



Unlocking the Mystery of The Hebrew Calendar

Winter 2018 - 5778

Rabbi Moshe Shulman
Young Israel of St. Louis

B.Sc., Computer Software Engineering

Jerusalem College of Technology



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 (Encyclopeda Judaica)
Note: defined from Jerusalem.
- **1 Hour = 1080 parts** (*Chalakim*)
 - *Wholly divisible by: 2, 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 20, 24, 27, 30*
- $1080 / 60 = 18$
- $18 \text{ parts} = 1 \text{ minute}$
- $1 \text{ part} = 3\frac{1}{3} \text{ seconds}$
- The Length of the Molad is the average length of the cycle of the moon, from Molad to Molad.

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

Length of a Molad

אין חדושה של לבנה פחותה מעשרים ותשעה יום ומחצה ושני
שלישי שעה ושבעים ושלושה חלקים (ר"ה כה.).

$$29.5d + \frac{2}{3}h + 73p$$

$$1 \text{ hour} = 1080 \text{ p}$$

$$\frac{2}{3} h = 720 \text{ p}$$

$$\text{MOLAD} = 29d \ 12h \ 793p$$

כ"ט י"ב תשצ"ג

מחזור קטן – Machzor Katan (Leap Year Cycle)

גו"ח אדז"ט

3	ג
6	ו
8	ח
11	יא
14	יד
17	יז
19	יט

In every 19 year cycle,
3, 6, 8, 11, 14, 17, 19
are leap years.

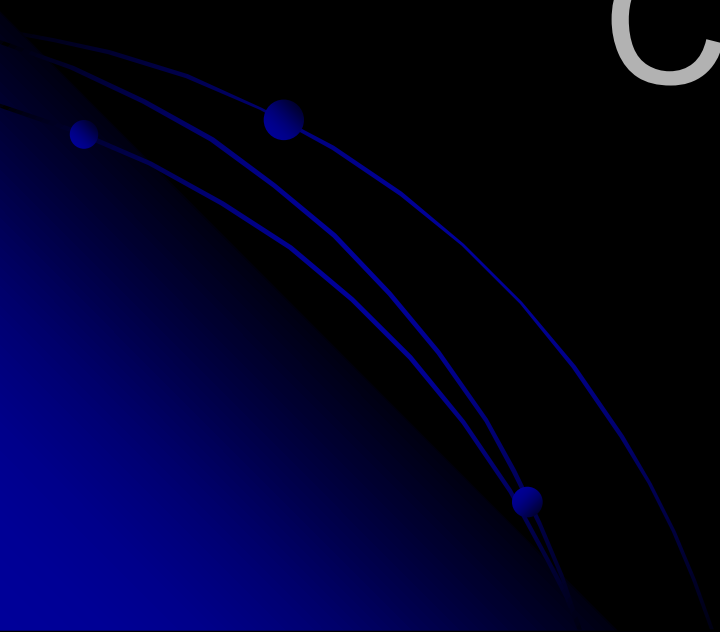
Summary

Tekufat Shmuel – Tropical Year	365d 6h	
Tekufat Rav Ada – Tropical Year	365d 5h 997p 48m	
Length of Molad	29d 12h 793p	כ"ט י"ב תשצ"ג
Molad Shift (monthly)	1d 12h 793p	אי"ב תשצ"ג
* Annual Molad Shift – Simple	4d 8h 867p	ד"ח תתע"ו
* Annual Molad Shift – Gravid	5d 21h 589p	הכ"א תקפ"ט
** 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	גו"ח אדז"ט

* Length of Year MOD 7

** In relation to the Lunar Year

III. Setting the Calendar



Length of Lunar Years

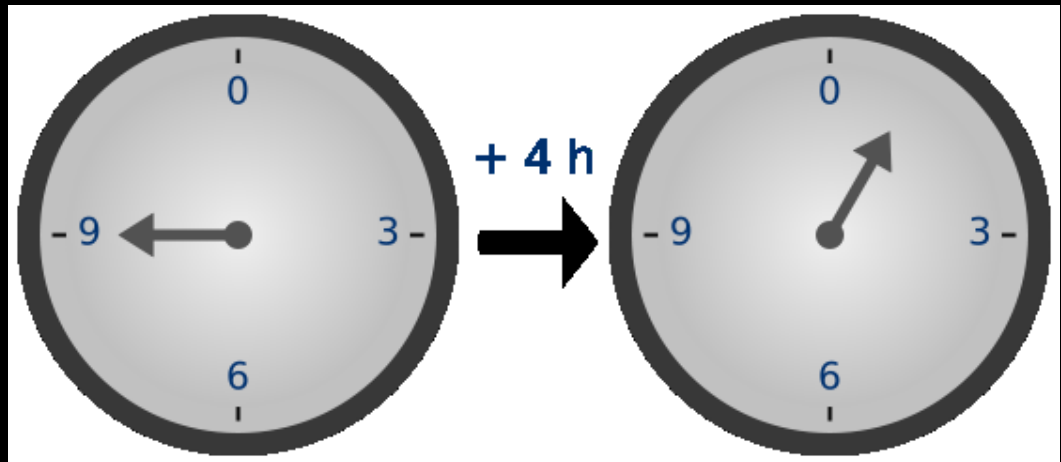
Length of Lunar “Simple” year				
	29d	12h	793p	1 month
x 12 =	354d	8h	876p	Lunar Year

Length of Lunar Gravid (Leap) year				
	29d	12h	793p	1 month
x 13 =	383d	21h	589p	Gravid Year

Calendar calculations are most interested in the change through the week. Therefore we need only calculate the change MODULO 7!!

Modular Division (MOD 7)

- **Modular arithmetic** (a.k.a “**clock arithmetic**”)
 - system of arithmetic for integers where numbers “wrap around” after reaching a certain value, the modulus.
- E.g. CLOCK - 12-hour time:
 - 9:00 o'clock + 4 hours = 1:00 o'clock.
 - clock time “wraps around” every 12 hours - arithmetic *modulo* 12



Molad Shift over One Year

MOD 7 Molad shift by **day of week**

Simple Year			
Simple	354d	8h	876p
Mod 7	4d	8h	876p

Gravid (Leap)			
Gravid	383d	21h	589p
Mod 7	5d	21h	589p

ד"ח תתע"ו – Simple Year: 4d 8h 876p
הכ"א תקפ"ט – Gravid Year: 5d 21h 589p

Calculating Molad Tishrei

Example 1

Given the Molad of Tishrei 5778
Calculate the Molad of 5779

Molad 5778: 5d 5h 520p
305th cycle, 2nd year – Simple year.

EXAMPLE 1: MOLAD 5770			
Molad 5778	5d	5h	520p
+ Molad Shift	4d	8h	876p
Molad 5779	2d	14h	316p

Calculating Molad Tishrei

Example 2

Given the Molad of Tishrei 5779
Calculate the Molad of 5780

Molad 5779: 2d 14h 316p
305th cycle, 3rd year – Gravid year.

EXAMPLE 2: MOLAD 5772			
Molad 5779	2d	14h	316p
+ Gravid Molad Shift	5d	21h	589p
Molad 5780	1d	11h	905p

Molad / Calendar Starting Point

R. Johanan b. Hanina said: The day consisted of twelve hours. In the first hour, his dust was gathered; in the second, it was kneaded into a shapeless mass...in the ninth, he was commanded not to eat of the tree...

אמר רבי יוחנן בר חנינא: שתיים
עשרה שעות היו היום; שעה ראשונה
- הוצבר עפרו, שניה - נעשה גולם...
תשיעית - נצטווה שלא לאכול מן
האילן (סנה' לח:)

- Molad Yishuv = First Molad Tishrei 'sanctified' by Adam
- 6d 14h = ז"ד
 - 1. 2nd Hour - Adam created = 14th hour of 24 hr day.
 - Assumption: The moon was created on day 4 (28 Elul) in a such a way as to 'renew' itself together with Adam. (R. Yosef Gaon)
 - 2. 9th hour – 1st Mitzvah – He 'sanctified' the New Moon at that time.
 - Molad falls 6 hours prior to being visible = 2nd hour (Tos. RH 8a)

Shenat Tohu – שנת תהו

The Primordial Year

- Molad Tishrei 1 = Friday, Day 6, 14h = ו"ד
- => World created on Day 1 = 25 Elul
- => Sun/Moon created on Day 4 = 28 Elul

“Shenat Tohu” – שנת תהו

**Hypothetical year starting 1 YEAR
PRIOR to Creation, containing the
5 days prior to Adam's creation.**

Molad Yishuv or Molad Tohu?

**19 year Cycle, and all lunisolar calendar
calculations begin with Molad Tohu**

What year is it?

5778 from *Molad Tohu*

(Rambam)

Calculating Molad Tohu from וי"ד

Calculating Molad Tohu				
	6d	13h	1080p	Molad Yishuv (וי"ד)
-	4d	8h	876p	Yearly Molad Shift
=	2d	5h	204p	Molad Tohu (Yr 0)

Molad Tohu
2d 5h 204p
בהר"ד

MOLAD TISHREI *yr n*

- Molad Tishrei of *yr n* can be calculated from Molad Tohu
 - = Molad Tohu + $n \times$ Annual Molad Shift
 - To take into consideration the leap years, this is simplified by multiplying the number of 19 year cycles $\times$ the 'molad shift' of the Machzor Hakatan
- All numbers are MOD 7

Constants to Aid in Molad Math

Useful Calculations of Molad shifts (0 = Shabbat)			
Molad Tohu	2d	5h	204p
1 Month	1d	12h	793p
6 Months	2d	4h	438p
SIMPLE year (12 months)	4d	8h	876p
GRAVID year (13 months)	5d	21h	589p
19-yr Machzor HaKatan=235 months	2d	16h	595p

EXCEL PROGRAM TO CALCULATE MACHZOR HAKATAN				
MULTIPLE	DAYS	HOURS	PARTS	
235	1	12	793	
Mod 7	2	16	595	

D4=MOD(D3*A3,1080)

C4=MOD((QUOTIENT(D3*A3,1080))+C3*A3,24)

B4=MOD(QUOTIENT((QUOTIENT(D3*A3,1080))+C3*A3,24)+B3*A3,7)

When is Molad Tishrei 5778?

- $5778 = 304 \text{ r. } 2$
- $= 304 \text{ cycles} + 1 \text{ yr}$
since Molad Tohu.
- Molad Tohu
- $+ [304 \times (19 \text{ year shift})]$
- $+ [1 \times (\text{simple year})]$

19 Year Shift x # of cycles passed				
MULTIPLE	DAYS	HOURS	PARTS	
304	2	16	595	
Mod 7	5	15	520	

Molad Shift x number of Simple Years				
MULTIPLE	DAYS	HOURS	PARTS	
1	4	8	876	
Mod 7	4	8	876	

Gravid Molad Shift x # of Gravid years				
MULTIPLE	DAYS	HOURS	PARTS	
0	5	21	589	
Mod 7	0	0	0	

Molad Tohu	2d	5h	204p
304 x 19 yr cycle	5d	15h	520p
1 Regular	4d	8h	876p
4 Gravid	0d	0h	0p
Mod 7=	5d	5h	520p

When is Molad Tishrei 5781?

- 5781 = 304 r. 5
- = 304 cycles + 4 yrs since Molad Tohu.

19 Year Shift x # of cycles passed				
MULTIPLE	DAYS	HOURS	PARTS	
304	2	16	595	
Mod 7	5	15	520	

Molad Shift x number of Simple Years				
MULTIPLE	DAYS	HOURS	PARTS	
3	4	8	876	
Mod 7	6	2	468	

Gravid Molad Shift x # of Gravid years				
MULTIPLE	DAYS	HOURS	PARTS	
1	5	21	589	
Mod 7	5	21	589	

- Molad Tohu
- + [304 x (19 year shift)]
- + [3 x (simple year)]
- + [1 x (gravid year)]

Molad Tohu	2d	5h	204p
304 x 19 yr cycle	5d	15h	520p
3 Regular	6d	2h	468p
1 Gravid	5d	21h	589p
Mod 7=	5d	20h	701p

מולדי תשרי שנות ד' קי"א – ו"א

Moladey Tishrey, Years 4111-6000 (351-2240 C.E.)

MOLADGTH	0		1		2		3		4		5		6		7		8		9	
YEAR																				
4111	3	10	566	0	19	362	6	16	951	4	1	747	1	10	543	0	8	52	4	16
4121	2	16	905	1	14	414	5	23	210	4	20	799	2	5	595	6	14	391	5	11
4131	3	11	957	2	9	466	6	18	262	4	3	58	3	0	647	0	9	443	4	18
4141	4	6	1009	1	15	805	0	13	314	4	22	110	2	6	986	1	4	495	5	13
4151	5	1	1061	2	10	857	6	19	653	5	17	162	3	1	1038	0	10	834	6	8
4161	4	8	320	3	5	909	0	14	705	4	23	501	3	21	10	1	5	886	5	14
4171	5	3	372	2	12	168	1	9	757	5	18	553	3	3	349	2	0	938	6	9
4181	5	22	424	3	7	220	0	16	16	6	13	605	3	22	401	1	7	197	0	4
4191	5	4	763	4	2	272	1	11	68	5	19	944	4	17	453	2	2	249	6	11
4201	5	23	815	3	8	611	2	6	120	6	14	996	3	23	792	2	21	301	0	6
4211	6	18	867	4	3	663	1	12	459	0	9	1048	4	18	844	2	3	640	1	1
4221	6	1	126	4	22	715	2	7	511	6	16	307	5	13	896	2	22	692	1	20
4231	6	20	178	4	4	1054	3	2	563	0	11	359	4	20	155	3	17	744	1	2
4241	0	15	230	5	0	26	2	8	902	1	6	411	5	15	207	4	12	796	1	21
4251	6	21	569	5	19	78	3	3	954	0	12	750	6	10	259	3	19	55	2	16
4261	0	16	621	5	1	417	3	22	1006	1	7	802	0	5	311	4	14	107	1	22
4271	1	11	673	5	20	469	3	5	265	2	2	854	6	11	650	5	9	159	2	17
4281	0	17	1012	6	15	521	4	0	317	2	21	906	0	6	702	4	15	498	3	13
4291	1	12	1064	5	21	860	4	19	369	2	4	165	1	1	754	5	10	550	2	19
4301	2	8	36	6	16	912	5	14	421	2	23	217	0	8	13	6	5	602	3	14
4311	1	14	375	0	11	964	4	20	760	3	18	269	1	3	65	5	11	941	4	9
4321	2	9	427	1	6	1016	5	15	812	3	0	608	1	22	117	6	6	993	3	15
4331	3	4	479	0	13	275	6	10	864	3	19	660	1	4	456	0	1	1045	4	10
4341	3	23	531	1	8	327	5	17	123	4	14	712	1	23	508	6	8	304	5	5
4351	3	5	870	2	3	379	6	12	175	3	20	1051	2	18	560	0	3	356	4	12
4361	4	0	922	1	9	718	0	7	227	4	16	23	2	0	899	0	22	408	5	7
4371	4	19	974	2	4	770	6	13	566	5	11	75	2	19	951	0	4	747	6	2
4381	4	2	233	2	23	822	0	8	618	4	17	414	3	14	1003	0	23	799	5	8
4391	4	21	285	2	6	81	1	3	670	5	12	466	2	21	262	1	18	851	6	3
4401	5	16	337	3	1	133	0	9	1009	6	7	518	3	16	314	1	1	110	6	22
4411	4	22	676	3	20	185	1	4	1061	5	13	857	4	11	366	1	20	162	0	17
4421	5	17	728	3	2	524	2	0	33	6	8	909	3	17	705	2	15	214	0	0
4431	6	12	780	3	21	576	1	6	372	0	3	961	4	12	757	3	10	266	0	19
4441	5	19	39	4	16	628	2	1	424	6	10	220	5	7	809	2	16	605	1	14
4451	6	14	91	3	22	967	2	20	476	0	5	272	6	2	861	3	11	657	0	20
4461	0	9	143	4	17	1019	2	2	815	1	0	324	5	9	120	4	6	709	1	15
4471	6	15	482	5	12	1071	2	21	867	1	19	376	6	4	172	3	12	1048	2	10
4481	0	10	534	4	19	330	3	16	919	1	1	715	6	23	224	4	8	20	1	16
4491	1	5	586	5	14	382	4	11	971	1	20	767	6	5	563	5	3	72	2	11
4501	0	11	925	6	9	434	3	18	230	2	15	819	0	0	615	4	9	411	3	6
4511	1	6	977	0	4	486	4	13	282	1	22	78	0	19	667	5	4	463	2	13
4521	2	1	1029	6	10	825	5	8	334	2	17	130	0	1	1006	5	23	515	3	8
4531	2	21	1	0	5	877	4	14	673	3	12	182	0	20	1058	5	5	854	4	3
4541	2	3	340	1	0	929	5	9	725	2	18	521	1	16	30	6	0	906	3	9
4551	2	22	392	0	7	188	6	4	777	3	13	573	0	22	369	6	19	958	4	4
4561	3	17	444	1	2	240	5	11	36	4	8	625	1	17	421	6	2	217	4	23

Molad Tishrei Yr x?

By Calculations

- Molad Tishrei 5778 = 5d 5h 520p
- Molad Tishrei 5779 = 2d 14h 316p
- Molad Tishrei 5780 = 1d 11h 905p
- Molad Tishrei 5781 = 5d 20h 701p

MCLADOTH YEAR	0	1	2	3	4	5	6	7	8	9										
5741	4 22	236	3 1	853	0 11	371	4 20	387	3 17	976	1 2	772	0 0	281	4 9	77	1 17	953	0 15	462
5751	5 0	258	2 9	54	1 6	643	5 15	439	3 0	235	1 21	824	6 6	620	5 4	129	2 12	1005	6 21	801
5761	5 19	310	3 4	106	0 12	982	6 10	491	3 19	287	2 16	876	0 1	672	4 10	468	3 7	1057	0 16	853
5771	5 1	649	3 23	158	1 7	1034	5 16	830	4 14	339	1 23	135	0 20	724	5 5	520	2 14	316	1 11	905
5781	5 20	701	3 5	497	2 3	6	6 11	882	5 9	391	2 18	187	0 2	1063	6 0	572	3 9	368	0 18	164
5791	6 15	753	4 0	549	1 9	345	0 6	934	4 15	730	3 13	239	0 22	35	5 6	911	4 4	420	1 13	216

Excel formulas for generating Molad Chart

A	B	C	D	E	F	G	H	I
Sunday, October 02, 1921	3:54 AM	17 chalakim	57	17.27272727	54	1	9	989

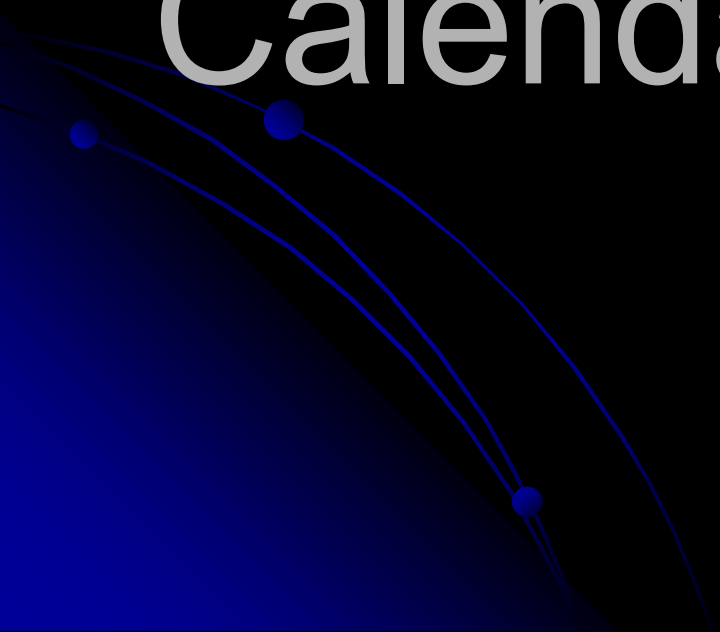
A1 = 9/21/1921 3:10:54 PM	Starting date
A2=A1+29.5305941358	Decimal value for Molad Shift, formatted as date
B2=A2	Formatted as time
C2=FLOOR(E2,1) & " chalakim"	Parts (rounded down to whole number)
D2=SECOND(A2)	Seconds
E2=D2/3.3	Parts (with decimal)
F2=MINUTE(A2)	Minutes
G2=WEEKDAY(A2+0.25)	# of day of week (add 0.25 to compensate for day starting at 6:00pm)
H2=HOUR(A2+0.25)	Hour of day
I2=F2*18+E2	Total Parts out of hour

Molad Chart 5778 (2017-2018)

Friday, September 02, 1921	3:10 PM	16 chalakim	54	16.36363636	10		6	21	196
Sunday, October 02, 1921	3:54 AM	17 chalakim	57	17.27272727	54		1	9	989

Wednesday, September 20, 2017	11:28 PM	16 chalakim	54	16.36363636	28		5	5	520
Friday, October 20, 2017	12:12 PM	17 chalakim	57	17.27272727	12		6	18	233
Sunday, November 19, 2017	12:57 AM	0 chalakim	1	0.303030303	57		1	6	1026
Monday, December 18, 2017	1:41 PM	1 chalakim	4	1.212121212	41		2	19	739
Wednesday, January 17, 2018	2:25 AM	2 chalakim	7	2.121212121	25		4	8	452
Thursday, February 15, 2018	3:09 PM	3 chalakim	11	3.333333333	9		5	21	165
Saturday, March 17, 2018	3:53 AM	4 chalakim	14	4.242424242	53		7	9	958
Sunday, April 15, 2018	4:37 PM	5 chalakim	17	5.151515152	37		1	22	671
Tuesday, May 15, 2018	5:21 AM	6 chalakim	21	6.363636364	21		3	11	384
Wednesday, June 13, 2018	6:05 PM	7 chalakim	24	7.272727273	5		5	0	97
Friday, July 13, 2018	6:49 AM	8 chalakim	27	8.181818182	49		6	12	890
Saturday, August 11, 2018	7:33 PM	9 chalakim	31	9.393939394	33		1	1	603

IV. So What does the Calendar Look Like?



How Many Days in Each Month?

The Rabbis of Caesarea said in the name of R. Abba: How do we know that a month is not reckoned by its hours? Because it says, 'until a month of days' - you reckon a month by days, but you do not reckon a month by hours.

מנין שאין מחשבין שעות לחדשים?
שנאמר (במדבר י"א) עד חדש ימים -
ימים אתה מחשב לחדשים, ואי
אתה מחשב שעות לחדשים (גמ' מגילה
ה.).

- Molad = ~29.5 days.
- Calendar “Month” will be EITHER 29 OR 30 days.
 - 30 day months = מלא, “Full”
 - 29 day months = חסר, “Deficient”

How Many Days Rosh Chodesh does Each Month Have?

A 2 day Rosh Chodesh always follows a “Full” month – חדש מלא

Day 30 of old month = 1st day RC

Day 1 of new month = 2nd day RC

ל' תשרי = א' דראש חדש חשון

א' חשון = ב' דראש חדש חשון

“Birdseye View of Hebrew Calendar”

Month		Days in Month		Days of Rosh Chodesh	
Tishrei – תשרי		30			
Cheshvan – חשון		29			
Kislev – כסלו		30			
Tevet – טבת		29			
Shevat – שבט		30			
Adar I – א' – אדר	Adar – אדר	30	29		
Adar II – ב' – אדר		29			
Nisan – ניסן		30			
Iyar – אייר		29			
Sivan – סיון		30			
Tamuz – תמוז		29			
Av – אב		30			
Ellul – אלול		29			

“Birdseye View of Hebrew Calendar”

Month		Days in Month		Days of Rosh Chodesh	
Tishrei – תשרי		30		1*	
Cheshvan – חשון		29		2	
Kislev – כסלו		30		1	
Tevet – טבת		29		2	
Shevat – שבט		30		1	
Adar I – א' אדר	Adar – אדר	30	29	2	2
Adar II – ב' אדר		29		2	
Nisan – ניסן		30		1	
Iyar – אייר		29		2	
Sivan – סיון		30		1	
Tamuz – תמוז		29		2	
Av – אב		30		1	
Ellul – אלול		29		2	

* Two days of Rosh Hashanah is an exception, for reasons unrelated to the calendar. They are 1 + 2 of Tishrei

חשון / כסלו – “Variable Months”

Month		Days in Month		Days of Rosh Chodesh	
Tishrei – תשרי		30		1	
Cheshvan – חשון		29/30		2	
Kislev – כסלו		29/30		1/2	
Tevet – טבת		29		1/2	
Shevat – שבט		30		1	
Adar I – א' – אדר א'	Adar – אדר	30	29	2	2
Adar II – ב' – אדר ב'		29		2	
Nisan – ניסן		30		1	
Iyar – אייר		29		2	
Sivan – סיון		30		1	
Tamuz – תמוז		29		2	
Av – אב		30		1	
Ellul - אלול		29		2	

Year “Types”

Note: there is no Year with חשון=30 and כסלו=29, because it would achieve the same total number of days annually, and would be redundant.

A.K.A.

* Defective

** Excessive

ח, כ, ש	חשון	כסלו
חסרה Chaseirah Incomplete*	29	29
כסדרה Kesidrah Regular	29	30
שלימה Shleimah Complete**	30	30

Relationship between Molad & Rosh Chodesh



ROSH HASHANAH

is determined by **MOLAD TISHREI**
(with 4 exceptions - Dechiyot)

ROSH CHODESH

is determined by the alternating 29-30 day
month cycle

*irrespective of the molad of that
month.*

