

HfYdhck!?ÒdYb]W_.'9]b'FY]gYZØ\fYf'ni BUhi fž'?i `hi f'i bX'; Ybi gg

9bhXYW_Yb^G]Y^HfYdhck!? OdYb]W_.^a U`Yf]gWXY^BUhi fž _i`hi fY``Y`<][\`][\hgž_i`]bUf]gWXY^? Ogh`]WX_Y]hYb^i bX gdUbbYbXY^; fY]nY]hUb[YVchY^k UfhYb^Ui Z'G]Y^



CV'Xi 'bi b'Y]b'5VYbhYi Yf']a ': fY]Yb'gi W\gh'cXYf'Y]bZUW\'bi f'X]Y Uha YbXY'GW\Ob\Y]h'XYf'I a [YVi b['[Yb]Y» Yb'a OW\hYghž'HfYdhck!? OdYb]W_'\Uh'ZØf'YXYb'Yhk Ug'ni 'V]YhYb"'I bX'j Yf[]gg'b]W\hž'X]Y Y]bn][Ufh][Yb'GhUXhhY]'Y'a]h']\fYb'j YfghYW_hYb'; Y\Y]a h]ddg'ni Yf_i bXYbž'X]Y'bi f'XUfUi Z'k UfhYbž'j cb'X]f'YbhXYW_h'ni 'k YfXYb" 8 Uni '_ca a Yb'X]Y'`YV\UZhYb'J YfUbghU`hi b[Yb'i bX': YghYž'X]Y'XYb`c_U`Yb'@YVYbggh]`'k]XYfgd]Y[Y`b'i bX'XUg'; Ya Y]bgW\UZhg[YZØ\`]b'X]YgYa 'VYnUi VYfbXYb'6Yn]f_'ghÀf_Yb"

A UWX 'X]WX 'VYfY]hž'HfYdhck!? ÒdYb]W_'ni 'Yf_i bXYb' 'Y]b'Cfhž'Ub XYa 'BUhi f'i bX'?i `hi f'Y]bY'\Ufa cb]gWXY'Gma V]cgY'Y]b[Y\Yb" @Ugg'i bg'Ui Z'X]YgY'FY]gY'[Y\Yb'i bX'X]Y'j YfgWX]YXYbYb': UWYhhYb X]YgYg'VYa Yf_Ybgk YfhYb'GhUXhhY]`g'Yf_i bXYb°

9bhXYW_i b['XYf'a U`Yf]gW\Yb'K À`XYf'i bX GYYb']b'HfYdhck!? ÒdYb]W_

$$\begin{split} &\text{HfYdhck} \ !? \ OdYb] \ W_{\ Z'Y} \ bYf'XYf'[fO) \ hYb'6Yn] f_Y'jcb'6Yf'] bz']gh'Y] b \\ &\text{kulfYg'DUfUX} \ Yg'ZOf'B Uhif'] \ YvluvYf''A \]h'gY] bYb'Uig[YXYlbhYb K \ A`XYfb'ibX'] Xm``]gW\ Yb'GYYb'V] YhYh'X] YgY'FY[]cb'Y] bY \\ &\text{k} \]``_caa YbY': `iWh'Uig'XYa'ifVUbYb'HfiVY`'XYf'< UidhghUXh'' \ VYf'''$$$'< Y_hUf'K U`XZAW\ Y'ibX'nU\`fY] W\ Y'; Yk \ AggYf'`UXYb Y] bz'X] Y'[fObY'GY] hY'6Yf`] bg'ni YbhXYW_Yb'''<]Yf'g] bX'Y] b][Y</p>
[\`][\hgz'X] Y'G] Y'k \ A\fYbX'\ \ \ fYf'9f_ibXib[Yb'b] W\ h'j YfdUggYb gc``hYb'''$$

5a 'GWX `UWX hYbgYY'Z]bXYb'G]Y'b]WXh'bi f'Y]b'k i bXYfgWX ÒbYg
DUbcfUa Už'gcbXYfb'Ui WX'nU\`fY]WXY'A Ò[`]WX_Y]hYb'ZØf
K UggYfgdcfh"'CV'GWXk]a a Ybž'GY[Y'b'cXYf'Y]bZUWX'bi f
YbhgdUbbYb' 'XYf'GWX`UWXhYbgYY']gh'Y]b'VY`]YVhYf'Cfh'ZØf
9]b\Y]a]gWXY'i bX'Hci f]ghYb"'8]Y'i a `]Y[YbXYb'GdUn]Yfk Y[Y'g]bX
]XYU`'ZØf'Y]bYb'[Ya Øh`]WXYb'Fi bX[Ub[ž'VY]'XYa 'G]Y'X]Y'BUhi f']b
j c``Yb'NØ[Yb'[Yb]Y» Yb'_ÒbbYb"

9]b'k Y]hYfYg'<][\`][\h']gh'XYf'; $fc * Y `A \varnothing[[Y`gYY\check{z}`XYf'[f\grave{O}*hYGYY`6Yf`]bg'''GY]bY'IZYf'V]YhYb'nU\`fY]WXY': fY]nY]ha \grave{O}[`]WX_Y]hYb\check{z}$ XUfi bhYf'6cchgZU\fhYbž'FUX!'i bX'K UbXYfk Y[Y'''G]Y'_ \grave{O} bbYb'\]Yf [Ubn'Y]bZUWX'Y]b'HfYhVcch'a]YhYb'cXYf'Ub'Y]bYa 'XYf'j]Y`Yb GhfUbXUVgWXb]hhY'X]Y'GcbbY'[Yb]Y*Yb'''8Yf'A $\varnothing[[Y`gYY']gh$ VYgcbXYfg']a 'Gca a Yf'Y]b'VY`]YVhYf'Cfh'Z \varnothing f'Y]b'D]W_b]W_'cXYf Y]bY'YbhqdUbbhY'NY]h'a]h': fYi bXYb'i bX': Ua]`]Y''

 $8 \ Yf'A \ \varnothing[\ [\ Y'k\ U'X']gh'Y]b'k\ Y]hYfYg' \not\Rightarrow k\ Y`]b''HfYdhck\ !?\ OdYb] \ w'' \ 8\]YgYf'[\ fc \ Y'K\ U'XVYfY] \ W'' YfghfY \ w''hg] \ W'' \ \varnothing VYf''' \ w'' \ & $' < Y_hUf'' b X'' \ VY' YfVYf[\ h'Y]bY'' j]Y`ZÀ`h][\ Y': `cfU'' b X': Ui b U''' <]Yf'[\]Vh'Yg \ nU\`fY] \ W'' YK Ub XYf!'' b X'F UXk Y[\ Yž'X]Y'gck c\``ZØf'[\ Ya\ Øh`] \ W'Y \ GdUn]Yf[\ Ab[\ Y'U`g'Ui\ W'' ZØf'gdcfh`] \ W'' < YfUi\ gZcfXYfi\ b[\ Yb\ [\ YY][\ bYhg]bX'''9]b' VYgcbXYfYg'9f`YVb]g']gh'X]Y'6YghY][\ i\ b['`XYg'' A\ \varnothing[\ [\ Y`hi\ fa\ gž'XYf'a\]h'gY]bYb'(\ $'A\ YhYfb' < O\ Y'Y]bYb\ UhYa\ VYfUi\ VYbXYb'5i\ gV`] \ W_''Ui\ Z'X]Y' \ @Ub XgW\ UZh'fi\ bX'i\ a\ "XYb\ A\ \varnothing[\ [\ Y`gYY'V]YhYh''$

- GWX`UWX hYbgYY. '6Y`]YVhYf'Cfh'ni a 'GWXk]a a Yb'i bX 9bhqdUbbYb"
- ; fc » Yf A Ø[[Y`gYY. ; fÒ » hYf GYY 6Yf`]bgž]XYU` ZØf 6cchghci fYb"
- A Ø[[Y`k U`X.; VYf'%"%&\$'<Y_hUf'K À`XYf'ni a 'K UbXYfb i bX'FUXZU\fYb"
- A Ø[[Y`hi fa . DUbcfUa UV`]W_ ØVYfX]Y l a [YVi b["

 $: \emptyset f "Jc[Y`!" ib X"H]Yf`]YV \setminus UVYf"]gh"XYf"B Uhi fgWX i hn[YV]Yh \\ 9fdYhU`" j cb"VYgcbXYfYa "\delta hYfYggY"" <]Yf"_\ObbYb"G]Y"gY`hYbY \\ Jc[Y`UfhYb"VYcVUWXhYb" ib X"X]Y"fi\][Yž" ib VYf\Ø\fhY"B Uhi f [Yb]Y\delta Yb""8]Y"UVk YWXg`ib[gfY]WXY"@UbXgWXUZhž"VYghY\YbX"Uig : Yi WXh[YV]YhYb" ib X"K\A`XYfbž"]gh"dYfZY_h"Z\Øf"Y]bYb"fi\][Yb"HU["]b XYf"B Uhi fž"UVgY]hg"XYg"gh\AXh]gWXYb"; YgWXY\Ybg"$

8 UgʻGhcf_ck YfʻHY]WX ; YV]YhʻV]YhYhʻYVYbZU``gʻY]bʻ[fc» Ufh][Yg 9f`YVb]gʻZØf`B Uhi f`]YV\UVYf"'8]Yʻ_`UfYbʻ; Yk ÀggYf`g]bXʻ<Y]a UhʻZØf j YfgWX]YXYbYʻ:]gWXYž'k Ugʻ5b[`YfʻUbn]Y\h"'8]Yʻfi\][YʻI a [YVi b[Y][bYhʻg]WXʻdYfZY_hʻZØf`Y]bYbʻYbhgdUbbhYbʻHU[ʻUaʻK UggYfž'k c G]YʻX]YʻZf]gWXYʻ@ʻZhʻi bXʻX]YʻZf]YX`]WXYʻGh]``Yʻ[Yb]Y»Ybʻ_ObbYb"

Cfh	5_h]j]hÀhYb	6YgcbXYf\Y]hYb
GWX`UWX hY b gY Y	GWk]a a YbžGY[Y`b	; Ya Øh`]W\Y
		GdUn]Yfk Y[Y
; fc»Yf'AØ[[Y`gYY	6cchghci fYbž	GWN ÒbghYf 5igV`]W_
	D]W_b]W_	
A Ø[[Y`k U`X	K UbXYfbž [*] FUXZU\fYb	; fc»Y'K U`XZÀWXY
9fdYhU`	Jc[Y`VYcVUW\hib[lbVYfØ\fhYBUhif

♣D'HfYdhck!? OdYb]W_']gh'Yg'Y]bY'k U\fY': fYi XYž'Xi fW\'X]Y'B Uhi f ni 'gW\'YbXYfbž'a]h'XYf': Ua]`]Y'cXYf': fYi bXYb'NY]h'ni 'j YfVf]b[Yb i bX'X]Y'j]Y`ZÀ`h][Y'H]Yf!'i bX'DZUbnYbk Y`h'ni 'VYcVUW\hYb"'8]YgY FY[]cb'\Uhij]Y`a Y\f'ni 'V]YhYb'U`g'bi f']\fY'GYYb'i bX'K À`XYf/'g]Y]gh'Y]b'Cfh'XYf'Fi \Y'i bX'XYg': f]YXYbgž'XYf'Yg'k Yfh']ghž'YbhXYW_h ni 'k YfXYb"'K Ybb'G]Y'a Y\f'ØVYf'X]YgY'k i bXYfgW\ObY'; Y[YbXYfZU\fYb'a OW\hYbž'_ObbYb'G]Y'X]Y'c ZZ]n]Y``Y'K YVg]hY'VYgi W\Ybži a 'i a ZUggYbXYfY' ♣DZcfa Uh]cbYb'i bX'H]ddg'ni 'Yf\U`hYb"

? i `hi fY``Y'<][\`][\hg. `A i gYYb'i bX \]ghcf]gW\Y'Gh\AhhYb

 $\label{eq:helicondecomposition} HfYdhck \ !? OdYb]W_{Z}Y]b''6Yn]f_']b''6Yf']bZ'V]YhYh'Y]bY''ZUgn]b]YfYbXYA \]gWXib[''Uig'; YgWX]WXhY'ibX''?i`hifž'ibX'']gh'VY_Ubbh'ZØf'gY]bYnU\`fY]WXYb''AigYYb''ibX'\]ghcf]gWXYb''GhÀhhYbž'X]Y''gckc\`Y]b\Y]a \]gWXY'U`g''UiWX']bhYfbUh]cbU`Y''6YgiWXYf'Ubn]Y\Yb''$

9]b 'VYXYi hYbXYg'<][\`][\h']gh'XUg'GW\`cgg'? ÒdYb]W_ž'XUg'Ui g
XYa '%+"'\J\f\i bXYfh'ghUa a h'i bX'ZfØ\Yf'U`g'K c\bg]hn'XYf
VfUbXYbVi f[]gW\Yb'?i fZØfghYb'X]YbhY"'< Yi hY'VY\YfVYf[h'XUg
GW\`cgg'XUg'A i gYi a 'ZØf'GhUXh[YgW\]W\hYž']b'XYa
]bhYfYggUbhY'5i gghY``i b[Yb'ni f'; YgW\]W\hY'XYf'FY[]cb'i bX
ØVYffUgW\YbXY'?i bghk Yf_Y'ni 'gY\Yb'g]bX"'8Yf'GW\`cggdUf_ž'Y]bY
W\Ufa UbhY'DUf_`UbXgW\UZhži a []Vh'XUg'; YVÀi XY'i bX'`ÀXh'ni
YbhgdUbbYbXYb'GdUn]Yf[Àb[Yb'Y]b"

9]b'k Y]hYfYg'A i gg']gh'XUg'K YbXYbgW\`c » ž'Y]b'a U`Yf]gW\Yg < YffYb\Ui gž'XUg'j cb'Y]bYa 'k Y]h`Ài Z][Yb'DUf_'i a [YVYb']gh'' <]Yf _ObbYb'6Ygi W\Yf'X]Y'gW\ObY'5fW\]hY_hi f'VYk i bXYfb'i bX']b'X]Y ; YgW\]W\hY'6Yf`]bg'Y]bhUi W\Yb'''6Ya Yf_Ybgk Yfh']ghž'XUgg'XUg ; YVÀi XY'Y]bgh'XYb'; YgW\k]ghYfb'XYf'?i fZØfghYb'j cb 6fUbXYbVi f['U`g'FYg]XYbn'X]YbhY'i bX'U`g'ni gÀhn`]W\Yg'NYi [b]g XYf 'XYf'FY[]cb'[]`h''

: Øf'?i bgh`]YV\UVYf']gh'X]Y'; fUZ]_k Yf_ghUhh']a 'GhUXhhY]`'HfYdhck Y]bY'ZUgn]b]YfYbXY'9bhXYW_i b["'G]Y'V]YhYh'K cf_g\cdg'i bX 5i gghY``i b[Yb'Ubž'X]Y'g]W\'a]h'j YfgW\]YXYbYb'8fi W_hYW\b]_Yb VYZUgqYb"'C Zh'Z]bXYb'\]Yf'Ui W\'J YfUbghU`hi b[Yb'i bX'A Àf_hY ghUhhžik UgʻX]YʻA Ò[`]WX_Y]hʻV]YhYhžiX]Yʻ5fVY]hYbʻ`c_U`Yfʻ? Øbgh`Yfini VYk i bXYfbʻi bXini '_Ui ZYb"

9]b'k Y]hYfYf'_i `hi fY``Yf'GW\Uhn']a '6Yn]f_']gh'XUg'
HYW\b]_a i gYi a ']b'XYf'BÀ\Y'XYg'A Ø[[Y`gYYg"'<]Yf'k YfXYb'X]Y
9bhk]W_`i b[Yb'XYf'HYW\b]_'i bX' \DXi ghf]Y[YgW\]W\hY'XYf'FY[]cb
`YVYbX]["'8]Y'5i gghY``i b['i a ZUggh'U``Yg'j cb'U`hYb'A UgW\]bYb'V]g
\]b'ni 'a cXYfbYb'HYW\bc`c[]Yb'i bX']gh'Y]b'k U\fYf'; Ybi gg'ZØf
HYW\b]_]bhYfYgg]YfhY'i bX': Ua]`]Yb"

8]Y'<Y]a Uhghi VY'? ÒdYb]W_']gh'Y]b'_`Y]bYfž'UVYf'ZY]bYf'Cfhž'Ub
XYa 'X]Y'; YgW\]W\hY'? ÒdYb]W_g'V]g']bg'%- "'\\J\f\i bXYfh'\]bY]b
Yf_i bXYh'k YfXYb'_Ubb"'<]Yf'Z]bXYb'6Ygi W\Yf'9f]bbYfi b[gghØW_Y
i bX'i a ZUb[fY]W\Y'\DZcfa Uh]cbYb'ni f'?i `hi f'i bX'@YVYbgk Y]gY'XYf
XUa U`][Yb'NY]h"'8]Y'Yb[U[]YfhYb'A]hUfVY]hYf'[YVYb'[YfbY
5i g_i bZh'i bX'YfnÀ\`Yb'; YgW\]W\hYbž'X]Y'X]Y'JYf[Ub[Yb\Y]h
`YVYbX]['k YfXYb'`UggYb"

 $8 \ Uf \emptyset V Y f``\]b \ Ui \ g`]gh`X Y f`GW\ `Yi \ gYbdUf_`Y]b Y``\]ghcf]gW\ Y`GhÅhhY \check{z} \\ X]Y`c Zh`\emptyset V Y fgY \ Yb`k \]fX"`5b`X Y f`U`hYb`GW\ `Yi \ gY`Yf`Y V Yb`G]Y`X]Y \\ V Yk \ Y[\ hY`; \ YgW\]W\ hY`X Y f`GW\]ZZZU\ fh`]b`6 Y f`]b`i \ bX`Y f\ U`hYb`Y]b Yb \\ 9]b V`]W_`]b`X]Y`K \ UggY fk \ Y[\ Yž`X]Y`Y]b gh`j \ cb`j \]hU`Yf`6 Y X Yi \ hi \ b[\ `ZØf X Yb` < Ub X Y``k \ Uf Yb"`8 Y f`DUf_`gY`V gh`]gh`Y]b`hc``Yf`C fh`ni \ a \\ 9b hgd Ubb Yb`i \ bX`ZØf`D]W_b]W_g`a \]h`6`]W_`Ui \ Z`X]Y`K \ UggY fghfU\sigma Y"$

Cfh	6YgWkfY]Vib[6YgcbXYf\Y]hYb
GWX`cgg'?ÒdYb]W_	AigYia ZØf	K i bXYfgWX ÒbYf
	GhUXh[YgWX]WXhY	GWX`cggdUf_
K YbXYbgWX`c»	< YffYb\Ui gʻ]a ʻDUf_	<pre><]ghc f]gWX Y F Y g]XYb n</pre>
; fUZ]_k Yf_ghUhh	?Øbgh`Yf]gWXY	FY[]cbU`Y'?i bgh
	K cf_g\cdg	
HYWMb]_a i gYi a	HYWxb]_! ii bX	⇒hYfU_h]j Y 91 dcbUhY
	⇒bXighf]Y[YgWX]WXhY	
< Y]a Uhghi VY	<]ghc f]gW\ Y	@YVYbX][Y
? Òd Y b] W_	5i gghY``i b[Yb	9fnÀ\`i b[Yb
GWX`Yi gYbdUf_	<]ghc f]gW\ Y	≠Xm``]gW\Yf
	K UggYfghfU»Y	9f\c`i b[gcfh

Ni 'XYb': Ygh]j U`g'i bX'J YfUbghU`hi b[Yb']b'HfYdhck!?ÒdYb]W_
[Y\Òfh'Ui W\'XUg'?ÒdYb]W_Yf'5`hghUXhZYghž'XUg'b]W\h'bi f
?i `hi fž'gcbXYfb'Ui W\'`c_U`Y'?i bgh'i bX'; Ughfcbca]Y'ZY]Yfh'''<]Yf
_ÒbbYb'6Ygi W\Yf'X]Y'; YgW\]W\hY'XYf'GhUXh'_YbbYb`YfbYb'i bX']b
X]Y'`c_U`Y'; Ya Y]bgW\UZh'Y]bhUi W\Yb"'8Yf'\]ghcf]gW\Y'?Yfb'j cb
?ÒdYb]W_']gh'j c```j cb'_`Y]bYb'@\XYbž'X]Y'\UbX[YZYfh][hY'DfcXi _hYibXfY[]cbU`Y'GdYn]U`]h\hYb'UbV]YhYb"

?i`]bUf]gWXY'?Ògh`]WX_Y]hYb'XYf'FY[]cb. 9ggYb'ibX'Hf]b_Yb

HfYdhck!? OdYb]W_ž'VY_Ubbh'ZØf'gY]bY'bUhi fbU\Y'@U[Y'i bX'XYbj]Y`Yb'; Yk ÀggYfbž']gh'b]W\h'bi f'Y]b'Cfh'ZØf'GW\Ob\Y]h'i bX
9bhgdUbbi b[ž'gcbXYfb'Ui W\'Y]b'GW\a Y`nh]Y[Y`'_i `]bUf]gW\Yf; YbØggY"'<]Yf'Z]bXYb'G]Y'Y]bY'VfY]hY'DU`YhhY'Ub'[Ughfcbca]gW\Yb5b[YVchYbž'X]Y'gck c\``X]Y'hfUX]h]cbY``Yb'6Yf`]bYf'?ØW\Y'U`g'Ui W\]bhYfbUh]cbU`Y'GdYn]U`]hÀhYb'i a ZUggYb"'Jcb'[Ya Øh`]W\Yb'7UZÅgV]g'\]b'ni 'Y`Y[UbhYb'FYghUi fUbhg'V]YhYh'XYf'GhUXhhY]`'ZØf'YXYb; Ui a Yb'XUg'F]W\h][Y"

9]b 'VYgcbXYfg'VY`]YVhYg'; Yf]W\hgUb[YVch']b'HfYdhck!? OdYb]_']gh X]Y'\(\forall Yf\)'\(\forall Yf\)'\(\for

- BUa Y. 6Yf`]bYf'6ci `YhhY
- < Ui dhVYghUbXhY]`Y. '< UW_ZY]qW\z`Nk]YVY`bz'; Yk ØfnY
- 6 Y g c b X Y f \ Y] h Y b . "C Zh a] h ? U f h c ZZY `g U `U h `g Y f j] Y f h

: Øf'@]YV\UVYf'j cb']bhYfbUh]cbU`Yf'? ØWXY'\À`h'HfYdhck!? ÒdYb]W_
YVYbZU``g'Y]bY'J]Y`nU\``Ub'Cdh]cbYb'VYfY]h"'+b'XYb'`YhnhYb'*\J\fYb
\UVYb'g]WX'a Y\fYfY'FYghUi fUbhg'YhUV`]Yfhž'X]Y'YI ch]gWXY'5fca Yb
i bX'FYnYdhY'Ui g'j YfgWX]YXYbYb'HY]`Yb'XYf'K Y`h'UbV]YhYb"
6YgcbXYfg'\Yfj cfni \YVYb'g]bX'X]Y'Ug]Uh]gWXYb'FYghUi fUbhgž
X]Y'a]h']\fYb'Zf]gWXYb'Ni hUhYb'i bX'j]Y`ZÀ`h][Yb'; Yf]WXhYb'X]Y
; YgWXa ÀW_Yf'Ui Z'XYf'Ni b[Y'nYf[Y\Yb'`UggYb"

9]b'k Y]hYfYg'<][\`][\h']gh'XUg'GW Òb\Ui gYf'5``YYž'Y]b
a U`Yf]gW\Yf'6ci `Yj UfXž'XYf'j]Y`Y'gh]`j c``Y'FYghUi fUbhg'i bX'7UZÅg
VY\YfVYf[h"'<]Yf'[]Vh'Yg'nU\`fY]W\Y'A Ò[`]W_Y]hYbž'X]Y'XYi hgW\Yb
6]YfgdYn]U`]hÀhYb'ni '[Yb]Y» Yb'cXYf'g]W\'a]h'Y]bYa '; `Ug
fY[]cbU`Ya 'K Y]b'ni 'j Yfk Ò\bYb"'8Ug'K]fhg\Ui g'Ua
A Ø[[Y`gYY']gh'VY]gd]Y`gk Y]gY'VY_Ubbh'ZØf'gY]b'Ub[YbY\a Yg
5a V]YbhY'i bX'gY]bY'\Yfj cffU[YbXY'?ØW\Yž']b'XYf'`c_U`Y'Ni hUhYb
[fc»[YgW\f]YVYb'k YfXYb"

; Yf]W\h	6YgWXfY]Vib[9a dZc\`YbY`6Y]`U[Y
6Yf`]bYf	; Y <i>Z</i> Ø``hYf'HY]['UiZ	Ni W_Yf VYghfYi h
DZUbb_i WXYb	< YZY!6Ug]gž'cZh'a]h	
	A Ufa Y`UXY	
?YggY`[i`UgW\	< Yfn\UZhYg	?UfhcℤY`b′cXYf′6fch
	: `Y]gW [Yf]W hž	
	[Y_cWkh [·]]b [·] Y]bYa	
	[fc»Yb [·] HcdZ	
GUi YfVfUhYb	9]b[Y_cWXhYg	Fch_c\`ibX'?bÒXY`
	F]bXZY]gWX^]b^gØ»!	
	gUi fYf [·] GUi VW	

K Yf'Y]b'VYgcbXYfYg'; YgWXa UW_gYf`YVb]g'gi WXhž'gc``hY'XUg' :]gWXfYghUi fUbh'Ua 'A Ø[[Y`gYY'VYgi WXYb'''<]Yf'_ÒbbYb'G]Y Zf]gWXY'i bX'fY[]cbU`Y':]gWX [Yf]WXhY'[Yb]Y» Ybž'X]Y'Ui g'XYb i a `]Y[YbXYb'; Yk ÀggYfb'ghUa a Yb"'8Yf'6`]W_'Ui Z'XYb'A Ø[[Y`gYY k À\fYbX'XYg'9ggYbg'a UWXh'XUg'9f`YVb]g'bcWX'i bj Yf[Ygg`]WXYf"

J Yf[YggYb 'G]Y 'b]W\ hz Y]bY 'XYf 'nU\ `fY]W\ Yb '7 UZ\ g']b 'XYf

I a [YVi b['Ui gni dfcV]YfYb" '8]YgY 'V]YhYb '_\Ogh\]W\ Y '?i W\ Yb 'i bX

? UZZYY 'Ui g'`c_U`Yb 'F OghYfY]Yb 'Ub" '8 Ug'7 UZ\ 'Ua '< Ui dhd`Uhn']gh

: Øf Y]b 'Ui h\Ybh]gW\Yg'_i `]bUf]gW\Yg'9f`YVb]g'Ya dZ]Y\`h'Yg'g]W\
Ui W\Z'Ub Y]bYa 'XYf'fY[Y`a À»][Yb'K cW\Yba Àf_hY']b 'HfYdhck!
? OdYb]W_'hY]`ni bY\a Yb"'<]Yf'V]YhYb'`c_U`Y'6Ui Yfb'i bX
DfcXi nYbhYb'Zf]gW\Yž'gU]gcbU`Y'DfcXi _hY'Ub"'G]Y'_ObbYb'Zf]gW\Yg
C Vghž'; Ya ØgYž'\Ui g[Ya UW\hY'5i Zghf]W\Y'i bX'Yl ei]g]hY
? AgYgcfhYb'YbhXYW_Ybž'X]Y'G]Y'XUbb'ni '< Ui gY'cXYf']a 'Y][YbYb
: Yf]YbUddUfhYa Ybh'ni VYfY]hYb'_ObbYb"</pre>

8]Y '_i `]bUf]gW\Yb'A O[`]W_Y]hYb']b'HfYdhck!?OdYb]W_'g]bX'gc

j]Y`ZÀ`h]['k]Y'X]Y'A YbgW\Ybž'X]Y'\]Yf'`YVYb"'CV'fi gh]_U`'cXYf

a cXYfb' 'X]Y'FY[]cb'V]YhYh'ZØf'YXYb'; YgW\a UW_'i bX'; Y`XVYi hY`
Yhk Ug"'6Y]'Y]bYa '6Ygi W\']b'X]YgYf'W\Ufa UbhYb'9W_Y'6Yf`]bg
gc``hYb'G]Y'g]W\'X]Y'; Y`Y[Yb\Y]h'b]W\h'Ybh[Y\Yb'`UggYbž'Y]b][Y
XYf'VYghYb'`c_U`Yb'?Ogh`]W_Y]hYb'ni 'dfcV]YfYb"

5_h]j 'gY]b.': fY]nY]hUb[YVchY'i bX'Ci hXccf! 5VYbhYi Yf

HfYdhck!? OdYb]W_ža]hgY]bYba U`Yf]gWXYb@UbXgWXUZhYbiibXnU\`fY]WXYb:fY]nY]ha O[`]WX_Y]hYbžV]YhYhCihXccf!9bh\ig]UghYbY]bY:Ø``Y`Ub'5_h]j]hÀhYb"'8]Y'?ca V]bUh]cb'Uig'K À`XYfbž;Yk ÀggYfbiibX'k Y]h`ÀiZ][Yb'DUf_g``ÀXh'XUni 'Y]bž'X]Y'BUhif']bjc``Yb'NØ[Yb'ni'[Yb]Y»YbiibX'U_h]jini'gY]b"'CV'VY]a'K UbXYfbžFUXZU\fYb'cXYf'DUXXY`b'']b'X]YgYf'6Yf`]bYf'FY[]cb']gh'ZØf'YXYbYhk Ug'XUVY]"

K UbXYfb i bX F UXZU\fYb

8]Y 'UVk YWkg'i b[gfY]Wk Y '@UbXgWk UZh'j cb 'HfYdhck!? OdYb]W_Y][bYh'g]Wk '\Yfj cffU[YbX'ZØf'Ui g[YXY\bhY'K UbXYf!'i bXFUXhci fYb"'9g'[]Vh'nU\`fY]Wk Y [i h'Ui g[YgWk]`XYfhY'K UbXYfk Y[YibX'FUXk Y[Yž'X]Y'Xi fWk 'K À`XYfž'DUf_g'i bX'Ybh'Ub['XYf'j]Y`YbGYYb'ZØ\fYb"'6YgcbXYfg'\Yfj cfni \YVYb'g]bX.

 $\bullet \ \ 8\ Yf\ GdfYYk\ U`X\ \check{z}\ VY_Ubbh'\ ZO\!\!\!\!Df\ gY\]bY\]Xm``]gW\ Yb$

- K UggYfk Y[YibXibVYfØ\fhYBUhif"
- 8Yf'8U\aY'F]jYfž'XYf'nU\`fY]WXY'AÒ[`]WX_Y]hYb'ZØf
 6cchg!'ibX'5b[Y`UigZØ[Y'V]YhYh"
- $8 Y f' D \hat{A} b h Y f k U \hat{X} Z' Y] b' k i b X Y f g W \hat{O} b Y f' K A \hat{X} W Y b d U f _ Z'] X Y U \hat{Z} G f' Y] b Y b' f i \] [Y b' G d U n] Y f [U b ['c X Y f' Y] b' D] W _ "$

 $: \emptyset f `F U X Z U \setminus f Y f `] g h `X Y f `8 U \setminus a Y !F U X k Y [`Y] b Y `V Y `] Y V h Y `F c i h Y \check{z} `X] Y X i f W X `X] Y `f Y] n j c ``Y `I a [Y V i b [`Z Ø \ f h `i b X `U h Y a V Y f U i V Y b X Y 5 i g V `] W_Y `U i Z X] Y `B U h i f `V] Y h Y h '' `9 [U `ž `c V `G] Y `Y] b Y `Y b h g d U b b h Y F U X h c i f `c X Y f `Y] b Y `g d c f h `] W X Y f Y `< Y f U i g Z c f X Y f i b [`g i W X Y b ž `\] Y f Z b X Y b `G] Y `X] Y `d U g g Y b X Y `G h f Y W_Y "$

K UggYfgdcfh

8]Y 'nU\`fY]W\Yb'; Yk ÀggYf']b'HfYdhck!? ÒdYb]W_'g]bX'Y]b'DUfUX]Yg ZØf'K UggYfgdcfh`]YV\UVYf"'8Yf'GW\k]Y`ck gYY'i bX'XYf'; fc y A Ø[[Y`gYY'g]bX']XYU`'ZØf'5_h]j]hÀhYb'k]Y.

- ? Ubi ZU\fYb i bX ? U^U_ZU\fYb. A]YhYb G]Y Y]b 6cchi bX Yf_i bXYb G]Y X]Y fi \][Yb K UggYfk Y[Y XYf I a [YVi b["
- GY[Y`b`i bX`K]bXgi fZYb.`DfcZ]h]YfYb`G]Y`j cb`XYb cdh]a U`Yb`6YX]b[i b[Yb`i bX`Y]bYf`J]Y`nU\``j cb K UggYfgdcfhnYbhfYb"
- $GWK k]a a Yb. 8]Y GhfÀbXY fi bX i a X]Y GYYb V]YhYb X]Y A Ò[<math>]WK_Y]h\check{z}g]WK Ub k Ufa Yb HU[Yb UVni <math>@VYb$ "

 $: \emptyset f^*X]Y Yb][Yb\check{z}^*X]Y^*XUg^*K UggYf^*]YVYf^* hfc W_Yb ^*Yf^*YVYb\check{z}^*[]Vh^*Yg A \mathring{O}[^*]WX_Y]hYb^*ni a ^*5b[Y^*b''^*CV^*G]Y^*gW^*cb^*Y]b^*YfZU\^fYbYf^*5b[^*Yfg]bX^*cXYf^*Yg^*Y]b^*ZUW^*Y]ba U^*Ui gdfcV]YfYb^*a <math>\mathring{O}W$ ^hYb \mathring{z}^*X]Y ?ca V]bUh]cb^*Ui g^*Fi \Y^*i bX^*BUhi f^*a UW^*Yb^*XUg^*5b[Y^*b^*]b^*X]YgYf FY[]cb^*VYgcbXYfg^*fY]nj c^**'''

GdcfhibX:]hbYgg]a : fY]Yb

±b 'HfYdhck!? ÒdYb]W_'[]Vh'Yg'Ui W\ 'nU\`fY]W\Y'GdcfhY]bf]W\ hi b[Ybž X]Y'Yg'XYb'9]b\Y]a]gW\Yb'i bX'6Ygi W\Yfb'Yfa Ò[`]W\Ybž']\fY:]hbYgg']a': fY]Yb'ni 'j YfVYggYfb"'±b'j]Y`Yb'DUf_g'i bX; fØbUb`U[Yb'Z|bXYb'G]Y.

- :]hbYgg!DUfWci fgžX]Y ZØf i bhYfgW]YX`]WXY HfU]b]b[g`Yj Y``Ui g[Y`Y[h'g]bX"
- Gdcfhd`ÀhnY`ZØf::i»VU``ž'6Ug_YhVU```cXYf'Jc``YmVU``ž'X]Y
 gckc\``ZØf'JYfY]bg!'U`g'UiW\'ZØf':fY]nY]hgdcfh'VYhf]YVYb
 kYfXYb"
- DUf_g'a]h'Hf]a a !8]W !DZUXYbž'X]Y'g]W 'dYfZY_h'ZØf'Y]b i a ZUgqYbXYg'K cf_ci h']a ': fY]Yb'Y][bYb"

9]b'VY`]YVhYg'N]Y`ZØf'Gdcfh`Yf']gh'XYf'K U`XVUX'HfYdhck ž'k ca Ub'Ub'?i fgYb'k]Y'Mc[U'cXYf'HU]'7\]'bY\a Yb'_Ubb"'8]YgY?i fgY'k YfXYb'cZh'X]fY_h'Ui Z'XYb'K]YgYb']ba]hhYb'XYf'BUhi fUb[YVchYb' 'Y]bY'dYfZY_hY'A Ò[`]W_Y]hž'g]W\ni 'YbhgdUbbYb'i bX[`Y]W\nY]h]['U_h]j 'ni 'V`Y]VYb"

: Ua]`] $YbZfYibX`]WXY'5_h]j]hAhYb$

 $\label{eq:hamiltonian} HfYdhck !? OdYb]W_`V]YhYh`Ui Wk`Y]bY`J]Y`nU\``j cb`5_h]j]hÀhYb`ZØf : Ua]`]Yb"`J]Y`Y`XYf`cVYb`[YbUbbhYb`: fY]nY]ha O[`]Wk_Y]hYb`g]bX _]bXYfZfYi bX`]Wk`i bX`V]YhYb`GdU» <math>Z$ Øf`U``Y`5`hYfg[fi ddYb"`8 UfØVYf \]bUi g`[]Vh`Yg.

- Gd]Y`d`ÀhnY`]b'j]Y`Yb'DUf_gž'X]Y': UbhUg]Y'i bX'6Yk Y[i b[ZÒfXYfb"
- N]f_i gj cfghY``i b[Yb i bX H\YUhYfj cfZØ\fi b[Yb i]b XYb Gca a Yfa cbUhYbžX]Y : Ua]`]Yb Ubn]Y\Yb"
- : U\ffUXj Yf`Y]\ghUh]cbYbž'X]Y'Yg'Yfa Ò[`]W\Ybž'X]Y FY[]cb'VYei Ya 'a]h'XYf': Ua]`]Y'ni 'Yf_i bXYb"

Gc``hYb'G]Y'g]W\'bUW\'Y]bYa 'Yf`YVb]gfY]W\Yb'HU[']b'XYf'BUhif YbhgdUbbYb'k c``Ybž'V]YhYb'nU\`fY]W\Y'7UZÅg'i bX'FYghUi fUbhg']bXYf'FY[]cb'X]Y'A Ò[`]W_Y]hž'fY[]cbU`Y'?Ògh`]W_Y]hYb'ni[Yb]Y»Yb"'DfcV]YfYb'G]Y'XYZh][Y'6Yf`]bYf'; Yf]W\hY'cXYf'`c_U`YGdYn]U`]hÀhYbž'i a 'XYb'HU['Ui q_`]b[Yb'ni '`UggYb"

8]Y'W\Ufa UbhYb'GhUXhhY]`Y'i bX']\fY ; Y\Y]a h]ddg

HfYdhck . 9]b GhUXhhY] a]h; YgWX]WX hY

 $\label{thm:linear} HfYdhck ``Uh`Y]bY`ZUgn]b]YfYbXY`; YgWX]WXhYž`X]Y`V]g`]bg`A]hhY`U`hYfni fØW_fY]WXh"`9]b`UVgc`i hYg`A i gg`]gh`XYf`HfYdhck Yf`DUf_ž`XYfb]WXh`bi f`Y]b`gWX\ObYf`9f\c`i b[gcfh`]ghž`gcbXYfb`Ui WX`XUg VYY]bXfi W_YbXY`GWXk YXYb!8Yb_a U``VY\YfVYf[h" <]Yf`_ObbYbG]Y`[Ya Øh`]WX`gdUn]YfYb`[Y\Ybž`^c[[Yb`cXYf`Y]bZUWX`X]Y`BUhi f [Yb]Y`Yb"`9]b`; Y\Y]a h]dd`]gh`XUg`_`Y]bY`7UZÅ`]a `DUf_ž`XUg_Ogh`]WXYb`?i WXYb`i bX`Zf]gWXYb`?UZZYY`UbV]YhYh"$

$? \text{OdYb} W_. 8 \text{Ug } \] ghcf]gWXY < Yfn$

 $8 \ Yf'6 \ Yn]f_? \ Od \ Yb] \ W_` \ Uh'Y]b \ Y'a \ U`Yf]g \ W \ Y'5 \ hgh U Xh X X] \ Y'a \]h'] \ f \ Yb : UW \ k \ Yf_ \ Ai g Yfb'i b X' X Ya 'V Yf Ø \ a h Yb'? Od Yb] \ W_Yf' G W \ cgg \ n]Y \ h'j]Y Y'6 Ygi W Yf' Ub''' = G W \ cgg' V Y Z]b X Yb'g] W 'X]Y'' \ GUa a `i b['XYf'? i b gh[Yk Yf V Y'i b X' X Ug' < i a Vc`Xh! Ai g Yi a ž X]Y'Y]b Yb'6 Ygi W 'k Yfh'g]b X'''9]b'; Y \ Y]a h]dd' \]Yf']gh' X Yf'' \ GhUXhhY]`'N Yfb g X c f Z Z X Y f'Yhk Ug' UV g Y]hg' X Yf' Hci f]gh Y b gh f Oa Y \ `]Y[h'i b X'] X m``]g W Y' G Y Yb'i b X' W Ufa Ubh Y'_`Y]b Y' 7 U Z Åg' V] Yh Yh''' \$

$5 h! HfYdhck. 8 Ug \]ddY J]YfhY$

 $5`h! HfYdhck ~`\ Uh'g]WX']b`XYb``YhnhYb`&U\ fYb'ni ~Y]bYa ~`VY`]YVhYb < chgdch`ZØf''l b[Y'@Yi hY'i bX'?fYUh]j Y'Ybhk]W_Y`h''' <]Yf'Z]bXYb`G]YnU\`fY]WXY'_fYUh]j Y'; YgWXÀZhYž'5hY`]Yfg'i bX''7UZÅgž'X]Y'Y]bY$

[Ya Øh`]WXY'5ha cgd\ÀfY'V]YhYb"'9]b'; Y\Y]a h]dd']gh'XYf' HYa dY`\cZYf': Y`Xž'k c'G]Y'b]WXh'bi f'gWX`Ya a Yb'_ObbYbž gcbXYfb'Ui WX'Ub'j YfgWX]YXYbYb'J YfUbghU`hi b[Yb'i bX'A Àf_hYb hY]`bY\a Yb"'JYfgi WXYb'G]Y'XYb': ccX!Hfi W_'X]fY_h'Ua 'DUf_'ZØf Y]b][Y'XYf'VYghYb'GhfYYh!: ccX!; Yf]WXhY']b'XYf'GhUXh''

5X`Yfg\cZ.8YfK]ggYbgW\UZhgghUbXcfh

5X`Yfg\cZk]fX`cZh`U`g`X]Y`G]`]Wcb`JU``Ym`8Yi hgWk`UbXg VYnY]W\bYhi bX`VY\YfVYf[h`Y]bY`a cXYfb`[YghU`hYhY`5fWk]hY_hi f gck]Y`]bbcj Uh]j Y`I bhYfbY\a Yb`i bX`: cfgWki b[g]bgh]hi hY" 6Ygi WkYb`G]Y`X]Y`7UgUV`UbWU`:]`a ghi X]c`ZØf`Y]bYb`6`]W_`\]bhYf X]Y`?i`]ggYb`XYf`:]`a dfcXi_h]cb"`9]b`; Y\Y]a h]dd`]gh`X]Y` K]ggYbgWk UZhga Y]`Yžk c`fY[Y`a À»][`]bhYfYggUbhY 5i gghY``i b[Yb`i bX`JYfUbghU`hi b[Yb`ghUhhZ]bXYb"

6Yhf]YVgZØ\fib[YbibXJYfUbghU`hib[Yb

9]b'k Y]hYfYf'; Y\Y]a h]dd']b'HfYdhck!?ÒdYb]W_'g]bX'X]Y
fY[Y`a À»][Yb'GhUXhZØ\fi b[Yb'i bX'JYfUbghU`hi b[Ybž'X]Y'h]YZYfY
9]bV`]W_Y']b'X]Y'; YgWX]WXhY'i bX'X]Y'?i `hi f'XYf'GhUXhhY]`Y'V]YhYb"
6YgcbXYfg'VY`]YVh'g]bX'X]Y'\]ghcf]gWXYb'GhUXhZØ\fi b[Ybž'X]Y
gdUbbYbXY'; YgWX]WXhYb'i bX'5bY_XchYb'YfnÀ\`Yb"'GWXUi Yb'G]Y
Ui Z'XYf'K YVgY]hY'XYf'Hci f]gh]_'HfYdhck!?ÒdYb]W_'j cfVY]žii a
U_hi Y``Y'JYfUbghU`hi b[Yb'i bX'[YZØ\fhY'Hci fYb'ni 'YbhXYW_Yb"

?i `hi fY``Y'9j Ybhg']a '@c_U`Yb': `U]f

 $? OdYb]W_g`WWUfa UbhY`5`hghUXh`VY\YfVYf[h`\AiZ][`A Uf_hhU[YibX': Ygh]j U`gž`X]Y`XUg``c_U`Y`< UbXk Yf_`ibX`X]Y`; Ughfcbca]Y ZY]Yfb''`< U`hYb`G]Y`5i ggWWUi `bUWW`XYa `S? OdYb]W_Yf`?ibgh!`ibX?i`hifZYghSž`XUg`YXYg`&U\f`nU\`fY]WWY`? Øbgh`Yf`ibX`Aig]_YfUbn]Y\h''`9g`[]Vh`Ui WW`XYb`K Y]\bUWW hga Uf_hž`XYf`Y]bY kibXYfVUfY`5ha cgd\AfY`a]h``c_U`Yb`GdYn]U`]hAhYb`V]YhYh''$

; Y\Y]a b]ggY XYf; Ughfcbca]Y

 $VY_Ubbh" 5VgY]hg`XYf`[fc "Yb`GhfU" Yb`Z]bXYb`G]Y`j]Y`Y`_`Y]bYž ZUa]`]Yb[YZØ\fhY`FYghUifUbhg`ibX`?bY]dYb"`9]b`;Y\Y]ah]dd`ZØf@]YV\UVYf`XYf`]hU`]Yb]gWXYb`?ØWXY`]gh`Y]b`_`Y]bYg`FYghUifUbhž`XUg \UbX[YaUWXhY`DUghU`ibX`Zf]gWXY`NihUhYb`gYfj]Yfh"`8]Y`:]gWXYfY]]b`? OdYb]W_`]gh`YVYbZU``g`Y]bYb`6YgiWX`kYfhž`b]WXh`bif`kY[Yb`XYg_Ogh`]WXYb`:]gWX[Yf]WXhgž`gcbXYfb`UiWX`kY[Yb`XYg`6`]W_Yg`UiZXUg`KUggYf"$

: Un]h'ni 'XYb'; Y\Y]a h]ddg

 $8]Y `W Ufa UbhYb `GhUXhhY] `Y `j cb `HfYdhck !? OdYb] W_ `V] YhYb `Y] bY J]Y `nU ``Ub `9f` YVb] ggYb ~z X]Y `j cb `XYf `B Uhi f `V]g `ni f `? i `hi f `fY] W Yb " 9 [U `z `c V `G]Y `Ui Z `XYf `Gi W Y `b UW `\] ghcf] gW Ya :: `U] f ~z _i `] b Uf] gW Yb @Y W_ YfV] ggYb `c XYf `] b b c j Uh] j Yb `J Yf UbghU `hi b [Yb `g] b X ~z X] YgY GhUXhHY] `Y `\ UVYb `ZØf `YXYb `Yhk Ug `ni `V] YhYb " @UggYb `G]Y `g] W `NY] h ~z Yf_i b XYb `G]Y `X]Y __`Y] b Yb `; UggYb `i b X [Yb]Y ~yb `G]Y `X]Y ; UghZfYi b XgW UZh XYf `J cfcfhY `6Yf`] b g "$

JYfUbghU`hi b[Yb'i bX': YghY. '8 Ug'@YVYb']b HfYdhck!? OdYb]W_'Yf`YVYb

HfYdhck!? OdYb]W_žVY_Ubbh ZØfgY]bY a U`Yf]gWXYBUhifibX`X]Y WXUfa UbhYb GhUXhhY]`YžV]YhYh XUg [UbnY **\\f'ØVYfY]b Vi bhYg GdY_hfia `Ub'JYfUbghU`hi b[Yb'i bX': YghYbž'X]Y`XUg'@YVYb']b X]YgYf'Y]bn][Ufh][Yb'6Yf`]bYf'FY[]cb'nia '@Yi WXhYb'Vf]b[Yb"'9[U`žcV'G]Y'Y]b'?i `hi fYbh\i g]Ughž'Y]b'; Yb]Y» YfcXYf'Y]b'Ci hXccf!: Ub g]bXž'\]Yf'[]Vh'Yg'ZØf'YXYb'Yhk Ug'ni 'YbhXYW_Yb'i bX'ni 'Yf`YVYb"

9]b <][\`][\h']a 'J YfUbghU`hi b[g_U`YbXYf']gh'XUg'HfYd hc k Yf < UZYb ZYghž XUg'YXYg' \sharp J\f']a 'GdÀhgca a Yf'ghUhhZ]bXYh''5b XYb I ZYfb 'XYf'GdfYY'j YfgUa a Y`b'g]W\nU\`fY]W\Y'6Ygi W\Yfž'i a `c_U`Y'; Ughfcbca]Yž'<UbXk Yf_g_i bgh'i bX'@]j Ya i g]_'ni [Yb]Y» Yb'''8]Y'5ha cgd\ÀfY']gh'ZYgh`]W\'i bX'Y]b`UXYbXž'k À\fYbX 6cchgZU\fhYb'Ui Z'XYf'GdfYY'i bX'j YfgW\]YXYbY'5_h]j]hÀhYb'ZØf?]bXYf'X]Y'J YfUbghU`hi b['VYfY]W\Yfb''

9]b k Y]hYfYg VYa Yf_Ybgk YfhYg 9j Ybh]gh XUg ? OdYb]W_Yf 5 hghUXhZYghž XUg]a 5i [i gh ghUhhZ]b XYh i b X X]Y 6 Ygi W Yf]b X]Y \ Yfn]W Y 5 ha cgd \ AfY XYf \]ghcf]gW Yb 5 hghUXh Yb hZØ\ fh" <]Yf k YfXYb hfUX]h]cbY `Y GdY]gYb i b X ; YhfAb_Y Ub [YVchYbž i b X Yg []Vh nU\ fY]W Y GhAb XY a]h < Ub Xk Yf_g_i bgh" A i g]_! 5 Whg j YfgW]Y XYb Yf ; YbfYg gcf[Yb ZØf [i hY @Ui b Yž i b X X]Y GhfU» Yb g]b X ZYgh]W XY_cf]Yfh" 9]b < O\ Ydi b_h XYg : YghYg]gh XYf hfUX]h]cbY`Y : Yghi a ni [ZXYf X]Y ; YgW]W hY ? OdYb]W_g ZY]Yfh"

 $8]Y `GhYfbYba Uf_h']a `K]bhYf'j Yfk UbXY`h'XYb'K i `YdUf_']b'Y]b nUi VYf\UZhYg'K]bhYfk i bXYf`UbX"'<]Yf'_ObbYb'6Ygi W\Yf \UbX[YZYfh][hY'; YgW\Yb_Y'i bX'@YW_YfY]Yb'_Ui ZYb'i bX'X]Y gh]a a i b[gj c``Y'5ha cgd\AfY'a]h'@]W\hYfb'i bX'A i g]_'[Yb]Y»Yb'' 9g']gh'XYf'dYfZY_hY'Cfhž'i a 'g]W\'Ui Z'X]Y': Y]YfhU[Y'Y]bni gh]a a Yb i bX'`c_U`Y'? Ogh`]W_Y]hYb'ni 'dfcV]YfYb''$

: Øf X]Y GdcfhVY[Y]ghYfhYb i bhYf i bg []Vh Yg Y]bY FY]\Y j cb J YfUbghU hi b[Ybž X]Y XUg; Ya Y]bgW UZhg[YZØ\`ghÀf_Yb" 8 Yf GhfU» Yb`Ui Z Xi fW 'HfYdhck!? ÒdYb]W ž XYf 'A\f`]W ghUhhZ]b XYhž Vf]b[h @Ai ZYf Ui g XYf FY[]cb i bX XUfØVYf \]bUi g ni gUa a Yb" 8]Y GhfYW_Yb ZØ\fYb Xi fW X]Y gW ÒbghYb 9W_Yb XYg 6Yn]f_Yg i bX V]YhYb gck c\`Y]bY gdcfh`]W Y < YfUi gZcfXYfi b['U`g Ui W X]Y A Ò[`]W _Y]hž X]Y a U`Yf]gW Y I a [YVi b['ni '[Yb]Y» Yb"

JYfUbghU`hib[AcbUh	Cfh
HfYdhck Yf' < UZYbZYgh	5i [i gh	HfYdhck
? Òd Y b] W_ Y f	5i [i gh	? Òd Y b]W_
5`hghUXhZYgh		
GhYfbYba Uf_h	8YnYa VYf	Ki\`YdUf_
GhfU» Yb`Ui Z	5df]`	HfYdhck!?ÒdYb]W_

8]Y 'HfUX]h]c b Y ``Y b 'GhUX hhY]`ZY ghY 'g]b X 'Y]b Y 'k Y]hY fY
A O[`]WX_Y]hZ'X]Y '`c_U`Y '? i `hi f`ni 'Yf`YVYb" 8]YgY : YghY 'Z]b XYb ']b
j YfgWX]Y XYb Yb 'GhUX hhY]`Yb 'ghUhh'i b X 'dfÀgYbh]YfYb 'X]Y
i bhYfgWX]YX`]WX Yb : UWY hhYb 'XYf'; Ya Y]bgWX UZh" 'A i g]_Z'HUbn'i b X
K cf_g\cdg'Yfa O[`]WX Yb 'Yg'XYb '6Ygi WX YfbZ'U_h]j 'Ub 'XYf
_i `hi fY``Yb 'GnYbY 'hY]`ni bY\a Yb"

9]b 'V Ygcb X Y fg 'V Y`]Y V h Y g '9 j Y b h ']gh 'X] Y 'B U W h 'X Y f 'A i g Y Y b ž 'X] Y Y]ba U`]a '\(\text{J} \) f 'gh U h \(\text{Z} \) b X Y h " \(\text{NU \ 'Y } \) W \(Y \) A i g Y Y b 'i b X ; \(\text{U \ 'Y f } \) Y b '] b H f Y d h c k !? \(\text{O} \) d Y b '] \(\text{Y \ 'I H \(\text{M} \) f Y b 'V] g '\(\text{g} \) A h '] b '\(X \) Y B U W \(\text{N \ i b X \ V } \) Y h Y b '\(\text{g} \) G g d \(\text{A} \) h '] b '\(X \) Y D f c [f Ua a Y \(\text{Z} : \text{\text{M} \ f i b [Y b 'i b X 'K cf_g \ cdg 'U b " \ 8 \) Y g \\(\text{g} \) Y b Y [f c \(\text{V} \) U f h [Y '; Y 'Y [Y b \ Y] h \(\text{Z} \) i \(\text{h} \) f g h Y b '\(\text{S} \) i \(\text{f} \) f g Y b Y '\(\text{S} \) Y b '\(\text{S} \) i \(\text{f} \) f g Y b Y '\(\text{S} \) Y b '\(\text{S} \) i \(\text{S} \) Y b '\(\text{S} \) i \(\text{S} \) i \(\text{S} \) i \(\text{S} \) Y b '\(\text{S} \) i \(\text{S} \) Y b '\(\text{S} \) i \(\text{S} \) Y b '\(\text{S} \) i \(\text{S} \) Y b '\(\text{S} \) i \(\text{S} \) Y b '\(\text{S} \) i \(\text{S} \) i \(\text{S} \) i \(\text{S} \) Y b '\(\text{S} \) i \(\text{S} \) i \(\text{S} \) i \(\text{S} \) Y b '\(\text{S} \) i \(\text{

8 UgʻGca a YfZYghʻ]a '6chUb]gWX Ybʻ; UfhYbʻghY``hʻY]bY kibXYfVUfYʻA Ò[`]WX_Y]hʻXUfžBUhi fʻibXʻ?i `hi fʻni jYfV]bXYb"<]Yf _ÖbbYbʻ6Ygi WXYfʻb]WX hʻbi fʻX]YʻVYY]bXfi W_YbXYbʻDZUbnYb VYki bXYfbžʻgcbXYfbʻUi WXʻUbʻj YfgWX]YXYbYbʻK cf_g\cdgʻibX: Ø\fib[YbʻhY]`bY\a Ybž'X]YʻX]YʻDZʻUbnYbk Y`hʻi bXʻX]Y lakY`hV]`Xib[`]bgʻNYbhfi a 'ghY``Yb"'?i`]bUf]gWXYʻGhÀbXYʻfi bXYb XUgʻ9f`YVb]gʻUVžʻk À\fYbXʻ@j Y!?cbnYfhYʻZØf`X]Yʻa ig]_U`]gWXY IbhYf\U`hi b[`gcf[Yb"

G]Y`XUg`?]bXYfgca a YfZYgh`]a : fY]nY]hdUf_`]a 'HfYdhck Yf`DUf_ VYgi WXYb"`Gd]Y`Yž`6UghY`ghUh]cbYb'i bX'?]bXYfh\YUhYf`Yfk UfhYb X]Y`_`Y]bYb`6Ygi WXYfž'k À\fYbX`X]Y`[fc»Y'; fØbZÀWXY`FUi a 'ZØf : Ua]`]Yb!D]W_b]W_g`V]YhYh"

± 'HfYdhck!? OdYb]W_'[]Vh'Yg'U`gc'j]Y`Y'A O[`]W_Y]hYbž'b]W\h'bif X]Y'GW\Ob\Y]h'XYf'BUhi f'i bX'XYf'GhUXhhY]`Y'ni '[Yb]Y» Ybž'gcbXYfbUi W\X]Y'; Ya Y]bgW\UZh'ni 'Yf`YVYb"'8]Y'J]Y`ZU`h'XYf JYfUbghU`hi b[Yb'i bX': YghY'a UW\h'X]YgY'FY[]cb'ni 'Y]bYa `YVYbX][Yb'Cfh'a]h'j]Y`'<Yfn'i bX'GYY`Y' 'Y]b'k U\fYg'⅓ k Y``]b 6Yf`]b°': Øf'U_hi Y``Y'±bZcfa Uh]cbYb'ni 'JYfUbghU`hi b[Ybž'X]Y']b HfYdhck!? OdYb]W_'ghUhhZ]bXYbž'VYgi W\Yb'G]Y'X]Y'c ZZ]n]Y``Y K YVgY]hY"

8 Y hU]`g

6 Ygi WX Yb 'G]Y 'i bg 'Ui Z 'Y]bY!fY]gY "XY