

# **MUSC4705**

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

HYfa 'H\fYY''##'&\$%-

# 7ci fgY'Cj Yfj ]Yk

### Ghuzz 7 cbhuWh8 Yhu]`g

'7cbj Ybcfg'

B Ua Y	9a U]`	5j U]`UV]`]lm	@cWJhjcb	D\cbY
GcbmU^@]ZgW\]m	g"`]ZgVX]m4 i bgk "YXi "Ui	6mYa U]` Uddc]bha Ybh	KYVghYf*%\$(	

#### GWkcc~7cbhJWh~abZcfa Uh]cb

Fcca " %&ž~Yj Y~" FcVYfhK YVghYf~6i ]`X]b[

D\cbY. f\$&Ł'-',) '(,) \*

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

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

 $\label{eq:hamiltonian} $$HY'GWCC``cZhY'5ftg'UbX'AYX]U'kci`X``]_Y'tc'FYgdYWM\cong \cong m5W_bck`YX[Y'thY'HfUX]tjcbU``7i gtcX]Ubgž thY'6YXY[U'`fPYbg]b[tcb'WJadi gtž; UX][U'`fP]tmUbX'5fth' '8Yg][b'7Uadi gYgt'UbX'thY'B[i bbUkU' dYcd'Y'fbi gtfU']Ub'8YZYbW': cfW'5WJXYam']b'7UbVYffUt'cZthY'`UbXg'k\YfY'YUWX'WJadi g'cZl BGK ']g`cWJtYX''$ 

# 7ci fgY 8YHJ] g

### 7 fYX]hDc]bhg'('

### Gi a a UfmcZh\Y 7ci fgY

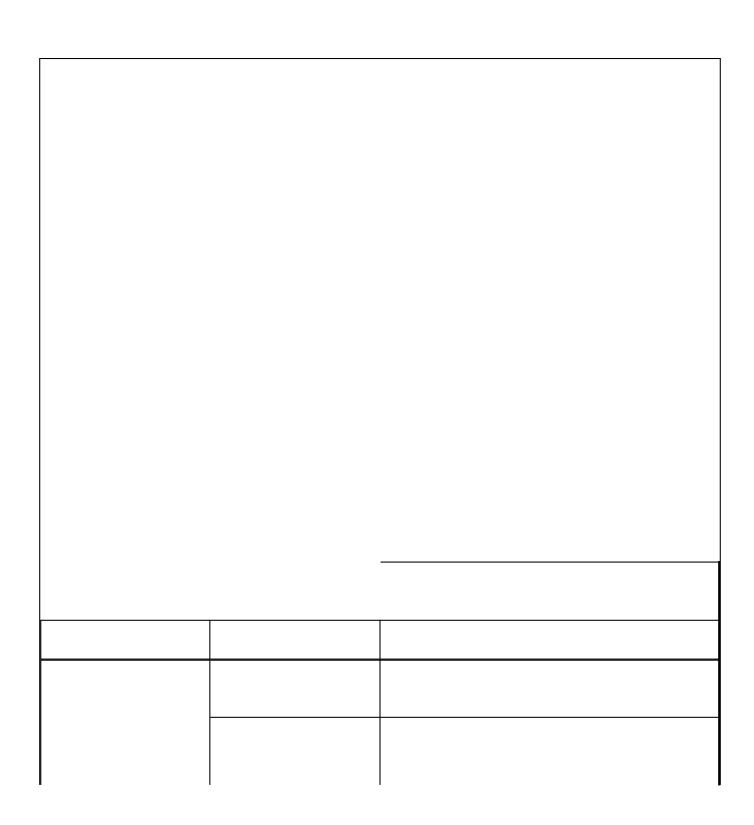
Gi VYWn5fYU. ? ge[U B Wb/ad\_ S` UW ? ge[U 5a\_ bae[f[a` + ? ge[U 7` eW\_ T W B Wb/ad\_ S` UW 5 gc/sf[a`

A I G7 ( +\$) 'DYfZcfa UbW' '@UVcfUrcfm8 'fA i g]W7 fYUhj Y 'DfUWJWY' 2]g 'h\ Y 'Zci fh\ 'UbX' Z]bU' 'DYfZcfa UbW' @UVcfUrcfmWci fgY' Zcf'mci f'A i g]W7 fYUhj Y 'DfUWJW' 'gHYUa "'Mci 'k ]` 'Wcbgc']XUhY' h\ Y 'a ]'YgrcbYg'UW\]Y YX |b YUf]Yf'DYfZcfa UbW' '@UV' Wci fgYg'h\ fci [ \ 'h\ Y'UXj UbW'a YbhcZmci f'HYW\ b]WU'ž'WYUhj Yž']bHYfdfYhj Y'UbX W' fUlrcf]U' 'g\_]' `g'' H\ Y'Wci fgY' ZcW gYg'cb'h\ Y'dYfZcfa Uhj Yž'WfYUhj Y'UbX'W' 'h fU' 'Y'A Ybhg'cZa i g]Wa U\_]b[hc'Ui [ a Ybhmci f']bX]j ]Xi U` 'UbX'Wc' 'YWfj Y'dYfZcfa UbW' 'YI dYf]YbW' 'UbX'YI dYff]gY'' '\d\ DX\]b '\d\ Y'bh\_]bXg'cZa i g]WJUbg'UbX'Uff]ghg \wc'`UVcfUhY' hc' \wfYUhY' ]bbcj Uhj Yž'W hjb[!YX[Y'dYfZcfa UbW' 'Zcfa Uhg'fYzYWfj Y'cZh\ Y'&%ghW'bh fmlg \wc'`UVcfUhY' hc' \wfYUhY' ]bbcj Uhj Yž'W hjb[!YX[Y'dYfZcfa UbW' 'Zcfa Uhg'fYzYWfj Y'cZh\ Y'&%ghW'bh fmlg \wc'`UVcfUhY' hc' \wfYUhY' ]bbcj Uhj Yž'W hjb[!YX[Y'dYfZcfa UbW' 'Zcfa Uhg'fYzYWfj Y'cZh\ Y'&%ghW'bh fmlg \wc'`UVcfUhj Y'dfc Ywcz' \\$'a ]bi hYg']b` 'Yb[h\ f&\ a ]bi hYg'Zcf' \wca dcgYfg\ Zk \]W' k ]` 'VY dfYgYbhYX']b' U'di V']WdYfZcfa UbW' 'Yj Ybh]b' HYfa '' ''Mci 'k ]` ''U'gc'YI hYbX'mci f'YI dYf]YbW' cZYbgYa V'Y a i g]Wa U\_]b[' VmdUff]\wfydhjb[' UbX'dYfZcfa ]b[']b' Ub' Uddfcj YX'YbgYa V'Y'cf' \wk\ Ua VYf!a i g]\w[fci d'i bXYf h\ Y'[i] XUbW' cZUb'YbgYa V'Y'X]fYWcf'cf' \wk\ Ua VYf'a i g]\wc\ U\k''

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

 $% ": Ug\]cb"UbX"fYU"]gY"dYfgcbU"`Uff]gf]W]XYUg"k ]h\ "h\ Y "bYW"ggUfm'hYW\ b]WU""\'z"a i g]WU""UbX dfYgYbfUf]cb"g_]"`g"fc"YI dfYgg"h\ Ya "k ]h\ "dfcZYgg]cbU"]ga "UbX"Wcbj ]Wf]cb"]b"U"di V"]WdYfZcfa UbW" & "5dd`mdf]bW]d"Yg"cZhYUa k cf_'fc"a i g]WYbgYa V"Y$ 

# HYUWX]b[ 'GhfUhY[]Yg'



# FYgci fW/g

# DfYgWf]VYX F Ygci fWYg

%''9j Yfmh\]b[ ']g'7 cbbYWYX. 'H\Y'Dck Yf'cZA i g]WVm'8 Ub]Y`'6 UfYbVc]a

&"'A chłobž'9a chłobž'UbX'@cj Y. 'H\Y'BUh fY'cZ5fhłghłWDYfZcfa UbWY'VmH\ca Ug'7 Ufgob'A Uf\_

'"'@YhhYfq'hc'U'Mcib['DcYhVmFU]bYf'F]`\_Y

("'HYFYgh]g'Bc]gY'Vm5YI'Fcgg

### FYWca a YbXYX FYgci fWyg

Bch'Uj U]`UV`Y

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

Gh XYbhZYXVUW\_`]XYbh]Z]YX`]ggi Yg`dYffU]b]b[`hc`h\Y`fYdYhUh]j Y`bUh fY`cZDYfZcfa UbWY`@UV`Wci fgYg h\fci [\ci hh\Y`XY[fYY"`5g`U`fYgi `hz`U`[fYUhYf`Ya d\Ug]g`cb`cf][]bU`z`]bbcj Uh]j Y`UbX`X]j YfgY`dYfZcfa UbWY! a U\_]b[`\Ug`VYYb`]a d`Ya YbhYX"`Gh XYbhg`UfY`YbWci fU[YX`hc`X]gW gg`h\Y]f`YI dYf]YbWg`X]fYWhmk ]h\`h\Y`YWfi fYf`UbX`cZYf`ZYYXVW\_`cb`\ck 'h\Y`Wci fgY`WUb`VY`]a dfcj YX`UbX`XYj Y`cdYX`Z fh\Yf"

Gi Va ]gg]cb cZ5ggYgga YbhHUg\_g

Gi Va ]gg]cb cZ5ggYgga YbhHUg\_g

### 5 WUXYa ]W<cbYghmUbX D`U[ ]Uf]ga

D`U[]Uf]ga i]gii g]b[ih\Yik cfXgicfi]XYUgicZch\YfgiUbXidfYgYbh]b[ih\Ya iUgimci fick b"i±i\WbihU\_Yia Ubm Zcfa gžZfca iXYi]VYfUhYiW\YUh]b[ihciU\W]XYbhU`m\Wcdm]b[iZfca iUigci f\Wik ]h\ci hiU\w\_bck iYX[Ya Ybh'

IBGK [fcidg'd'U[]Uf]ga ]bhc'h\Y'Zc``ck]b[ WUhY[cf]Yg.

7 cdm]b[.'i g]b['h\Y'gUa Y'cf'j Yfmg]a ]`Uf'k cfXg'hc'h\Y'cf][]bU`hYl h'cf']XYU'k ]h\ci h'UW\_bck `YX[]b['h\Y gci fW'cf'i g]b['ei chUh]cb'a Uf\_g"'H\]g'U`gc'Udd`]Yg'hc']a U[Ygž'Ufh'UbX'XYg][b'dfcYWhgž'Ug'k Y``'Ug dfYgYbhUh]cbg'k \YfY'gca YcbY'dfYgYbhg'Ubch\Yf'g']XYUg'cf'k cfXg'k ]h\ci h'WfYX]h'

⇒ Uddfcdf]UhY 'dUfUd\fUg]b[. '7\Ub[]b['U'ZYk'k cfXg'UbX'd\fUgYg'k\]Y 'a cghmfYhU]b]b['h\Y'cf][]bU`ghi Wh fY 'UbX#cf'dfc[fYgg]cb'cZ]XYUg'cZh\Y'cf][]bU`žUbX']bZcfa Uh]cb'k]h\ci hUW\_bck`YX[Ya Ybh'H\]g'U`gc Udd`]Yg']b'dfYgYbhUh]cbg'k\YfY'gca YcbY'dUfUd\fUgYg'Ubch\Yf'g']XYUg'cf'k cfXg'k]h\ci h'WfYX]h'UbX'hc d]YW]b['hc[Yh\Yf'ei chYg'UbX'dUfUd\fUgYg']bhc'U'bYk'k\c`Yžk]h\ci h'Uddfcdf]UhY'fYZYfYbW]b['"

7 c``i g]cb.'k cf\_jb['k]h\ch\Yfg'Vi hdUgg]b['cZZh\Y'k cf\_'Ug'U'dYfgcb'g']bX]j ]Xi U``k cf\_"'7 c``i g]cb'U`gc ]bWi XYg'dfcj ]X]b['mci f'k cf\_'hc'Ubch\Yf'ghi XYbhVYZcfY'h\Y'Xi Y'XUhYžcf'Zcf'h\Y'di fdcgY'cZh\Ya d`U[]Uf]g]b['UhiUbmh]a Yž'dUm]b['Ubch\Yf'dYfgcb'hc'dYfZcfa 'Ub'UWUXYa ]WhUg\_ž'ghYU']b['cf'UWei]f]b[ Ubch\Yf'dYfgcb'g'UWUXYa ]Wk cf\_'UbX'Wcdm]b[']hz'cZYf]b['hc'Wca d'YhY'Ubch\Yf'dYfgcb'g'k cf\_'cf'gYY\_]b[ dUma YbhZcf'Wca d'Yh]b['UWUXYa ]Wk cf\_"

±bUddfcdf]UhY`W]hUh]cb.`7]h]b[`gcifWrg`k\]W\`\UjY`bchVYYb`fYUXžk]h\cihUW\_bck`YX[]b[`h\Y`´gYWcbXUfm´gcifWrZfca`k\]W\`\_bck`YX[Y`cZh\Ya`\Ug`VYYb`cVhU]bYX"

8 i d`]\WUh]cb`ffgY`Zd`U[]\Uf]ga "Ł gi Va]\h]b[`mci f`ck b`k cf\_ž]b`k \c`Y`cf`]b`dUfhžk \YfY`]h\Ug`dfYj]ci g`m VYYb`dfYdUfYX`cf`gi Va]\hYX`Zcf`Ubch\Yf`UggYgga Ybhcf\Wci fgY`UhI BGK `cf`Ubch\Yf`i b]j Yfg]\m'

7 cffYWnfYZYfYbWlb[ 'dfUWnWyg.

• DUfUd\fug]b[ z'gi a a Uf]q]b[ z'YggUmk f]hb[ 'UbX'ha Y'a UbU[ Ya Ybh

#### 5 WUXYa ]W = b Zcfa Uh cb.

: cf`YggYbhJU``gh XYbh`]bZcfa UhJcb`fY`UhJb[ 'hc.

- fYei Yghg Zcf Yl hYbg]cb/
- `UhY`gi Va ]gg]cbg`[i ]XY`]bYg/
- fYj ]Yk 'cZa Uf\_g/
- I BGK '< YU`h\ 'UbX'GUZYhm'dc`]W[Yg/
- YI Ua ]bUhcb dfcWXi fYg/
- gdYWJU``Wcbg]XYfUHjcb`]b`H\Y`Yj YbhcZ]``bYgg`cf`a ]gUXj Ybhi fY/
- gh XYbhYei ]mUbX X]gUV]`]m/
- UbX'ch\Yf'YggYbhJU`'UWUXYa ]W]bZcfa UhJcbž'gYY

\hdg.#k k k "Uffg"i bgk "YXi "Ui #W ffYbhgh XYbhg#UWJXYa ]W]bZcfa Uf]cb#dfchcWc`g![i]XY`]bYg#

,

## a U[Y'7fYX]h

Gc`c'DYfZcfa UbWY'A U\_]b['&\$%

#### 7F = 7CG

7F = 7CG Dfcj ]XYf 7cXY. \$\$\$-,;