

MUSC1708

65 DYfZcfa UbW @UVcfUhcfm5

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

7ci fgY'Cj Yfj]Yk

GHJZZ7cbHJWh8YHJ]`g

7cbj Ybcfg

BUa Y	9a U]`	5j U]`UV]`] m	@cWUhjcb	D∖cbY
DUi `A W8Yfa ch	dUi`"a WXYfa chn4 i bgk "YXi "Ui	VmYa U]`	C b`]bY	

GWXcc`7cbHJWh = DZcfa Uhlcb

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

Fcca " %&ž@Yj Y`" žFcVYfhK YVghYf'6i]`X]b[ff %(Ł

D\cbY. f\$&Ł'-',) '(,) *

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$

5ggYgga Ybh

±b 'HUg_'%zghi XYbhg'k]``'VY'a Uf_YX'Ug'U'[fci d"'GhfUhY[]Yg'cZ]bWi g]cbž'Wc!cdYfUh]cbž'UbX'a Yh\cXg'cZ cb']bY'Wc``UVcfUh]cb'k]``'VY'k cf_!g\cddYX"'

+b 'HUg_'&ž']bglfi a Ybh')]glg'UbX'j cWU`]glg'k]``VY'a Uf_YX'Ug'UVcj Y"

7 ca dcg]h]cb a Urcfg k]``VY a Uf_YX]bX]j]Xi U``mXi Y hc h\Y X]ZZYfYbhbUhi fY cZh\Y]f hUg_"

 $H\Y'ZcW'g'cZhY'UggYgga Ybh]g'cb'h\Y'WfYUh]j] ImmcZh\Y'gh XYbhfg']XYUg'' \\ \pm i]g'i bXYfghcX'h\UhU```gh XYbhfg \\ k]```\Uj Y'j Ufm]b['UWW'gg'hc'Y'YWfcb]WUbX'X][]h\D'hcc`g'UbX'k]```bch'VY'UggYggYX'cb'h\Y'Ui X]c'ei U`]hmcZ UbmfYWcfX]b[g'''H\Y']XYU']g'hc'VY'WfYUh]j Y'k]h\ 'h\Y'hcc`g'Uj U]`UV'Y'hc'mci'''$

5ggYgga Ybh'HUg_g'

5ggYgga Ybh'hUg_	K Y][\h	8i Y'8UHY	Gh XYbh@YUfb]b[CihWca Yg 5ggYggYX
9bgYa V`Y`Wcblf]Vi ljcb`UbX dUfftWXYW_]b[(\$1	Bch5dd`]WUV`Y	-
A UghYfWUgg'Wf]h]ei Yg'	&\$1	K YY_'%\$	&
DYfZcfa UbW/#dfYgYbfUhjcbg H&'	(\$1	Bch5dd`]WUV`Y	%

5ggYgga Ybh'8YhJ]`g

5ggYgga Ybh% 9bgYa V`Y Wcbhf]Vi h]cb UbX dUfHWX YW_]b[

GhUfhXUhY. Bch5dd`]WUV`Y

8 YHJ] g.

9bgYa V`Y`dUfflWXYW_]b['k]```VY`i bXYfflU_Yb`]b`H%EH&`UbX`H' "`±bX]j]Xi U``mcf`]b`ga U```[fci dgžghi XYbhg`k]`` dYfZcfa 'k cf_g`cf`Yl WYfdhg`cZk cf_gžghi X]YX`UbX`dYfZcfa YX`Xi f]b['h\Y`hf]a YghYf"``K \YfY`Uddfcdf]UhYž Yl WYfdhg`k]```VY`gY`YWNX`Vmih\Y`dUfflWXYW_]b['Yl Ua]bYf"

8]fYWhZYYXVUW_`Xi f]b[`fY\YUfgU`g`UbX`k cf_g\cdg"`Gh XYbhgfWcbhf]Vi h]cb`hc`YbgYa V`Y`dYfZcfa UbWl'g`UbX k cf_g\cdg`k]``VY`UggYggYX`h\fci [\`U`dUfhWXYW_]b[`YI Ua]bUh]cb"

5ggYgga Ybh& A UghYfWUgg Wf]h]ei Yg

GHJfhXUhY. Bch5dd`]WUV`Y

@Yb[h\.')\$\$

8YHJ]`g.

5 d[f[cgWe k]```VY`gi Va]hhYX`UWfcgg`H\%`H&`UbX`H' "``H\YgY`k]```VY`fY`UhYX`hc`a UghYfWUggYg`dfYgYbhYX`Vm

5 hm/b XUbVW F Yei]fYa Ybhg

 $\hbox{Ghi XYbhg."} \hbox{UfY."ghfcb[`mYbWc'i fU[YX'hc."UhhYbX."U```WUggYg."UbX'fYj.]Yk. ``YVWi fY'fYWcfX]b[g''] } \\$

FYgci fW/g

DfYgWf]VYX F Ygci fWYg

%''9j Yfmh\]b[']g'7cbbYWYX.'H\Y'Dck Yf'cZA i g]WVm8Ub]Y``6UfYbVc]a

&" ``A chicbž'9a chicbž'UbX'@cj Y. `H\Y'B Uhi fY'cZ5fhighiWDYfZcfa UbWY'VmiH\ca Ug'7 Ufgcb'A Uf

' "@Yhhyfg hc U Mci b[DcYhVmF U]bYf F]`_Y

FYWca a YbXYX FYgci fW/g

BchUj U]`UV`Y

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

Ghi XYbhiZYXVUW_k]``VY`Wc``YWYX`Vch\`Xi f]b['WUgg`X]gW gg]cbg`UbX`h\fci [\`A m91 dYf]YbW'gi fj Ymg"H\Y ZYXVUW_dfcj]XYX`Vmghi XYbhg`k]``VY`UbU`mgYX`UbX`dfUWf]WU`ghYdg`k]``VY`hU_Yb`hc']bWcfdcfUhY`h\Y ZYXVUW_jbhc'h\Y`ghfi Whi fY`UbX`XY`]j YfmcZh\Y`Wci fgY`]b`gi VgYei YbhimYUfg"

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][\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

5WUXYa]W±bZcfaUhjcb

: cf'YggYbhJU`ghi XYbh]bZcfa UhJcb'fY`UhJb['lc.