

# **ARTS3039**

>UbY 5i ghYb ]b 7 cbhYl h

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

## 7ci fgY'Cj Yfj ]Yk

#### GHJZ:7cbHJWh8YHJ]`g

#### 7cbj Ybcfg

B Ua Y	9a U]`	5j U]`UV]`]lm	@cWJhjcb	D\cbY
9`]nUVYh\`A WA U\cb	Y"a Wa U∖cb4 i bgk "YXi "Ui	,		f\$&E'-',) %%*(

#### GWXcc`7cbHJWh =bZcfa Uh]cb

GWXcc`cZh\Y'5fhg'UbX'AYX]U

Fcca " %&ž@YjY`" žFcVYfhK YVghYf'6i]X]b['f) %(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'GWCC``cZhY'5ftg'UbX'AYX]U'kci`X``]_Y'tc'FYgdYWM\cong \cong m5W_bck``YX[Y'h\Y'HfUX]tjcbU``7igtcX]Ubgž h\Y'6YXY[U'`fPYbg]b[tcb'WJadigŁZ'; UX][U'`fP]tmUbX'5fthZ''8Yg][b'7UadigYgŁUbX't\Y'B[ibbUkU`dYcd'Y'fbighfU`]Ub'8YZYbW': cfW'5WJXYam]b'7UbVYffUŁ'cZh\Y'`UbXg'k\YfY'YUW\'WJadig'cZIBGK']g`cWJhYX''$ 

### 7ci fgY 8YHJ] g

#### 7 fYX]hDc]bhg \*

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

>UbY'5i ghYb'W ffYbhmYb'cmg'U'W hi fU'dcdi 'Uf]mmf]j U']b['h\UhcZG\U\_YgdYUfY"'H\]g'Wci fgY'U]a g'hc'hU\_Y UWWci bhcZh\Y'UV]X]b['fY'Yj UbW'cZ5i ghYbfg'k cf\_']b'h\Y'YUf'm&%ghWYbhi fm]b'hk c'X]gh]bWiVi hifY`UhYX k Umg"'C b'h\Y'cbY'\UbXž]hZcW gYg'cb'5i ghYbfg'f j Yb]']U'UbX'bcj Y`g'Ug'gcW]U'UbX'W hi fU'dfcXi Wg'cZ h\Y]f'hJa Y"'#iYl Ua ]bYg'\ck '\Yf'k cf\_g']bhYfUWigY'ZWcbgW]ci g`mk ]h\ 'WcbhYa dcfUfmfca Ubh]Wž'[ch\]WUbX gYbhJa YbhU''Z]WhJcb'Ug'k Y`''Ug'fWcbj YfgYfik ]h\ 'YUW\ ch\Yf'hc'Zcfa 'U'XmbUa ]WUbX']bhY``YWhi U``mW\U``Yb[]b[ VcXmcZk cf\_"'C b'U'a cfY'h\YcfYhWU'`Yj Y`ž']hYl d`cfYg'h\Y'j Uf]ci g'Wca dcbYbhg'cZ5i ghYbfg'`]hYfUfmghmY h\UhU``ck '\Yf'hc'gdYU\_'hc'dfYgYbhXUmfYUXYfg. '\Yf'i gY'cZ]fcbmž'\Yf'UV]`]mmhc']`i a ]bUhY'h\Y'gi VhY ffUbgZcfa Uh]cb'cZW\UfUWYf'cj Yf'hJa Yž'UbX'\Yf'i b]ei Y']bhYfa ]b['`]b['cZfca UbWY'UbX'fYU']ga "'H\fci [\h\YgY'hk c'`YbgYgž'h\Y'a cXi 'Y'XYa cbghfUhYg'h\Y'Wcbh]bi ]b['fY'Yj UbWY'cZ5i ghYbfg``]hYfUfmiUbX'a cfU' k cfXj ]Yk"

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

%"  $GdYU_:UbX'k f]hY'Wf]h]WU``m'UVci h'>UbY'5i ghYb'k ]h\]b`\Yf'W'hi fU`ž'\]ghcf]WU``UbX']bhY``YWhi U``WcbhYl h &" <math>\Rightarrow$ Ybh]Zm'UbX'UbU`mgY'h\Y'\_Ym'ZYUhi fYg'cZ5i ghYb'g'`]hYfUfmighm`Y

" 5fh/W `UhY fYUqcbq Zcf5i qhYb'q Wcbh/bi ]b[ fY`Yj UbW UbX dcdi `Uf]hm]b h\Y YUfm&%qhWbh fm

#### HYUWX]b[ GlfUhY[]Yg

D`YUqY'fYZYf'hc'h\Y']bZcfa Uhlcb']b'A ccX`Y

FYgci fWyg

DfYgWf]VYX`F Ygci fWYg`

Bch'Uj U]`UV`Y

FYWca a YbXYX FYgci fWYg

BchUj U]`UV`Y

### 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'''=\mathred{Image: Wa Jhmci f'Ugg][ ba YbhXi Y'hc'U'ZJi 'hk ]h\'Hi fb]h]b'mci 'a UmUdd'm\mathred{Image: Wa Jhmci f'Ugg][ ba YbhXi Y'hc'U'ZJi 'hk ]h\'Hi fb]h]b'mci 'a UmUdd'm\mathred{Image: Wa Jhmci f'Ugg][ ba YbhXi Y'hc'U'ZJi 'hk ]h\'Hi fb]h]b'mci 'a UmUdd'm\mathred{Image: Wa Jhmci f'Ub'Y! hYbg]cb\mathred{Image: Wa Jhmci h\Yf'f'Y'j UbhXcW a Ybhg\mathred{Image: Wa Uj''9! hYfbU''Gi ddcfhmci 'k ]'`

JbWi XY'Ug'Yj ]XYbW' hc'gi ddcfhmci f'Y! hYbg]cb'Udd']\wUh]cb"'\mathred{Image: Wa Uj''9! hYfbU''Gi ddcfhmci 'k ]'`

Ui hca Uh]\wU'`mfYW']j Y'U'h]\w\_Yhbi a VYf\mathred{Image: hY'Yd\cbY'mci 'k ]\tag{Y}\wu''mug\_'\mathred{Image: Wa'\mathred{Image: hY}\wu''mug\_'\mathred{Image: hY}\wu''mug\_'\mathred{Image: hY}\wu''mug\_'\mathred{Image: hY'Yd\cbY''mci 'k ]\tag{Y}\wu''mug\_'\mathred{Image: hY'\mathred{Image: hY'\mathred{I

; YbYfU`mž'UggYgga YbhiHug\_g'a i ghVY'gi Va ]hhYX'Y`YVWfcb]\WJ``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`hYfbUh]j 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 i]gii g]b[ih\Yik cfXgicfi]XYUgicZch\YfgiUbXidfYgYbh]b[ih\Ya iUgimci fick b"i=hWJbihU\_Yia Ubm Zcfa gžZfca iXYi]VYfUhYiWXYUh]b[ihciUWW]XYbhU`mWcdm]b[iZfca iUigci fWYik]h\ci hiUW\_bck iYX[Ya Ybh'

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

- 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

# 5 WUXYa]W + DZcfa Uh]cb

: cf'YggYbhJU`'ghi XYbhi]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 ]bUh]cb dfcW/Xi fYg/
- •