

MUSC2703

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7ci fgY'Cj Yfj]Yk

GHJZZ7cbHJWh8YHJ]`g

7cbj Ybcfg

| B Ua Y | 9a U]` | 5j U]`UV]`]lm | @cWUh]cb | D\cbY |
|--------------------------|-------------------------------|----------------|----------|-------|
| @Ui fU'7\]g`Yth >cbYq | n' (- , &&- 4 i bgk "YXi "Ui | VmUddc]bha Ybh | | |

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

Fcca ' %&ž@YjY`' žFcVYfhK YVghYf6i]`X]b[fl %(Ł

D\cbY. f\$&£'-',) '(,) *

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

K YVq]hY. k k k "Ufhq"i bak "YXi "Ui #qUa

 $\label{eq:hamiltonian} $$HY'GWKcc``cZhY'5ftg'UbX'AYX]U'kci`X``]_Y'hc'FYgdYWM\cong \cong m5W_bck`YX[Y'h\Y'HfUX]hjcbU``7ighcX]Ubgžh\Y'6YXY[U'`fPYbg]b[hcb'WJadigŁž'; UX][U'`fP]hmUbX'5fh\/'8Yg][b'7UadigYgŁ'UbX'h\Y'B[ibbUkU`dYcd'Y'fbighfU`]Ub'8YZYbW': cf\W'5\WJXYam]b'7UbVYffUŁ'cZh\Y'`UbXg'k\YfY'YUW\'WJadig'cZIBGK']g`c\WJhYX''$

7ci fgY 8YHJ] g

7 fYX]hDc]bhg'('

Gi a a UfmcZh\Y 7ci fgY

Gi VYWn5fYU. ? ge[UBWdXad_S`UW!? ge[U7`eW_T'W

#Dith]gidfUWfJWU``Wci fgYimci ik]```YI hYbXimci fiUXj UbWXXi]bghfi a YbhU`žij cWU``cfiWca dcg]hjcbig_]``gik]hh icbY! hc!cbYigi ddcfhZca iUigdYWJU`]ghhi hcfžiUbXiWcbhYl hi U`]gYih,YiUdd`]WUhjcbicZh\cgYig_]``gih\fci [\dUff]WJdUhjcbi]bik cf_g\cdgža UghYfWUggYgiUbXiYbgYa ViYg"iH\YgYiWca dcbYbhgik]```Wca V]bYihciYb\UbWimci figdYWJU`]ghighfYb[ih\giUbXi]bhYfYghgžik\]W\i]bih fbik]```]bZcfa imci fik cf_i]bih\YigdYWJU`]ghia U'cfgicZh\Y 6A i g"'`A]YghcbYgiZcfih\YiWci fgYiUfYi]bZcfa YXia i g]WJUbg\]džiZcfiVch\idYfZcfa YfgiUbXiWca dcgYfgžiUbXiVZYWMJ YidfUWJWYžiUgih\YiVUg]gicZ[cUi!cf]YbhYXžighfUhY[]WUbXiUi hcbca ci gia i g]Wa U_]b["'

7 ci fqY @YUfb]b['Ci hMca Yq

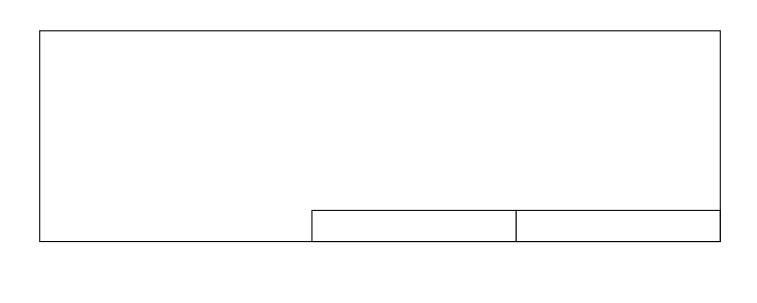
- %": cfa i `UhY`UfhjghjWcV^YWjj Yg`i bXYf`h\Y`[i]XUbWY`cZU`hYUWXYfž`XYa cbghfUhjb[i]bWfYUg]b[`hYWXb]WU` g_]```]b`dYfZcfa UbWY`cf`Wca dcg]hjcb
- &" 5dd`mih\Y`df]bW]d`Yg`cZYZZYWf|jY'dYfqcbU``dfUWf)WY
- '" =XYbhZmfY`Uhcbq\]dg'Ua cb['WcbhYl hi U``]ggi Yg']bZcfa]b['dYfZcfa UbWY'dfUWf)WY
- ("5dd`mdf]bWd`Yg`cZhYUakcf_hc`aig]WYbgYaV`Y

HYUWX]b[GhfUhY[]Yg

Ghi XYbhgʻi bXYfhU_YʻcbY!cb!cbYʻWcbgi `hUh]cbgʻk]h\ʻgdYW]Uʻ]ghih hcfgʻQʻl '%\ci fʻYUW\`hf]a YghYfQʻUhhYbX k cf_g\cdgʻGʻl '%') `\ci fgʻYUW\`hf]a YghYfQʻUhhYbX`a UghYfWUggYgʻ`YX`Vmj]g]h]b['Yl dYfhgʻOW\ccg]b['(`l` &\ci fgʻZfca 'b]bY`a UghYfWUggYgʻUWfcggʻh\Y`mYUfQʻUbX`dUfh]W]dUhY`]b`X]fYWhYX`YbgYa V`YgžW\ccg]b['Zfca 'U k]XY`fUb[Y`cZa i g]WJ``ghmYgʻUbX`W`hi fYgʻUbX`dUfh]W]dUh]b[']b`U`Z]bU``dYfZcfa UbWY`]b`YUW\`hf]a YghYf`Q`l &\ci fq`fY\YUfqU`g`]b`YUW\`hf]a YghYf`Q`

 $\textbf{BchY}. \ \ 'H\] g'] g' U' \& 'I \ C \ 7 \ \ 'Wci \ fg Y'' \ \ 'Wci \ 'k \] ``Ybfc``] b' (\ 'I \ C \ 7 \ '] b' Y UW \ \ \ 'c Zh f Y 'gi \ \ WW gg] j \ Y'h 'fa \ g'k \] h \ 'U' f Y gi \ 'h f Y dc f h Y Y w' i f g Y''$

MUSC2703 Term 2, 2021 published at 26-04-2021 // © University of New South Wales, 2021



8YHJ]`g.

3 diffej Wegk]```VY`gi Va]h\YX`UWfcgg`H%z`H&`UbX`H' "``H\YgY`k]```VY`fY`Uh\YX`hc`a Ugh\YfWUggYg`dfYgYbh\YX`Vm j]g]h]b['Yl dYfhg`]b`U`fUb[Y`cZa i g]\WJ`ghm`Yg`UbX`UWhj]h]Yg"``7 f]h]ei Y`ei Ygh]cbg`k]```VY`g\WJZc`XYX`hc Yb\Wci fU[Y`ghi XYbhg`hc`]XYbh]Zmi]ggi Yg`Zcf`X]g\W gg]cbz`UbX`hc`XfUk```]b_g`Ua cb['dYfZcfa Ub\W`Y`Ya Ybhg UbX`g\W.c`Uf`m`]h\YfUhi fY"

 $K f] h Y b Z Y Y X V U W_k] ```V Y d f c j] X Y X c b `] b Y h h f c i [\ A c c X Y]$

5 XX]hjc b&X**X}hjdj**ò&;`XYhU]`g.

: ci f`Wf]hjei Yg`UfY`hc`VY`gi Va]hhYX`]b`hchU`"`Gh XYbhg`g\ci `X`gi Va]h`Uh``YUgh`cbY`Wf]hjei Y`]b`YUWX`cZhYfV

.

Gi Va]gg]cb bchYg.]b WUgg dfYgYbhUhjcb

Hi fb]hjb gYhjb[. H\]g]g bchU Hi fb]hjb Ugg][ba Ybh

5ggYgga Ybh (. 'DfUW) WU YI Ua]bUh]cb

GhUfhXUhY. Bch5dd`]WUV`Y

@Yb[h\. '&) 'a]bi hYg

8YHJ]`g.

H\Y`YI Ua]bUhjcb`cZdYfZcfa UbWY`\Ug`hk c`fY`UhYX`dUffg": cf`]bghfi a YbhU``UbX`j cWU``ghi XYbhg`&) !a]bi hYg cZfYdYfhc]fY`k]```VY`dYfZcfa YX`]b`U`gYa]!Zcfa U``WcbWYfhYbj]fcba YbhUhh\Y`YbX`cZH&`f&& Ł".5hh\Y`YbX cZH' žghi XYbhg`k]```VY`YI Ua]bYX`cb`hYW\b]WU``fYdYfhc]fY`UbX`g][\hfYUX]b[`Uddfcdf]UhY`hc`h\Y]f

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|---|----|--|

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DfYgWf]VYX F Ygci fWYg

 $F \]b_\ddot{z} > "fPX" + "f&$$) + "? ge[US^bWbAd_S`UW E fgV[We [_ge[US^[fWbbdWfSf[a` \ddot{z}7 Ua Vf]X[Y.]7 Ua Vf]X[YA Vf]X[$

K]``]Ua cbž'5'&\$\$('f9X"Ł'? ge[US^7j UW'W UW, efcSfWY[We S` V fWUZ` [cgWe fa W ZS` UWbWb\ad_S` UWC | ZcfX | b]j Yfg]miDfYggžC | ZcfX

FYWca a YbXYX FYgci fW/g

 $6 \ UWX \ Z'7 \ "'D"'9"'fW+)' \ E'7 \ eeSk \ a` fZWF \ dyW3 \ d'a XB'Sk[`Y = WkTaSdV;`efdy_ W' fe'HfUbg''K]``]Ua'A] \ HWXY``"'BYk'Wcf_.'K "Bcfhcb'UbX'7c"'% (-$

6Yfa Ubž'6"'f&\$\$\$\tau'@afWe Xta_ fZWb[S` [efe TW UZ"'BYk '< Uj Yb. 'MJ'Y'I b]j Yfg]\textbf{m}DfYgg"

6YfbUWZD"'fV2+*L"'FZW[`fWdbdWfSf[a` aX8dW UZ ea`Y"'@cbXcb.; c``UbW\"

6i htž:>"ž/ '8 fYm2 gž:@":f9:Xg"L":f&\$\$%L":B 'Sk[`Yi [fZ: [efack, FZWZ[efac(US^SbbcaSUZ fa? ge[US^BWc2] S`UW'7 Ua Vf]X[Y:7 Ua Vf]X[Y:1 b]j Yfg]hmDfYgg"

 $6 \text{fck b} \\ \text{$\underline{z}$} \\ 7 \text{"if} \\ \text{\underline{b}} - - \\ \text{\underline{t}} \text{"5 See} \\ \text{[US ^S` V Da_ S` f[U b W} \\ \text{\underline{d}} \\ \text{[`Y bdSUf[UW#)' "} \\ \text{\underline{Z}} \\ \text{\underline{t}} + \text{""} \\ \text{\underline{z}} \\ \text{\underline{c}} \text{[\underline{Z}} \\ \text{\underline{c}} \text{[X. `C | \underline{Z}} \\ \text{\underline{c}} \\ \text{\underline{c}} \text{[X. `C | \underline{Z}} \\ \text{\underline{c}} \\ \text$

7 cY\`cžJ "'fPX"Ł"'f&\$\$' Ł"'5 S_ TdVYWUa_ bS` [a` fa fZWYg [fSd" 7 Ua Vf]X[Y. '7 Ua Vf]X[Y'I b]| Yfg]lmiDfYgg"

7 c ZZ|bž6" f% *\$!&t" F Z We[`YWde dWbWdfa [dW' f&bX 9 X"t" A Yh WXYbžB Yk '>YfgYmG WUfYWfck "

 $SSSSSS"fl/b-, +t'' 5aX() e eag` Ve aXe() Y() Y, bd() U(b^We S` V Sbb^(USf(a) aXhaUS^fWUZ` (cgWe i (fZ UZda_ Sf(Uhai W^UZSdfzfkbX^YX"t'' A Yhi W\Ybz'BYk '>YfgYm^GWUfYWfck''$

8 Uj]Xqcbž'>"'f&\$\$(Ł"FZW? qe[U BoSUf[f[a` Wdž 5`XYq\chž'5q\[UhY

9qd]b]žB"ff%+++L"DWbWdfa[dWXadfZWea?a ha[UWAYhWXbzBYk >YfqYmGWUfYWfck"

: UV]Ubž8"'f&\$\$' \L''4\$UZ b\Wd\ad_S` U\Wbd\SUf[U\W#+&' #+)' , 3 Ua_bd\\Z\W e[h\Wd\Mh[\W a\Xeag` V d\Wad\[Y S` V \f\Wd\f\g\W 5`\XYg\chz5g\[U\H'\"

: `Ya]b[žFYbÅY`f&\$\$(ŁFZW[``Wdha[UW, fZW_S][`YaXSe[`YWd'BYk`Mcf_. DYb[i]b'; fcid

; fYYbž6"'f%, *Ł"FZW[``WdYS_WaX_ge[U"'BYk 'Mcf_.'8ci V'YXUm'

< U[VYf[\check{z} ?"'f&\$\$' \check{z} Ef\$YWBdWeW UWX \check{z} : W\$V fa FaW S? S`g\$^Xad? ge[U[S`e'H\Y'gWUfYWfck'DfYgg]

< YfVYfhž'H"ž/ 'K U``UW'ž'>"'ff9Xg"Ł"'ff% - +Ł"'FZW5S_ TqVYWUa_ bS` [a` fa TqSee [`efqg_ W fe"'7 Ua Vf]X[Y UbX'BYk 'Mcf_ž'7 Ua Vf]X[Y'I b]j Yfg]|miDfYgg"

<]bgcbžA "'f&\$\$\$L"'9 g[VWfa fZWb[S` [efe dNbWdfa[dN'fl fX`YX"L"'6`cca]b[hcb. '\daggar X]UbU'l b]j Yfg]hmDfYgg"

Gi Va]gg]cb cZ5ggYgga YbhHUg_g

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

Image: Ybwci bhYf'U'dfcV'Ya k \Yb'UhYa dhjb['hc'gi Va]hmci f'Ugg][ba Ybhh\fci [\'Hi fb]h]bz'd'YUgY

HY'Yd\cbY'9| hYfbU''Gi ddcfhcb'-',) "''' %cf'Ya U]''h\Ya 'cb'Y! hYfbU'hY'hgi ddcfh4 i bgk "YXi "Ui ""Gi ddcfh
\ci fg'UfY', .\$\$Ua '-'%\$.\$\$da 'cb'k YY_XUmg'UbX'-.\$\$Ua '-').\$\$da 'cb'k YY_YbXg'fl *) 'XUmg'U'mYUft'''=\mathref{moi}
UfY'i bUV'Y'hc'gi Va]hmci f'Ugg][ba YbhXi Y'hc'U'ZJi 'hk]h\'Hi fb]h]b'mci 'a UmUdd'mZcf'Ub'Y! hYbg]cbz'Vi hmci
a i ghfYhJ]b'mci f'h]\W_Yhbi a VYf'Zfca '9! hYfbU''Gi ddcfhfU'cb['k]h\'Ubmch\Yf'fY'Yj UbhXcW a Ybhgthc
]bWi XY'Ug'Yj]XYbW''hc'gi ddcfhmci f'Y! hYbg]cb'Udd']\WJh]cb"'\mathref{moi} 'Ya U]''9! hYfbU''Gi ddcfhmci 'k]'`
Ui hca Uh]\WJ'`mfYW']j Y'U'h]\W_Yhbi a VYfz'Vi h]Zmci 'hY'Yd\cbY'mci 'k]'`bYYX'hc'gdY\WZ\WJ'`mUg_'Zcf'cbY''
Hi fb]h]b'U'gc'dfcj]XYg'i dXUhYg'cb'h\Y]f'gmghYa 'ghUh' g'cb'Hk]hYf''

; YbYfU``mž'UggYgga YbhiHug_g'a i ghVY'gi Va]hhYX'Y`YVWfcb]\W)``mij]U'Y]h\Yf'Hi fb]h]b'cf'U'A ccX`Y Ugg][ba Ybh'' =b']bgHJb\W'g'k \YfY'h\]g']g'bchdcgg]V`Yž']hk]```VY'gHJhYX'cb'mci f'\\circ i fgY'g'A ccX`Y'g]hY'k]h\U`hYfbUhjj Y'gi Va]gg]cb'XYHJ]`g''

cfi]bZcfa Uhjcbicbi\ckihcigi Va]hUgg][ba Ybhgicbi]bYij]UiA ccXiY.i\hdg.#gh XYbhi bgk "YXi "Ui #\ck! gi Va]hUgg][ba Ybha ccXiY

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.

 $7 \text{ cdm}b[...i g]b[...h\Y.gUa Y.cf.j Yfmig]a] \Uf'k cfXg'hc'h\Y.cf][]bU''hYl h'cf']XYU'k]h\ci h'U\V_bck `YX[]b[...h\Y.cf][]bU''hYl h'cf']XYU'k]h'cf']$

5WUXYa]W±bZcfaUhjcb

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