Unlocking the Mystery of The Hebrew Calendar

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Bibliography

- **Understanding the Jewish Calendar**, Rabbi Nathan Bushwick, Moznaim Publishing Corp. 1989
- **Halachic Times for Home and Travel**, Professor Leo Levi, Rubin Mass Ltd., 1992
- **The Comprehensive Hebrew Calendar**, Arthur Spier, Feldheim, 1986
- **Bircas HaChamah**, Rabbi J. David Bleich, Artscroll, 2009
- Encyclopedia Judaica, *Calendar*
- [http://individual.utoronto.ca/aribrodsky](http://individual.utoronto.ca/aribrodsky)
- [http://www.geocities.com/Athens/1584](http://www.geocities.com/Athens/1584)
- **Mishnah Torah**, Laws of Sanctification of the Moon, ch. 6-10
Lift up your eyes on high and see: who created these? He who brings out their host by number, calling them all by name; by the greatness of His might and because He is strong in power, not one is missing… (Is. 40:26)
1. Terms & Definitions
2. The Leap Year Cycle – המגזר הקטן
3. Setting the Calendar
4. So What does the Calendar Look Like?
5. Setting the Holidays: The Four Dechiyot
6. The קביעה (K’vi’a) – Year Types
7. Practical Calendar Issues (Anniversaries, Parshiyot)
8. Solar Calendar Mitzvoth: Birkat Hachamah
    Tal Umatar
I. Terms & Definitions
And God made two great lights; the large light to rule the day, and the small light to rule the night; and he made the stars....and God saw that it was good. (Gen. I)
The Astronomical Model
Calendar Definitions

**ASTRONOMICAL**

- **DAY:** 1 complete rotation of earth on its axis (divided into 24 equal units)
- **MONTH:** (synodic) “The mean interval between conjunctions of the Moon and Sun, corresponding to the cycle of lunar phases.” (~29.53 days)
- **YEAR:** 1 complete rotation of earth around the sun.

**HALACHIC**

- **DAY:** 1 complete cycle of setting, rising, and setting of the sun
- **MONTH:** Appearance of one new moon and the next
- **YEAR:** 1 cycle of long and short days = 1 cycle of seasons.
Definitions (continued)


tקופת תמוז
Tekufat Tamuz

**Summer Solstice**

Latin SOL (sun) + SISTERE (to stand still) - at the solstices, the Sun stands still in declination; longest day of the year, 1st day of summer.


tקופת טבת
Tekufat Tevet

**Winter Solstice**

shortest day of the year, 1st day of winter


tקופת ניסן
Tekufat Nisan

**Spring (Vernal) Equinox**

day=night, Latin AEQUUS (equal) + NOX (night), 1st day of Spring


tקופת תשרי
Tekufat Tishrei

**Autumnal Equinox**

day=night, 1st day of Fall


מולד
Molad

Conjunction of the moon between earth and sun - average time of appearance of moon from month to month (approximate definition, to be redefined later).
The Solar-Lunar Problem

The Problem

- 12 months (moon) = \( \approx 29\frac{1}{2} \times 12 \) = 354 d
- 1 year (sun) = \( \approx 365\frac{1}{4} \) d
- Difference: 11¼ days

Alternative Solutions

- **Roman Calendar: SOLAR**
  - Months lose connection to moon, 1/12th of Year.
- **Moslem Calendar: LUNAR**
  - Months lose connection to seasons.
The Ancient Egyptian Calendar

- Solar Year of 365 days
- 12 months x 30 days
- 5 days ‘added to the year by the god Thoth’
  - Birthdays of Osiris, Isis, Horus, Nephthys, and Set.
- Earliest civilization to accurately measure the solar year at 365 ¼ days, based on rising tides of the Nile.
- Julius Caesar's revolution of the Roman Calendar (46 BCE) based on his encounter with Cleopatra, and his enthrall with the simplicity and neatness of the Egyptian Calendar.
The Hebrew Calendar

יהיו בטש כספים

- Pesach must always fall after the spring/vernal equinox
- Link solar and lunar calendars by intercalating one month into the year every ~3 years (GRAVID or LEAP YEARS)
- Add alternative criteria re Holidays TBD
Attributed to Hillel II

Year 4111 to Creation or 351 CE

2 centuries after the destruction of the Temple.
R. Simeon b. Pazzi said in the name of R. Joshua b. Levi on the authority of Bar Kappara: He who knows how to calculate the cycles and planetary courses, but does not, of him Scripture says, ‘but they regard not the work of the Lord, neither have they considered the operation of his hands.’
Calendar Math

- **Molad** = The conjunction of the moon with the sun - the point at which the moon is directly between the earth and the sun (but not on the same plane) and is thus invisible (Encyclopaedia Judaica).
  - Note: defined from Jerusalem.

- The **Length** of the Molad is the average length of the cycle of the moon, from Molad to Molad.

- **1 Hour = 1080 parts** (Chalakim)
  - Wholly divisible by: 2, 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 20, 24, 27, 30

- **1080 / 60 = 18**
- **18 parts = 1 minute**
- **1 part = 3½ seconds**
Calendar Clock!

24 hour clock
Arbitrarily Starting @ 6:00pm

2d 3h = Sunday 9:00pm
0d 0h = Friday 6:00pm
0d 6h = Saturday 12:00am
5d 18h = Thursday 12:00pm
6d 22h = Friday 4:00pm
II. The Leap Year Cycle

המחזור הקטן
Safeguard the ‘springtime month’ so that you will be able to keep Passover to the Lord your G-d, since it was in the ‘springtime month’ that the Lord your G-d brought you out of Egypt, at night. (Deut 16:1)

G-d said to Moses and Aharon in Egypt: This month shall be for you the ‘head month.’ It shall be the first month of the year. (Ex. 12:1-2)

Midrash Sod Ha’ibur
At that moment, G-d transmitted to Moshe Rabeinu the precise rules for calculating the new moon, and informed him how to intercalate the year and establish the months...
The Dynamic Calendar & the Authority of the Beth Din

Mishnah RH 25a
On another occasion two witnesses came and said, we saw it at its proper time, but on the night which should have been new moon it was not seen, and Rabban Gamaliel [had already] accepted their evidence. Rabbi Dosa b. Harkinas said: they are false witnesses. How can men testify that a woman has born a child when on the next day we see her belly still swollen? Said R. Joshua to him: I see [the force of] your argument. Thereupon Rabban Gamaliel sent to him to say, I enjoin upon you to appear before me with your staff and your money on the day which according to your reckoning should be the day of atonement. R. Akiba went [to R. Joshua] and found him in great distress. he said to him: I can bring proof that whatever Rabban Gamaliel has done is valid, because it says, *these are the appointed seasons of the lord, holy convocations, which ye shall proclaim in their appointed seasons*, [which means to say that] whether they are proclaimed at their proper time or not at their proper time, I have no appointed seasons save these… He [R. Joshua] thereupon took his staff and his money and went to Jabneh to Rabban Gamaliel on the day on which the day of atonement fell according to his reckoning. Rabban Gamaliel rose and kissed him on his head and said to him: come in peace, my teacher and my disciple — my teacher in wisdom and my disciple because you have accepted my decision.
“Our Sages taught: Once the heavens were covered with clouds and the likeness of the moon was seen on the 29th of the month. The public thought to declare a ‘new moon’, and the Rabbinical Court wanted to sanctify it, but Rabban Gamliel said to them: ‘I have it on the authority of my father’s father that the renewal of the moon takes place after not less than twenty-nine and a half days, two-thirds of an hour, and seventy-three parts of an hour.’”
אורך חודשה של לבנה פחתת מעשרים וחמש שעות ועשרים ושש וחצי שניות
שהיא שעה ושבעים ושבעה חלקי מיום (ריה' חת).

\[29.5 \text{d} + \frac{2}{3} \text{h} + 73 \text{p}\]

1 hour = 1080 p

\[\frac{2}{3} \text{h} = 720 \text{p}\]

MOLAD = 29d 12h 793p

כ"ט י"בتش Cumberland
Accuracy of Molad

Molad: 29d 12h 793p = 29d 12h 44m 3\frac{1}{3}s
Astronomical: 29d 12h 44m 2.8s \[1\]

Difference:
- 0.5 second / month
- 6 seconds / year

In 2000 years the calendar would have lost 12,000 seconds, or 3\frac{1}{3} hours

1 day every 14,400 years!

# Length of Lunar Year

<table>
<thead>
<tr>
<th>Length of Lunar “Simple” year</th>
<th>29d</th>
<th>12h</th>
<th>793p</th>
<th>1 month</th>
</tr>
</thead>
<tbody>
<tr>
<td>x 12 =</td>
<td>354d</td>
<td>8h</td>
<td>876p</td>
<td>Lunar Year</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Length of Lunar Gravid (Leap) year</th>
<th>29d</th>
<th>12h</th>
<th>793p</th>
<th>1 month</th>
</tr>
</thead>
<tbody>
<tr>
<td>x 13 =</td>
<td>383d</td>
<td>21h</td>
<td>589p</td>
<td>Gravid Year</td>
</tr>
</tbody>
</table>
TEKUFAH SHIFT (Annual) = Difference between Lunar & Solar Year

<table>
<thead>
<tr>
<th>Tekufah Shift – Simple Years</th>
<th>365d</th>
<th>5h</th>
<th>1080p</th>
<th>Solar Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>354d</td>
<td>8h</td>
<td>876p</td>
<td>Lunar Year</td>
</tr>
<tr>
<td>=</td>
<td>10d</td>
<td>21h</td>
<td>204p</td>
<td>Tekufah Shift</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tekufah Shift - Leap Years</th>
<th>365d</th>
<th>6h</th>
<th>Solar Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>383d</td>
<td>21h</td>
<td>589p</td>
</tr>
<tr>
<td>=</td>
<td>- 18d</td>
<td>15h</td>
<td>589p</td>
</tr>
</tbody>
</table>
R. Huna b. Abin sent an instruction to Raba: When you see that the cycle of Tebeth extends to the sixteenth of Nisan, declare that year a leap year and have no doubts.

- Tekufat Nisan $\leq 15^{th}$, month is Nisan, and the year = ‘simple’
- If Tekufat Nisan $> 15^{th}$, month is Adar II, the year is a Leap Year
Applying the TEKUFAH SHIFT

- Given *tekufah* of year $x$
- $Tekufah\ x+1 = tekufah\ x + \text{TEKUFAH SHIFT}$

Year 1: Tekufat Nisan = Molad Nisan
Year 2: Tekufat Nisan = 10d 21h 204p
Year 3: Tekufat Nisan = 21d 18h 408p

21d 18h 408p > 15d = LEAP YEAR
Tekufat Nisan in Relation to Molad Nisan

- When *Tekufat Nisan* falls later than the 15th, that month is declared Adar II, and we apply the Gravid TEKUFAH SHIFT (subtract!) to calculate *tekufat nisan* of the following year!!

<table>
<thead>
<tr>
<th>1</th>
<th>0d 0h 0p</th>
<th>Hypothetical Molad=Tekufah</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>10d 21h 204p</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>21d 18h 408p</td>
<td>LEAP YEAR</td>
</tr>
<tr>
<td>4</td>
<td>3d 2h 899p</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>14d 0h 23p</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>24d 21h 227p</td>
<td>LEAP YEAR</td>
</tr>
<tr>
<td>7</td>
<td>6d 5h 718p</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>17d 2h 922p</td>
<td>LEAP YEAR</td>
</tr>
<tr>
<td>9</td>
<td>-(1d 12h 333p)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>9d 8h 537p</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>20d 5h 741p</td>
<td>LEAP YEAR</td>
</tr>
<tr>
<td>12</td>
<td>1d 14h 152p</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>12d 11h 356p</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>23d 8h 560p</td>
<td>LEAP YEAR</td>
</tr>
<tr>
<td>15</td>
<td>4d 16h 1051p</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>15d 14h 175p</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>26d 11h 379p</td>
<td>LEAP YEAR</td>
</tr>
<tr>
<td>18</td>
<td>7d 19h 870p</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>18d 16h 1074p</td>
<td>LEAP YEAR</td>
</tr>
<tr>
<td>20</td>
<td>0d 1h 485p = e = offset of 19 year cycle</td>
<td></td>
</tr>
</tbody>
</table>

**Normal**  +10d 21h 204p
**Gravid**  -18d 15h 589p
In every 19 year cycle, 3, 6, 8, 11, 14, 17, 19 are leap years.
Where are we?

- Calculate Year / 19
- Quotient (YR/19) = # of COMPLETED Cycles
- Remainder (YR/19) = Year within next Cycle
- Note: If remainder is zero = year 19!
- 3, 6, 8, 11, 14, 17, 19 = גו"ח אדר ט = 5776

\[
5776 / 19 = 304 \text{ r. } 0
\]

\[
5776 = 19^{\text{th}} \text{ year of cycle } #304
\]

\[
5776 = \text{LEAP YEAR}
\]
<table>
<thead>
<tr>
<th>Year</th>
<th>Calculation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>5777</td>
<td>19 = 304 r. 1</td>
<td>א</td>
</tr>
<tr>
<td>5778</td>
<td>19 = 304 r. 2</td>
<td>ב</td>
</tr>
<tr>
<td>5779</td>
<td>19 = 304 r. 3</td>
<td>ג</td>
</tr>
<tr>
<td>5780</td>
<td>19 = 304 r. 4</td>
<td>ד</td>
</tr>
<tr>
<td>5781</td>
<td>19 = 304 r. 5</td>
<td>ה</td>
</tr>
<tr>
<td>5782</td>
<td>19 = 304 r. 6</td>
<td>ו</td>
</tr>
<tr>
<td>5783</td>
<td>19 = 304 r. 7</td>
<td>ז</td>
</tr>
<tr>
<td>5784</td>
<td>19 = 304 r. 8</td>
<td>ח</td>
</tr>
<tr>
<td>5785</td>
<td>19 = 305 r. 9</td>
<td>ט</td>
</tr>
<tr>
<td>5786</td>
<td>19 = 304 r. 10</td>
<td>י</td>
</tr>
<tr>
<td>5787</td>
<td>19 = 304 r. 11</td>
<td>י&quot;א</td>
</tr>
<tr>
<td>5788</td>
<td>19 = 304 r. 12</td>
<td>י&quot;ב</td>
</tr>
<tr>
<td>5789</td>
<td>19 = 304 r. 13</td>
<td>י&quot;ג</td>
</tr>
<tr>
<td>5790</td>
<td>19 = 304 r. 14</td>
<td>י&quot;ד</td>
</tr>
<tr>
<td>5791</td>
<td>19 = 304 r. 15</td>
<td>ט&quot;א</td>
</tr>
<tr>
<td>5792</td>
<td>19 = 304 r. 16</td>
<td>ט&quot;ב</td>
</tr>
<tr>
<td>5793</td>
<td>19 = 304 r. 17</td>
<td>ט&quot;ג</td>
</tr>
<tr>
<td>5794</td>
<td>19 = 304 r. 18</td>
<td>ט&quot;ד</td>
</tr>
<tr>
<td>5795</td>
<td>19 = 305 r. 0</td>
<td>ט&quot;ה</td>
</tr>
</tbody>
</table>
Unresolved questions

- $e = 1h\ 485p$ offset must be accounted for or it will accumulate!
- Year 16 (15d 14h 175p) – presumed ‘simple’, but depending on when $molad nisan$ falls, in some years this could be the 16th of Nisan!
- Is there a hypothetical year when $molad nisan = tekufat nisan$? If not, when did the calendar actually start?
Towards a More Precise Calendar!

2 measurements for calculating the length of a Tropical Year.

1. **Tekufat Shmuel**: Year = 365d 6h

2. **Tekufat Rav Ada**: Year = 1/19\(^{th}\) of Machzor Katan
Calculation of Tekufat Rav Ada

Machzor Katan of 19 years
\[= 7 \times 13 + 12 \times 12 \text{ months} = 235 \text{ months}\]

Tropical Year = \[235 \times (29 \text{ days} 12 \text{ hours} 793 \text{ minutes}) / 19\]

<table>
<thead>
<tr>
<th>Tropical Year = 1/19 of Machzor Katan =</th>
<th>235 (29d 12h 793p) / 19</th>
</tr>
</thead>
<tbody>
<tr>
<td>365d 5h 997hp 48m</td>
<td>(6815d 2820h 186355p) / 19</td>
</tr>
<tr>
<td></td>
<td>(6939d 16h 595p) /19</td>
</tr>
<tr>
<td></td>
<td>= 365d 5h 997p 48m* (m=1/76p)</td>
</tr>
<tr>
<td>Conventional time</td>
<td>= 365d 5h 55m 25.4386s</td>
</tr>
</tbody>
</table>

\(* m = \text{moment} \)
### Accuracy of Calculation of Tropical Year*

<table>
<thead>
<tr>
<th>Tropical Year</th>
<th>Precision</th>
<th>Diff. (Days)</th>
<th>Diff. (seconds)</th>
<th>1 Day accumulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shmuel</td>
<td>365d 6h</td>
<td>0.00780</td>
<td>674</td>
<td>128 years</td>
</tr>
<tr>
<td>R. Ada</td>
<td>365d 5h 55m 25.4386s = 365.24682d</td>
<td>0.00462</td>
<td>399</td>
<td>216 years</td>
</tr>
<tr>
<td>Gregorian</td>
<td>365d 5h 49m 12s 365.24250d</td>
<td>0.00030</td>
<td>26</td>
<td>3323 years</td>
</tr>
<tr>
<td>Standard *</td>
<td>365d 5h 48m 46.069s = 365.2422d</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Pros & Cons of Tekufat Rav Ada

- **Pros**
  - No ‘remainder’ of 19 year cycle

- **Cons:**
  - Much more complicated to calculate
Which calculation to use?

- **Luni-solar Leap Year Calculations** are based on Tekufat Rav Ada, and pre-calculated by Hillel II.

- Calculations left to the people, namely **Tal Umatar & Birkat HaChamah**, would be simplified by using **Tekufat Shmuel**.

- Chazal, while aware of the inaccuracy of **Tekufat Shmuel**, were confident that the Moshiach would come long before this inaccuracy would pose any problem. (Perush, Rambam, KHC 9:3)
Summary

Tekufat Shmuel – Tropical Year: 365d 6h
Tekufat Rav Ada – Tropical Year: 365d 5h 997p 48m
Length of Molad: 29d 12h 793p
Molad Shift (monthly): 1d 12h 793p
* Annual Molad Shift – Simple: 4d 8h 867p
* Annual Molad Shift – Gravid: 5d 21h 589p
** Annual Tekufah Shift – Simple: 10d 21h 204p
** Annual Tekufah Shift – Gravid: -18d 15h 589p
Leap Years – “Machzor Hakatan”: 3, 6, 8, 11, 14, 17, 19

* Length of Year MOD 7
** In relation to the Lunar Year