday is 1, Saturday is 6), since, October 1st, 2023 is a Sunday, or 0, adding the number found to 0 is the day of the week that the person's birthday is in 2023, and we will use this to calculate when their birthday is in their birth year.

To find the day of the week the person was born on, the shift in days of the week from 2023 to their birth year is needed. Between two normal years a birthdate shifts forward one weekday. Therefore, we start by subtracting their birth year from 2023, and taking the absolute value of that number. Although every four years a leap day will cause the weekday your birthday falls on to shift forward 2 days. Hence we need to divide that answer by 4 and take the quotient, ignoring the remainder, to find the number of leap years, and thus, extra day shifts, that have occurred or will occur between 2023 and the person's birthday. We then add the number of leap years, plus the number of years between 2023 and the person's birthday to find how many day shifts have occurred. On birthdays on leap years after February and after 2023, or birthdays on leap years before February before 2023, an extra 1 needs to be added to compensate for a day shift that is lost. The number of day shifts is divided by 7 and the remainder is found; this was

done because the weekdays run in a cycle, and dividing by 7 and finding the remainder gets rid of the cycles, so less counting is needed. The day of the week found for 2023 is used again to base the shift of days off of, and if the year the person were born in was before October first, 2023, then shift backwards from the weekday in 2023 by the remainder, and if the year the person was born in was after October first, 2023, shift forwards from the weekday in 2023 by the remainder. The day that results after the shift is the day the person was born.

We know that our solution is correct and complete because we tested it with a variety of dates before and after October first, 2023. Based on those tests we refined our steps, and were able to create a complete solution and made sure it worked for many possible cases

EXTENSIONS:

What week out of 52 were you born in?
This extension can be used to make the problem easier or introduce a way of looking at the larger and more difficult weekday problem.

Can this process be coded into a program that gives the weekday a person was born on when their birth date was entered?
This extension could be used to have students show a deeper understanding of their solution and make connections between different academic fields.

Given the weekday, month, day, and range of years a person was born on, how small of a range is needed to pinpoint their year of birth? Why?
This extension is around the same difficulty to solve, when given the same materials one would have to use similar logic to that used for the problem given. They would have to approach the problem by looking at the yearly shift in weekday of a given date to discover when and why the cycle repeats.