

; GA!Gi ddcfh'i `"'8cVfY[c'DUghYfnU'%\$&#) ž' %!(%\* '?fU\_Œk a cV]`Y'Ž(, '\*\$, %\$+()) ž'B=D', %' ''), \*\$- 'F9; CB.'%, %\$, %' '( k k k "[ga!gi ddcfh"bYh

# Ga Ufh'7`]d'cf][ ]bU`





PPORT

#### Ga Ufh'7`]d'I dXUhY'hc'j Yfg]cb'&"&) °

 $\label{eq:hamiltonian} $H\setminus g'' \ dXUhY''UXXg'U'a\ cXY`g'J\&'\ )\ \check{z}'@\&`hc'h\Y``]gh`cZgi\ ddcfhYX'''Gi\ VX'd\ cbY'V&i\ `X`VY'i\ b`c\\YX'i\ g]b[\ 'I\ b`c\\Y]']U'HYghdc]bh`cdh]cbcZGa\ UfhA\ chc'''$ 

Ga Ufh'7`]d`]g`h\Y`bYk Ygh'7`]d`cb`k cfXk ]XY`a Uf\_Yh'`F][\hˈbck ']h]gʻcb`m'U'7`]dž'Vi hˈgccb`>H5; 'Zcf`A chcfc`U'd\cbYgʻk ]``VY UXXYX`flZYY`cZ'W\Uf[YŁ UbX`h\Yb`mci `Wb`fYdU]f`d\cbYgʻk ]h\``cgh'Vcch'ncbYž fYdU]f`d\cbYgʻi g]b[ 'Z ```ZUg\]b[ 'cf`hYgh 7DI #F 5A #: @5G<"`F][\hˈbck ']hfgʻZcf`gi fY`]b`7`]d`WbY[cfmg]bW']hfgʻa i `h]Z bWh]cbU'`XYj ]WY`:I @MI D85H56@9`: F 99`C: '7<5F; 9 hc gi ddcfhbYk 'a cXY`g`cZ'7' I I ž '9I I I 'UbX`J I I I "BUa Y '`Ga Ufh'''''''U`gc`Z]hg`hc`h\]gʻdfcXi Wh'dYfZYWhm! ']hfgʻj Yfmga Ufh'g]bW' mci Wbb`i d[fUXY`]h]b`fYU`!h]a Y`i g]b[ '5Wh]j YL 'j ]U`k YV`Vfck gYf`]b'`i gh'gYwbbXg'! mci 'WbbYWh'7`]d'j ]U'gdYW]U'`@DH'WUV`Y`k ]h\ Wa di hYf`UbX`h\Yb`fi b`U`k YVdU[Y`fgdYW]U``Wa dcbYbh'k ]```Ui hca Uh]WU`m'W\YW\_'bYk Ygh'GK 'j Yfg]cb`UbX`]Z Uj U]`UV`Y`i d[fUXY mci f'7`]d'hc`gi ddcfh'bYk Ygh'd\cbYgŁ"Bc`D7ž'bc`X]gUggYa V`]b[ 'cf`gdYV]U``hYW\b]WU``\_bck`YX[Y`bYYXYX`fi gh'WbbYWh'WUV`Y`hc d\cbY'UbX'dfYgg`F 98`Vi hhcb"

### 7i ffYbh`mgi ddcfhYX`d\cbY`a cXY`g.

BYk 'a cXY`g'UbX'j Yfg]cbg'fYei ]fY'cdYb]b[ 'd\cbY'UbX'hYgh'dc]bh'gc`i h]cb"'5```X]U[ fUa g'UbX'XYgWf]dh]cbg'mci 'WUb Z]bX'cb'dfcXi WYfffg'k YVg]hY"

## A CHCFC@5.

- '9%ž'@&ž'@\* ž'@+ž'| \*
- '5%\$\$\$'!'U`gc`Vcchij Yfg]cb`\$"\*"' "&`ff\$%"\$&"%\£ž`A \\$\$\$
- '5\*' \$ž'5, ' \$ž'5, ') ž'5, () ž'5- &\$ž'5- &)
- '9++\$ž'9%\$\$\$ž'9%\$+\$
- 'H&, \$ž'H&, \$]ž'H+&\$!H+&\$S; S\$) S\$, S, %Fž'H+&%ž'H+&\$]ž'H+&&]ž'H+&) Y
- 'J \* \$ž'J \* \$]ž'J \* \* ž'J \* \* ]ž'J + \$ž'J , \$
- '7%%) ž'7%' ž'7%) ) ž'7%) \*ž'7%) +ž'7%' \*ž'7&) \$ž'7&\*\* ž'7&\*\* ž'7&\*\* ž'7' '\$ž'7' '\$z'7' '\$z
- '9' \*) ž'9' , \$ž'9' +\$ž'9' +) ž'9' +, ]ž'9' \* ž'9' , ž'9) ) \$
- - JIII 'f6cch'@cUXYf'j Yf', "&' Ł']bWi X]b[ 'J' 'Fc[ Yfg'7UbUXU
  - 7-+)#J-,\$#9%\$\$\$'!`6cch'@cUXYf`\$"\*"%"&`fIVYhJ`#`bch`U```j Yfg]cbg`hYghYX`Ł
  - J''fF' + (S; S\$9"(\$"-\*FL



gbX&II ž gbX' II 'fljbW'' gbX' \*\$ 'g' \*\$\text{\$\z'} gbX\) II 'fljbW'' gbX\) +\$ 'a ) +\$\text{\$\z'} gbX\*II 'fljbW'' gbX\* \$\$ 'd\*\$\$#g\*\$\$\text{\$\z'} gbX, II

GcZhk UfY 'Zcf'i d[fUXY.

#### GdYWJU`ZYUhi fYg.

 $Ga\ Ufh!\ 7`]d`[\ Yhg`Yj\ Yb`Ga\ UfhYf``Bck \ ']h`k\ ]```fYWcfX`h\Y`\]ghcfm`cZi\ bgi\ WWggZl\ ``i\ b`cW\_`UhhYa\ dhg`UbX`fYUX`h\Y`Z]fa\ k\ UfY`cZa\ cV]`Y \\$ d\cbYg"'"Ga Ufit 7`]d FYUXYf"'i h]`]mm\Ug'VYYb 'UXXYX'hc 'Ga Ufit 7`]d 'hcc`\_[h"'=h'Wb 'fYhf]Yj Y'h\Y'\]ghcfmcZi bgi WWggZi ``i b`cW\_ 7i ghca Yf'WUb bck 'gYbX'ZUg\ 'Z]Yg'cZi b`cW\_YX'd\cbYg'hc 'ci f'F/  $8\cdot8dh''H\$ ]g'k Umi bgi ddcfhYX'd\cbY'a cXY`g'WUb 'VY'UXXYX'hc 'ci f'F/  $8\cdot8dh''H\$ ]g'k Umi bgi ddcfhYX'd\cbY'a cXY`g'WUb 'VY'UXXYX'hc 'ci f'F/  $8\cdot8dh''H\$ ]g'k Umi bgi ddcfhYX'd\cbY'a cXY`g'WUb 'VY'UXXYX'hc 'ci f'F/  $8\cdot8dh''H\$ ]g'k Umi bgi ddcfhYX'd\cbY'a cXY`g'WUb 'VY'UXXYX'hc 'ci f'F/  $8\cdot8dh''H\$ ]g'k Umi bgi ddcfhYX'd\cbY'a cXY`g'WUb 'VY'UXXYX'hc 'ci f'F/  $8\cdot8dh''H\$ ]g'k Umi bgi ddcfhYX'd\cbY'a cXY`g'WUb 'VY'UXXYX'hc 'ci f'F/  $8\cdot8dh''H\$ ]g'k Umi bgi ddcfhYX'd\cbY'a cXY`g'WUb 'VY'UXXYX'hc 'ci f'F/  $8\cdot8dh''H\$ Ga Ufh 7`]d``]gh cb U ZfYei Ybh VUg]g"

 $Bck `Ga Ufh'7`]d`\setminus Ug`gdYW]U`: @5G<`UbX`G9FJ =79`ZYUhi fYg`UXXYX`hc`k cf_`k]h\`D7`Wca di hYf``]_Y.$ 

6UW\_i d'Z ```Z'Ug\`! H\Y'Z bWh]cb`]g`]a d`Ya YbhYX'Zcf'Z ``mgUZY`Ga UfhA chc'hcc``cdYfUh]cb'k]h\`Mci f'A chcfc`U'd\cbYg"'K]h\`h\Y  $\label{eq:continuous} VUW\underline{i}\ d\ Z\underline{j}\Upsilon g\ mci\ \widetilde{i}\ d\ cUX\ ci\ f\ h\Upsilon Ua\ \ Wcbh]bi\ ci\ g\ mf\Upsilon d\ \Upsilon b]g\ \Upsilon g\ ZUg\ \ Z\underline{j}\Upsilon g\ XUhUVUg\Upsilon b$ 

 $\textbf{FYghcfY'Z} \overset{\sim}{} \textbf{TUg} \overset{\sim}{} \textbf{I} \overset{\sim}{} \textbf{Mc} i \overset{\sim}{} \textbf{WU} b \overset{\sim}{} \textbf{U} \overset{\sim}{} \textbf{V} \overset{\sim}{} \textbf{U} \text{mg} \overset{\sim}{} \textbf{fYghcfY'mc} i \overset{\sim}{} \textbf{f'd} \overset{\sim}{} \textbf{cbY'hc'} \overset{\sim}{} \textbf{b} \overset{\sim}{}$ **5i hc 'VUW\_i d#fYghcfY'gYW f]hm'UfYU**'!': cf'h\cgY'a cXY`g'k \YfY'gYW f]hm'UfYU'XcYg'bch'fYghcfY']hik ]``'VY'Ui hcgUj YX'k \]'Y YbhYf]b[`Vcch'a cXY"`=Z'bYYXYX'h\]g`ncbY`WUb`VY`fYghcfYX`k]h\`fYghcfY`gYW\f]hm'UfYU`Z bWh]cb"
FYUX'd\cbY`]bZc'!`Mci `WUb`[Yh'Z ``]bZcfa Uh]cb'cb'mci f'd\cbYž'bUa Y`m `A cXY`ž'=A 9=ž'I gYf'WcXYž'GYW\f]hm'WcXYž'CdYfUh]cb

VUbXž: ]fa k UfYž: `YI 'j Yfg]cbž'@Ub[ i U[ Y'dUW]

: `**Ug\]b[** '! 'G]a d`Y'd\cbY'ZUg\]b[

 $\textbf{FYdU]f'Z'Ug'} \textbf{]b[ '!': i ```d'cbY'Z'Ug']b[ 'f]bWi X]b[ '99DFCA 'ncbYgL'Vm'U'k cf_]b[ 'Z'Ug' 'Z']Y'''FYdU]f'Z'Ug' 'Z']Y''' CdfYdUfYX'Vm' CdfYdUfYX'Ym' CdfYdUfYX'Ym' CdfYdUfYX'Ym' CdfYdUfYX'Ym' CdfYdUfYX'Ym' CdfYdUfYX'Ym' CdfYdUfYX'Ym' CdfYdUfYY' CdfYdY' CdfYdY'$ Ga UfH 7`]d`XYj Y`cdYfg`hYUa `UbX`di h'ci h'Zcf`Ga UfH 7`]d`i gYfg`cb`ci f`gYfj Yf"`=b`d\cbYg`k ]h\`i bfYghcfUV`Y`gYW`f]hmUfYU`]h'k ]`` bch'VY'W\Ub[YX'Xi f]b['ZUg\]b[

# GdYWZWh]cb.

 $fYa\ cj\ Y`g]a\ `cW\_`]b`ZYk\ `gYWcbXg`Vmcb`mdfYgg]b[\ `cbY`Vi\ htcb`cb`7`]d$ ZfYY'id[fUXYg'Zcf'7|||ž'9|||ž'J|||'gYf]Yg bc D7 bYYXYX Zcf k cf\_ fYU`! h]a Y`i dXUhYg`UfY`a UXY`i g]b[ `5Wh]j YL`j ]U`=bhYfbYh`]b`ZYk `gYWcbXg X]a a Ybg]cbg. ', \* 'I '\* \* 'I '' & a a j c`hU[ Y 57 - J ž') \$ a 5 U`i a ]b]i a 'WUgg]b[

## DUW\_U[Y'WcbhU]bg.

Ga Ufh 7`]d WUV`YgʻZcf. !gYf]Yg<sup>-</sup>J !gYf]Yg<sup>.</sup>7 ! A chcfc`U'9' \*) ! A chcfc`U'7%%) '7%%\* !GYbXc 'G&\$\$#D&\$\$ !GYbXc'A))\$

6UhhYfm WcbbYWhcf k UffUbhm



5.ZhYf`difWkUgY`mci`a igh`WcbbYWh`]h`hc`D7`ig]b[`@DH`WUV`Y`fMUV`Y`bch`]bWiXYXŁžYbhYf`dfcXiWfffg`kYVg]hY`UbX idXUhY'ga Ufh'W]d hc h\Y'bYk Ygh'Z]fak UfY'jYfg]cb"'Hc'WcbbYWh'hc'D7'd`YUgY'igY'g]ad`Y'dUfU``Y`'WUV`Y'k\]W\'Wbb VY Vci [\h]b UbmWta di hYf g\cd"I dXUhYg UfY : F 99 cZ W\ Uf[Y"

¥ &\$&& k k k "[ ga ! gi ddcfh"bYh

