

7ci fgY'Cj Yfj]Yk

GHJZZ7cbHJWh8YHJ]`g

7cbj Ybcfg

BUa Y	9a U]`	5j U]`UV]`] m	@cWUh]cb	D\cbY
9a a U'5"'>UbY	Ya a U"^UbY4 i bgk "YXi "Ui	6miUddc]bha Ybh		\$(%& '(&-
				\$&+

GWkcc~7cbhJWh~abZcfa Uh]cb

GVXcc``cZhY`5fhg`UbX`AYX]U

Fcca ' %&ž@YjY`' žFcVYfhK YVghYf6i]`X]b[fl %(Ł

D\cbY.'f\$&E'-',)'(,)*

9a U]` gUa 4 i bgk "YXi "Ui

K YVq]hY. k k k "Ufhq"i bak "YXi "Ui #qUa

 $\label{eq:hamiltonian} $$HY'GWKcc``cZhY'5ftg'UbX'AYX]U'kci`X``]_Y'hc'FYgdYWM\cong \cong m5W_bck`YX[Y'h\Y'HfUX]hjcbU``7ighcX]Ubgžh\Y'6YXY[U'`fPYbg]b[hcb'WJadigŁž'; UX][U'`fP]hmUbX'5fh\/'8Yg][b'7UadigYgŁ'UbX'h\Y'B[ibbUkU`dYcd'Y'fbighfU`]Ub'8YZYbW': cf\W'5\WJXYam]b'7UbVYffUŁ'cZh\Y'`UbXg'k\YfY'YUW\'WJadig'cZIBGK']g`c\WJhYX''$

7ci fgY 8YW] g

7 fYX]hDc]bhg**

Gi a a UfmcZh\Y 7ci fgY

#DITH JG Wei fgYžmei fì "YUfb 'Ub ']bbcj Uhj Y '&V!gYY_]b[#&V!`UbX]b['a Yh\cX'h\Uh']g'VUgYX'cb'h\Y '`UhYgh`UVci f a Uf_YhfYgYUfW\Z'UbX'h\Uhk]"`cZYf'Wf]hJWU`]bg]XYf']bg][\hg`]bhc'h\Y 'WUfYYfg'mci 'Wcj Yh''Mci fi 'Vi]'X'U dcfhzc']c'h\Uhg\ck WUgYg'mci f`k cf_ž\cbYg'mci f'd]hW\]b['g_]``gž'UbX'fYZ]bYg'mci f`gW\a ccnY"'6YghcZU``ž h\Y'Wci fgYfg'VYgdc_Y'UddfcUW\a YUbg'mci fi cb`miYj Yf'bYYX'hc'ZcW g'cb'h\Y'&Vg'UbX']bXi ghf]Yg'h\Uh]bhYfYghmci "'#iXcYgbffia UhhYf'k\Yh\Yf'h\YgY']bj c'j Y'&i fbU']ga ž'UXj YfhJg]b['UbX'DF —cf'gca Yh\]b['Y`gY YbhJfY`m''Mci 'WUb'i gY'h\]g'Wci fgY'hc'hUf[YhUbmdcg]hJcb'mci '`]_Y"'

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7ci fgY @YUfb]b[Ci hWca Yg

%" F YgYUfWX 'UbX'UbU`mgY'a YX]U`]bXi ghfmidfcWrggYg'UbX'dfUWf]Wrg" &" @cWUhY'h\Y]f'ck b'a YX]U'dfUWf]Wr'k]h\]b'h\Y'W ffYbha YX]U']bXi ghfm' ' " 9 ZZYWf]j Y`mdfYgYbhih\Y]f'a YX]U'dfUWf]Wr'UbX'YI dYfh]gY'hc'dchYbh]U`'Ya d`cmYfg" (%0 %0

F Yaci fWya

DfYgWf]VYX F Ygci fWYg

GYY'Wci fgY'g]hY'cb'A ccX`Y"

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7ci fgY 9j U'i Uh]cb UbX 8Yj Y`cda Ybh

Gi Va]gg]cb cZ5ggYgga YbhHUg_g

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Image: Ybwei bhyfu'dfcv'ya k \yb'uhhya dhjb['hc'gi va]hmci f'Ugg][ba Ybhh\fci [\ 'Hi fb]h]bž'd'YUgY

Hy'Yd\cby'9| hy'fbu''Gi ddcfhcb'-',) '' ' ' %cf'Ya U]''h\Ya 'cb'Y! hy'fbu'hy'hgi ddcfh4 i bgk "YXi "Ui "''Gi ddcfh
\ci fg'UfY', .\$\$Ua '-'%\$.\$\$da 'cb'k YY_XUmg'UbX'-.\$\$Ua '-').\$\$da 'cb'k YY_YbXg'fl *) 'XUmg'U'mYUft"'=Z'mci
UfY'i bUV'Y'hc'gi va]hmci f'Ugg][ba YbhXi Y'hc'U'ZJi 'hk]h\ 'Hi fb]h]b'mci 'a Um'Udd'mZcf'Ub'Y! hy'bg]cbž'Vi hmci
a i ghfYhJ]b'mci f'h]W_Yhbi a VYf'Zfca '9! hy'fbU''Gi ddcfhfU'cb['k]h\ 'Ubmch\Yf'fy'Yj UbhXcW a Ybhgt'hc
]bWi XY'Ug'Yj]XYbW' 'hc'gi ddcfhmci f'Y! hy'bg]cb'Udd']WUh]cb"'=Zmci 'Ya U]''9! hy'fbU''Gi ddcfhmci 'k]'`
Ui hca Uh]WJ'`mfYW']j Y'U'h]W_Yhbi a VYfZ'Vi h]Zmci 'hY'Yd\cbY'mci 'k]``bYYX'hc'gdYW]Z]WJ'`mUg_'Zcf'cbY''
Hi fb]h]b'U'gc'dfcj]XYg'i dXUhy'g'cb'h\Y]f'gmghYa 'ghUh' g'cb'Hk]hyf''

; YbYfU`mž'UggYgga YbhiHug_g'a i ghVY'gi Va]hhYX'Y`YVWfcb]\WJ``mij]U'Y]h\Yf'Hi fb]h]b'cf'U'A ccX`Y Ugg][ba Ybh''=b']bgHJb\W'g'k \YfY'h\]g']g'bchdcgg]V`Yž']hk]```VY'gHJhYX'cb'mci f'\\circ i fgY'g'A ccX`Y'g]hY'k]h\U`hYfbUh]j Y'gi Va]gg]cb'XYHJ]`g"

cfi]bZcfa Uhjcbicbi\ckihcigi Va]hUgg][ba Ybhgicbi]bYij]UiA ccXiY.i\hdg.#gh XYbhi bgk "YXi "Ui #\ck! gi Va]hUgg][ba Ybha ccXiY

5 WUXYa]W<cbYghmUbX D`U[]Uf]ga

D`U[]Uf]ga `]g`i g]b['h\Y`k cfXg`cf`]XYUg`cZch\Yfg`UbX`dfYgYbh]b['h\Ya `Ug`mci f`ck b"`±hWJb`hU_Y`a Ubm Zcfa gžZfca `XY`]VYfUhY`W\YUh]b['hc`UWW]XYbhJ``mWcdm]b['Zfca `U`gci fWY`k]h\ci hUW_bck `YX[Ya Ybh'

IBGK [fcidg'd'U[]Uf]ga]bhc'h\Y'Zc``ck]b['WUhY[cf]Yg.

 $7 \text{ cdm}b[...i g]b[...h\Y.gUa Y.cf.j Yfmig]a] \Uf'k cfXg'hc'h\Y.cf][]bU''hYl h'cf']XYU'k]h\ci h'U\V_bck `YX[]b[...h\Y.cf][]bU''hYl h'cf']XYU'k]h'cf']$

- i bXYfgHUbX'mci f'f][\hg'UbX'fYgdcbg]V]`]h]Yg'Ug'U'gh XYbh'UhI BGK
 VY'Uk UfY'cZd`U[]Uf]ga ž'Wcdmf][\hz'I BGK 'Gh XYbh'7cXY'cZ7cbXi Wh'UbX'5VWWdhUV`Y'I gY'cZ IBGK =7 HF Ygci fWrg Dc`]Wh

5WUXYa]W±bZcfaUhjcb

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