

MUSC4705

DYfZcfa UbWY @UVcfUhcfmi8 fA i g]W7 fYUhjj Y DfUWfWŁ

HYfa 'Hk c''# '&\$&\$

7ci fgY'Cj Yfj]Yk

GHJZZ7cbHJWh8YHJ]`g

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B Ua Y	9a U]`	5j U]`UV]`]lm	@cWUhjcb	D\cbY
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GWXcc`7cbHJWh = DZcfa Uhlcb

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

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

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

 $\label{eq:hamiltonian} $$HY'GW.cc``cZh,Y'5ftg'UbX'AYX]U'k ci`X``]_Y'tc'FYgdYWM\cong \cong m5W_bck``YX[Y'th,Y'HfUX]tjcbU``7i gtcX]Ubg\cong hY'6YXY[U'``fPYbg]b[tcb'WJa di g\cong \cong \cong \cong mUbX'5fti/'8Yg][b'7Ua di gYg\cong \cong \con$

7ci fgY 8YW] g

7 fYX]hDc]bhg'('

Giaa UfmcZh\Y 7ci fgY

Gi VYWf5fYU. ? $ge[U BWbXad_S`UW]$? $ge[U 5a_bae[f[a`l? ge[U 7`eW_TW] BWbXad_S`UW5goSf[a`leath]]$

A I G7 (+\$) 'DYfZcfa UbW' @UVcfUrcfm8 'fA i g]W7 fYUh] Y'DfUW]W' L']g'h\Y'Zci fh\ 'UbX'Z]bU' 'DYfZcfa UbW' @UVcfUrcfm8' fA i g]W7 fYUh] Y'DfUW]W' a U'cf" 'Mci 'k]``'Wcbgc`]XUhY' h\Y'a]'YgrcbYg' UW]Yj YX]b 'YUf]Yf'DYfZcfa UbW' @UV'Wci fgYg'h\fci [\'h\Y'UXj UbWa YbhcZmci f'hYW\b]WU'ž'WYUh] Y'z]bhYfdfYh] Y'UbX W fUhcf]U`'g_]``g"'H\Y'Wci fgY'ZcW gYg'cb'h\Y'dYfZcfa Uh] Y'zWfYUh] Y'UbX'W 'h fU`'Y'Ya Ybhg'cZa i g]Wa U_]b[hc'Ui [a Ybhmci f']bX]j]Xi U`'UbX'Wc``YWh] Y'dYfZcfa UbW''YI dYf]YbW''UbX'YI dYfh]gY"' \dangle UXX]h]cbzmci 'k]`` Wf]h]WU``mYI Ua]bY'h\Y'bUh fY'cZdYfZcfa UbW''UbX'h\Y'j Uf]YX'k Umg'X]ZYfYbh_]bXg'cZa i g]WJUbg'UbX'Uff]ghg

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5ggYgga YbhHUg_g

Gi Va]gg]cb bchYg.@j Y DYfZcfa UbW

5ggYgga Ybh' . K f]HYb DcfhZc`]c

GhUfhXUhY. Bch5dd`]WUV`Y

@Yb[h\.`a UghYfWUgg'Wf]h]ei Yg'!`) \$\$ k cfXg'YUW\/fYgYUfW\'dUdYf'%\$\$\$ k cfXg

8YHJ]`g.

%) \$\$ 'k cfXg'''''

Ghi XYbhgʻUfYʻhcʻWa dʻYhYʻhk cʻf&ŁfYdcfhgʻdfcj]X]b[ʻWf]hJWDʻfYZYWf]cbʻUbXʻWa dUf]gcbʻcZ]ggi YgʻfU]gYXʻ]b Zci fʻa UghYfWUggYgʻUhhYbXYXʻcjYfʻHYfa gʻ%ž&ʻUbXʻ' žʻUbX`UʻfYgYUfW\dUdYfʻ]bj Ygh][Uh]b[ʻUʻbcb!HfUX]hJcbUʻ dYfZcfa UbWYʻdfcYWhYmYgHUV`]g\YX`Ufh]gh#Ufhgʻcf[Ub]gUhJcb"

: YYXVUW_'j]U'@A G

5XX]h]cbU`XYhJ]`g.

F YgYUfWX #7 fYUhjj Y Dfc YWh

5 f]hY VY[]bb]b[

7\ccgY`U`fYU``a ca Ybh`]b`mci f``]ZY`h\UhW\Ub[YX`mci f`WcbW\dh]cb`cZmci fgY`ZUg`U`a i g]VJUb''`±\`U`fYU` gYbgYž'h\]gʻa ca Ybh`Zcfa gʻdUfhcZmci fʻbUffUhj Y`]XYbh]mk\]W\`mci `UfY`UhhYa dh]b[`hc`YI dfYggž'fYU`]gY`cf fY\ci bh`]b`a i g]\W\`Zcfa "'5`hYfbUhj Y`mž'mci `a Um]a U[]bY`gi W\`Ub'Yj YbhUbX`cbY`h\Uhc\W\fg`]b`Ubch\Yf h]a Y`UbX`d`U\W\"'H\Y`Z]fghghYdž']g`hc`\WYUhY`U`bUffUhj Y`VUgYX`cb`mci f`dUff]\W``Uf`f]hY`cZdUggU[YžfYU``cf]a U[]bYX`]b`h\Y`Zcfa `cZ`h\Y`XYdUfh fYž'h\Y`ci fbYmž'UbX`h\Y`fYh fb`Vi h_YYd]b[`]b`a]bX`h\Uhih\Y\Wb\Zh\Y`a]XXY`dUfhž'h\Y`ci fbYm]g`h\Y`\Wb\Zh\Cf`ghUhY`cZ`]a]bU`]m'

 $\label{eq:continuous} $$ Mci f'a i g] WU``dfYgYbhUh]cb`WUb`VY`Ubm``Yb[h\`VYhk YYb')``UbX'%)`a]bi hYg''`H\Y'a U]b`W\U``Yb[Yg']b'h\]g dfc'YWhUfY.$

%'''fYU']g]b[''hNY'YIdYf]YbWY'cZ']a]bU']mi]b'aig]WU''Zcfa

&"'dfcXi V]b['Wc[YbWmUbX'U'gUh]gZm]b['g\UdY'hc'h\Y'dfYgYbhUh]cbž'UbX

'"`7 fYUh]b['U'gYbgY'h\Uh'mci f'WfYUh]j Y'UfhYZUWhWca Yg'Zfca ``]j YX'Yl dYf]YbWY"

A CF 9 '89H5 @G 'CB 'H< 9 '56CJ 9 'DF C>97 H '5F 9 'B 7@ 898 'B 'A CC8@9. '\| '\ G '9GG9B H = 5@'H < 5H MCL 'F 958 'H < 9A "

7 ca dUfUhjj Y A UghYfWUgg 7 f]hjei Yg

⇒hNY'Wca dUfUhjjY'a UghYfWUgg'Wf]hjei Yg'mci	i k]``]bhYfdfYhkUmg`]b`k\]WX`jUf]cig`aig]WdfUW i jhjcbYfg

5 https://bxubwww.Fyei]fYaYbhg

Ghi XYbhg`UfY`ghfcb[`mYbWcifU[YX`hc`UhhYbX`U```WUggYg`UbX`fYj]Yk ```YWhifY`hY`wcfX]b[g'' All for the following of the follo

7ci fgY'GWXYXi `Y

J]Yk 'WUgg'ha YHUV'Y

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8 UHY	HmdY	7 c bhYtbth
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Bch'Uj U]`UV`Y

FYWca a YbXYX FYgci fWYg

F Ygci fWg'k]``'VY'fYWca a YbXYX']b'A ccX`Y"

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

Gi Va]gg]cb cZ5ggYgga YbhHUg_g Hi fb]h]b Gi Va]gg]cb

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][\hzil BGK `Gh XYbh7cXY`cZ7cbXi WhUbX`5VWWdhUv`Y`I gY`cZ I BGK `=\forall H`F Ygci f\W\g`Dc`]\wh
- 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