

# **ARTS1011**

±bj Ybh]b[ 'h\Y'GY`Z'7 fYUh]j Y'K f]h]b[ ']b'h\Y'8][ ]hU`'5[Y

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

# 7ci fgY'Cj Yfj ]Yk

#### Ghuzz 7 cbhuWh8 Yhu]`g

'7cbj Ybcfg'

B Ua Y	9a U]`	5j U]`UV]`]hm	@cWJhjcb	D\cbY
DUi `'8 Uk gcb	dUi `"XUk gcb4 i bgk "YXi "Ui			

#### GWXcc~7cbhJWh~abZcfa Uhlcb

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'h\Y'HfUX]tjcbU``7igtcX]Ubgž h\Y'6YXY[U'`fPYbg]b[tcb'WJadigŁZ'; UX][U'`fP]tmUbX'5fti/'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 8YW] g

7 fYX]hDc]bhg\*\*

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

K \UhiXcYg`]ha YUb'hc`k f]hY`UVci hci fgY`j Yg`]b`Ub`U[ Y`cZfYU`]mm\i b[ Yfž'k ]h\`[ YbfYg`gi W\`Ug`Ui hc`]Wf]cb UbX`a Ya c]f`dfc`]ZYfUh]b[ žUbX`k ]h\`gcWJU`a YX]U'dfcj ]X]b[ `Yj YfmcbY`k ]h\`U'di V`]WdfcZ]`Y3`=Zdf]bhW\`h fY cZh\Y`; i hYbVYf[ `YfU`\Ug`[ ]j Yb`k Umhc`X][ ]hU`W\`h fY`cZh\Y`; cc[ `Y`YfUž'h\]g`\Ug`cb`m]bWfYUgYX'h\Y Ua ci bhcZhYI hih\Uhik Y`UfY`]a a YfgYX`]b"`\b`h\]g`Wti fgY`mci `k ]```YI d`cfY`\ck ``]hYfUh fY`\Ug`Wta dYhYX`k ]h\ž UVgcfVYXžUbX`fYa YX]UhYX`bYk 'hYW\bc`c[ ]Yg`cZWta a i b]WUh]cb"`Nci `k ]```UddfcUW\`'WfYUh]j Y`k f]h]b[ '`Ug`U a cXY`cZYI dfYgg]cb'h\UhiYa Yf[ Yg`Zfca 'UbX`W]fW\`UhYg`k ]h\]b`U`a i W\``Uf[ Yf`hYI hi U``Ybj ]fcba Ybhz`UbX`mci k ]```dfcXi WY`mci f`ck b`]bbcj Uh]j Y`Yb[ U[ Ya Ybhg`k ]h\`WcbhYa dcfUfma YX]U`]b`U`dfUWf]WU``k cf\_g\cd g]h Uh]cb"

.

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

%" 8 Ya cbglfUhY '\_bck `YX[ Y`cZ\ck `WcbhYa dcfUfm`]hYfUhi fY 'Yb[ U[ Yg`k ]h\ bYk 'a YX]U` &" → XYbh]ZmZcfa U``Y`Ya Ybhg`cZ`]hYfUhi fY 'UbX`\ck 'h\YmcdYfUhY`k ]h\]b`UbX`UWfcgg`[ YbfYg ' " I bXYfghUbX`h\Y`h\Y`dfUWf]WU``XYVN]g]cbg`k f]hYfg`a U\_Y`]b`fY`Uh]cb`hc`h\Y`WfUZncZk f]h]b[ ' (" 7 f]h]WU``mUddfU]gY`h\Y]f`ck b`k cf\_`UbX`h\Y`k cf\_`cZch\Yfg`) " 8 fUZnžfYj ]gYž'UbX`YX]h`h\Y]f`ck b`a Ubi gWf]dhg`

#### HYUWX]b[ GhfUhY[]Yg

D`YUgY`fYZYf`hc`h\Y`]bZcfa Uh]cb`]b`A ccX`Y

## 5ggYgga Ybh

# 5ggYgga Ybh'HUg\_g'

5ggYgga Ybh'hUg_	K Y][ \h	8iY'8UhY	Gh XYbh@YUfb]b[ Ci hWca Ygʻ5ggYggYX
HYI h U`7 c``U[Y'	' \$1	Bch5dd`]WUV`Y	% <u>ž&amp;</u> Ž
: ]bU``7 fYUh]j Y`K cf_`	) \$1	Bch5dd`]WUV`Y	%ž&Ž Ž( ž)
Hi hcf]U``DfYdUfUh]cb`	&\$ı	Bch5dd`]WUV`Y	' <u>ž(</u> ž)

#### 5ggYgga Ybh8YHJ]`g

5ggYgga Ybh% HYI hi U`7c``U[Y

GhUfh XUhY.

**8YHJ]**`g. '%\$\$\$`k cfXgGh XYbhg`k ]```fYWY]j Y`k f]hhYb`ZYYXVUW\_`cb`h\Y]f`k cf\_"

5ggYgga Ybh&: ]bU`7fYUh]j Y`K cf\_

GhUfh'XUhY.

**8YHJ]`g**. '&\$\$\$!' \$\$\$`k cfXg"H\]g`]g`h\Y`Z]bU``UggYgga Ybh'HUg\_"`Gh XYbhg`k ]```fYWY]j Y`k f]hhYb`ZYYXVUW\_cb h\Y]f`k cf\_"

5ggYgga Ybh' . Hi hcf]U DfYdUfUh]cb

GHJfh XUhY.

8 YHJ]`g. '5```ghi XYbhg`a i ghigi Va ]h\U`XfUZha Ubi gWf]dh\Zcf`[ fci d`k cf\_g\cdd]b[ ']b`WUgg"'H\Ymk ]```fYWY]j Y k f]h\Yb'ZYYXVUW\_cb'h\Y]f`k cf\_`]b`dfc[ fYgg"Ghi XYbhg`a i ghidfcj ]XY`k f]h\Yb'ZYYXVUW\_cb'U```XfUZh a Ubi gWf]dhg`gi Va ]h\YX`Zcf`k cf\_g\cdd]b[ "'H\]g`k ]```VY`a cb]hcfYX`cb'A ccX`Y`cf`]b`WUgg"

FYgci fWYg

DfYgWf]VYX F Ygci fWYg

Bch'Uj U]`UV`Y

FYWca a YbXYX FYgci fWYg

Bch'Uj U]`UV`Y

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

Gi Va ]gg]cb cZ5ggYgga YbhHUg\_g

Gi Va ]gg]cb cZ5ggYgga YbhHUg\_g

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

\_Zmci YbWci bhYf'U'dfcV`Ya 'k \Yb'UhYa dhJb[ 'hc'gi Va ]hmci f'Ugg][ ba Ybhh\fci [ \ 'Hi fb]hJbž'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'' =Zmci
UfY'i bUV`Y'hc'gi Va ]hmci f'Ugg][ ba YbhXi Y'hc'U'ZUi 'hk ]h\'Hi fb]hJb'mci 'a Um'Udd'mZcf'Ub'Y! hYbg]cbžVi hmci
a i ghfYhU]b'mci f'hJW\_Yhbi a VYf'Zfca '9! hYfbU``Gi ddcfhfU'cb[ 'k ]h\'Ubmch\Yf'fY`Yj UbhXcW a Ybhgt'hc
]bWi XY'Ug'Yj ]XYbW'hc'gi ddcfhmci f'Y! hYbg]cb'Udd`]WUhJcb'' =Zmci 'Ya U]`'9! hYfbU``Gi ddcfhmci 'k ]``

#### 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"'=hWUb`hU\_Y`a Ubm Zcfa gžZfca `XY`]VYfUhY`W\YUh]b[ 'hc`UWW]XYbhU``mWcdm]b[ 'Zfca `U`gci fW'k ]h\ci hUW\_bck `YX[ Ya Ybh'

 $I BGK `[fci dg'd`U[]Uf]ga `]bhc'h\Y'Zc``ck]b[`WUhY[cf]Yg.$ 

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

- 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±bZcfaUh]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`th\ 'UbX'GUZYtmidc`]M]Yg/
- YI Ua ]bUh]cb dfcW/Xi fYg/
- gdYWJU``Wcbg]XYfUhJcb`]b`h\Y`Yj YbhcZ]``bYgg'cf'a ]gUXj Ybh fY/
- gh XYbhYei ]mrUbX X]gUV]`]mr/
- UbX'ch\Yf'YggYbhJU`'UWUXYa ]W]bZcfa UhJcbž'gYY