

MDIA3012

7 ca a i b]WUh]cb]b 5 Wh]cb

HYfa 'C bY''##'&\$&%

7ci fgY'Cj Yfj]Yk

GHJZZ7cbHJWh8YHJ]`g

7cbj Ybcfg

B Ua Y	9a U]`	5j U]`UV]`] m	@cWUh]cb	D\cbY
JU`YbhJbU^6UÖ	j "VUi 4 i bgk "YXi "Ui	Hi YgXUmgž	K YVghYf" %%8	Ž*‰-',),-
		%DA!&DA		+(

GWkcc~7cbhJWh~abZcfa Uh]cb

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

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D\cbY. f\$&£'-',) '(,) *

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

K YVg]hY. k k k "Ufhg"i bgk "YXi "Ui #gUa

 $\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 8YHJ] g

7 fYX]hDc]bhg**

Gi a a UfmcZh\Y 7ci fgY

#Jih]g'Wti fgY'mci k]``Yb[U[Y'k]h `U'fYU`!k cfX'Vf]YZ]b'h Y'Z]Y'X'cZdi V']WfY`Uhjcbg#JXj Yfhjg]b['hc']XYbh]Zm UbX'XYZ]bY'U'Wta a i b]WJhjcb'dfcV'Ya 'cf'cVghJWY'Zcf'Ub'cf[Ub]gUhjcb''Mci 'k]``fYgYUfWX'h]g'dfcV'Ya ž XYj Y'cd'UghfUh'[]Wwta a i b]WJhjcb'd'Ub'hc'gc'j Y']hz'UbX']a d'Ya Ybhmci f'd'Ub'k \]'Y a cb]hcf]b['UbX Yj U'i Uhjb[']hg'fYgi 'hg'''Mci 'k]``VY'dfcj]XYX'h Y'cddcfhi b]hmhc']a d'Ya YbhghfUh'[]Wwta a i b]WJhjcb'hUWJWg fY`UhYX'hc'UXj cWJWhz'XYg][bž'a Uf_Yhjb[ž'a YX]U'WtbhYbhUbX'cb`]bY'd`Uhzcfa g']b'U'fYU'!']ZY'gWYbUf]c'' H\Y'dfUWJ\WJ'`g_]``g'mci 'k]``[U]b'UbX'h\Y'dfcZYgg]cbU`'bYhk cf_g'mci 'k]```XYj Y'cd'Xi f]b['h\]g'Wti fgY'k]`` Ui [a Ybhmci f'a YX]U!VUgYX'dcfhzc`]c'UbX'7 J ž'\Y'd]b['mci 'hc'g\UdY'mci f'Z hi fY'WJfYYf'hfUYWfcfm''

7ci fgY @YUfb]b['Ci hWca Yg

- &" 8 Yj Y`cdž]a d`Ya Ybhža cb]hcfž'UbX`Yj U`i UhY`U`ghfUhY[]\W\ca a i b]\W\r]cb`d`Ub"
- '"7caaib]WUHY'UbX'Wc``UVcfUHY'YZZYWNjY'm'

HYUWX]b[GhfUhY[]Yg

 $H\[g] \wci fgY'k\]^{"Vi}\] X'cb'h Y'_bck \ YX[\ Y'h Uhghi XYbhg' \ Uj Y'[\ U]bYX'UVci h wca a i b] \wuhjcb'ghlh' [\]Yg h fci [\ 'h Y]f' XY[\ fYY'dfc[\ fUa''' < YfY z'ghi XYbhg' k\]^{"di h]bhc'dfUwljW'' h Y]f'ghfUhY[\] \wca a i b] \wuhjcb'g_]^g'hc bchcb'mXYj Y'cd'Vi h'U`gc']a d'Ya Ybh'U'fYU'! `]ZY' Wca a i b] \wuhjcb'dfc'Ywl'' K \]'Y''Ywli fYg'k\]'''dfcj]XY'h Ya k]h '_Ym'WcbW'dhg' Zfca 'UXj cwuwhubX'bcb!dfc Zhwca a i b\wuhjcbz'hi hcf]U''Uwlj]hjYg'k\]'''U''ck 'h Ya 'hc'k cf_ \wc''UVcfUhj Y'mcb'h Y' Zcfa i 'Uhjcb'cZghfUhY[\]]\wubX\cf\wYUhj Y'a YX]U'hUwlj\wj Zcf'h Y]f'wca a i b]\wuhjcb dfc'Ywlz'k\] [\wwxxfYgg'h Y'bYYXg'cZh Y]f'fYU'!k cf'X'Vf]YZ''H\Ymk\]'''VY'UV'Y'hc'cdYfUhY'g]a i 'hUbYci g'm Vch\']b'h Y'UwuXYa]\wubX'dfcZYgg]cbU''Ybj\]fcba Ybhz'Udd'm]b['X]XUwlj\wbchjcbg']bhc'h Y'fYU''k cf'X'cZa YX]U \wca a i b]\wuhjcb''$

5 https://bxubwww.Fyei]fYaYbhg

7ci fgY GWX YXi `Y

J]Yk 'WUgg'ha YhUV'Y

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8UHY	Hmd Y	7 cbh/bh
K YY_'%'%) ': YVfi Ufm!'%- : YVfi Ufm	; fci d'K cf_	D@95G9'G99': @@G7<98 @9'C: 'H<9 7C FG9'CB'ACC8@9"

FYgci fWfg

DfYgWf]VYX F Ygci fWYg

BchUj U]`UV`Y

FYWca a YbXYX FYgci fWYg

Bch'Uj U]`UV`Y

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

±DZcfa U``ZYYXVUW_`cb`h\Y`Wci fgY`k]```VY`gci [\hih\fci [\`Ub`]b!WUgg`ei Ygh]cbbU]fY`Xi f]b[`h\Y`Wci fgY`cZh\Y`gYa YghYf"

: cf²/bu¹·wci fgY'Yj u`i uhjcbžghi XYbhg'k]``fYWV]j Y'u``]b_'hc'h\Y'A m9l dYf]YbWV'gi fj Ymihck ufXg'h\Y'YbX'cZ h\Y'gYa YghYf"

Gi Va]gg]cb cZ5ggYgga YbhHUg_g

Hi fb]h]b Gi Va]gg]cb

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 bXYfgfUbX mci f'f][\hg'UbX'fYgdcbg]V]`]hJYg'Ug'U'gh XYbhUhl BGK
- VY`Uk UfY`cZd`U[]Uf]ga ž`Wcdmf][\hz'l BGK `Gh XYbh7cXY`cZ7cbXi WhUbX`5VWWdhUV`Y`l gY`cZ I BGK `=\forall H`F Ygci f\W\g`Dc`]\m\m
- VY 'Uk UfY 'cZh\Y 'ghUbXUfXg 'cZVY\Uj]ci f'Yl dYWYX 'cZYj YfmcbY ']b 'h\Y 'l BGK 'Wca a i b]hm
- `cWUHY 'gYfj]WYg'UbX ']bZcfa UH]cb'UVci hI BGK 'UbX'I BGK '@]VfUfm

Gca Y'cZh\YgY'UfYUg'k]``VY'ZJa]`]Uf'hc'mci ž'ch\Yfg'k]``VY'bYk"'; U]b]b['U'gc`]X'i bXYfgHJbX]b['cZU``h\YfY`UhYX'UgdYWng'cZ9@+69'k]``\Y`d'mci 'a U_Y'h\Y'a cghicZmci f'ghi X]Yg'UhI BGK "'\\hd.##qi VYWfi |XYg"`]VfUfm'i bqk "YXi "Ui #\`]qY#JVci hY`]qY