МИНИСТЕРСТВО НАУКИ И ВЫСШЕГО ОБРАЗОВАНИЯ РОССИЙСКОЙ ФЕДЕРАЦИИ
федеральное государственное автономное образовательное учреждение высшего образования
"САНКТ-ПЕТЕРБУРГСКИЙ ГОСУДАРСТВЕННЫЙ УНИВЕРСИТЕТ АЭРОКОСМИЧЕСКОГО ПРИБОРОСТРОЕНИЯ"

Кафедра №21

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(подпись)
«28» мая 2021 г.

РАБОЧАЯ ПРОГРАММА ДИСЦИПЛИНЫ

«Направляющие среды в авиационной электросвязи»
(Наименование дисциплины)

Код специальности	25.05.03
Наименование специальности	Техническая эксплуатация транспортного радиооборудования
Наименование специализации	Техническая эксплуатация радиоэлектронного оборудования аэропортов и воздушных трасс
Форма обучения	заочная

Санкт-Петербург – 2021

Лист согласования рабочей программы дисциплины

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«26» мая 2021 г, протокол №7

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ZZZ]QDQLXP	FRP We_dljhggh [b[ebhl_qgZy kbkl_fZ]QD

l_j_q_gv bgnhjfZpbhgguo l_ogheh]bc

l_j_q_gv ijh]jZffgh]h h[_ki_q_gby bkihevamgbh]h h[jZah\Zl_evgh]h ijhp_kkZ ih ^bkpbiebg_

l_j_q_gv bkihevam_fh]h ijh]jZffgh]h h[_ki_q_gby ij_^klZ

LZ[ebpZ – l_j_q_gv ijh]jZffgh]h h[_ki_q_gby

i i	GZbf_gh\Zgb_
	0DWK&$’

l_j_q_gv bgnhjfZpbhggh kijZ\hqguo kbkl_f bkihe hkms_kl\e_gbb h[jZah\Zl_evgh]h ijhp_kkZ ih ^bkpbiebg_

l_j_q_gv bkihevam_fuo bgnhjfZpbhggh kijZ\hqguo \ kb lZ[ebp_

LZ[ebpZ – l_j_q_gv bgnhjfZpbhggh kijZ\hqguo kbkl_f

i i	GZbf_gh\Zgb_
	KWWS ZZZ JORVVDU\ UX =ehkkZjbe\ ehl\ mu okleem‘\[Zj_lcf
	KWWS ZZZ HR QVDXhgWmeqWZgllexk

FZl_jbZevgh l_ogbq_kdZy [ZaZ
KhklZ\ fZl_jbZevgh l_ogbq_kdhc [Zau g_h[oh^bfhc
h[jZah\Zl_evgh]h ijhp_kkZ ih ^bkpbiebg_ ij_^klZ\e_g \ lZ[el

LZ[ebpZ – KhklZ\ fZl_jbZevgh l_ogbq_kdhc [Zau

i i	GZbf_gh\Zgb_ khklZ\ghc qZklbGhf_j Zm^blhjbb fZl_jbZevgh l_ogbq_kdhc [Zauijb g_h[oh^bfhklb	
	Fmevlbf_^bcgZy e_dpbhggZy Zm^blhjby	
	Mq_[gZy eZ[hjZlhjby	

Hp_ghqgu_ kj_^kl\Z ^ey ijh_^_gby ijhf_‘mlhqghc Z
KhklZ\ hp_ghqguo kj_^kl\^ey ijh_^_gby ijhf_‘mlh
h[mqZxsboky ih ^bkpbiebg_ ijb_^_g \ lZ[ebp_

LZ[ebpZ – KhklZ\ hp_ghqguo kj_^kl\ ^eyghjh\Z l^_ kbZypbjbf_‘m

<b^ ijhf_‘mlhqghc Zll_klZpbb	l_j_q_gv hp_ghqg
>bnn_j_gpbjh\Zgguc aZqzl	Kibkhd \hijhkh\ AZ^Zqb

< dZq_kl_ djbl_jb_\ hp_gdb mjh\gy knhjfbjh\Zg
dhfi_l_gpbc h[mqZxsbfbky ijbf_gy_lky [Zeehjfbjh\Zgy rdZeZ kbkl_jZ\ hp
dhfi_l_gpbc dhlhjZy ijb_^_gZ \ lZ[ebp_ fh‘<lbkihevah\Zfl_v
[ZeevgZy rdZeZ fh^mevgh j_clbg]h\hc kbkl_jZ\ bZ Mgb
bkihevah\Zgby dhlhjhc mklZgh\e_gu khhl_jZ\ mxsbff Zehhl Ze
=M:l

LZ[ebpZ –Djbl_jbb hp_gdb mjh\gy knhjfbjh\Zgghklb dhfi_l

Hp_gdZ dhfi_l_gpbb [ZeevgZy rdZeZ	OZjZdl_jbklbdZ knhjfbjh\Zgguo dhfi_l_gpbc
'hlebqgh“ 'aZql_gh“	– h[mqZxsbcky]em[hdh b \k_klhjhgg_ mk\h fZl_jbZe – m_j_ggh eh]bqgh ihke_^h\Zl_evgh b]jZfh – hibjZykv gZ agZgby hkgh\ghc b ^hihegbl_ l_kgh ijb\yau\Z_l mk\h_ggu_ gZmqgu_ iheh‘_g ^_yl_evghklvx gZijZ\e_gby – mf_eh h[hkgh\u\Z_l b Zj]mf_glbjm_l \u^\b]Z – ^_eZ_l \u\h^u b h[h[s_gby – k\h[h^gh \eZ^__l kbkl_fhc Zkigu b Zehyb c
'ohjhrh“ 'aZql_gh“	– h[mqZxsbcky l_j^h mZ\fhbc ifZl]jbZe]jZfhlg ih kms_kl\m baeZ]Z_l _]h hibjZykv gZ ebl_jZlmju – g_ ^himkdZ_l kms_kl_gguo g_lhqghkl_c – m\yau\Z_l mk\h_ggu_ agZgby k ijZdlbq_k gZijZ\e_gby – Zj]mf_glbjm_l gZmqgu_ iheh‘_gby – ^_eZ_l \u\h^u b h[h[s_gby

Hp_gdZ dhfi_l_gpbb [ZeevgZy rdZeZ	OZjZdl_jbklbdZ knhjfbjh\Zgguo dhfi_l_gpbc
	± \eZ^__l kbkl_fhc ki_pbZebabjh\Zgguo ihgylb
©m^h\e_l\hjbl_evgh^a ©aZql_gh^a	± h[mqZxsbcky mk\hbe h\ghc dhhjkZ fguc fZl_jb ih kms_kl\m baeZ]Z_l _]h hibjZykv gZ agZg ebl_jZlmju ± ^himkdZ_l g_kms_kl_ggu_ hrb[db b g_lhqg ± bkiulu\Z_l aZljm^g_gby \ ijZdlbq_kdhf ijbf gZijZ\e_gby ± keZ[h Zj]mf_glbjm_l gZmqgu_ iheh`_gby ± aZljm^gy_lky \ nhjfmebjh\Zgbb \u\h^h\ b h[h ± qZklbqgh \eZ^__l kbkl_jfh\Zgkiupbi\Zgbyab c
©g_m^h\e_l\hjbl_evgh^a ©g_ aZql_gh^a	± h[mqZxsbcky g_ mk\hbe agZqbl_evghc qZ fZl_jbZeZ ± ^himkdZ_l kms_kl_ggu_ hrb[db b g_ jZkkfhlj_gbb ijh[e_f \ dhgdj_lghf gZijZ\e_gbb ± bkiulu\Z_l ljm^ghklb \ ijZdlbq_kdhf ijbf_g_g ± g_ fh`_l Zj]mf_glbjh\Zlv gZmqgu_ iheh`_gby ± gnhjfmebjm_l \u\h^h\ b h[h[s_gbc

Lbih\u_ dhgljhevgu_ aZ^Zgby beb bgu_ fZl_jbZeu
<hijhku aZ^Zqb ^ey wdaZf_gZ ij_^klZ\e_gu \ lZ[ebp_
LZ[ebpZ ± <hijhku aZ^Zqb ^ey wdaZf_gZ

‹ i i	l_j_q_gv \hijhkh\ aZ^Zq ^ey wdaZf_gZ	Dh^ bg^bdZ hjZ
	Mq_[guf ieZghf g_ ij_^mkfhlj_gh	

<hijhku aZ^Zqb ^ey ^bnn_j_gpbjh\Zggh]h aZq_lZ ij_^kl

LZ[ebpZ ± <hijhku aZ^Zqb ^ey ^bnn_j_gpbjh\Zggh]h aZq_lZ

‹ i i	l_j_q_gv \hijhkh\ ^ey ^bnn_j_gpbjh\Zggh]h aZq_lZ	Dh^ bg^bdZ hjZ
	Hkgh\gu_ wlZiu jZa\blby kh\j_f_gghc dZ[_evghc k\yab	
	DeZkkbnbdZpby gZijZ\eyxsbo kbkl_f	
	DeZkkbnbdZpby gZijZ\ey_fuo WF<	
	Qlh lZdh_ nhlhgbaZpby "	HID
	OZjZdl_jbklbdZ l_jfbgZ ©pbnjh\baZpby^a	
	Qlh lZdh_ hilbdh\baZpby "	HID
	AgZqbfu_ wlZiu jZa\blby hilbq_kdbo l_ogheh]bc ?KK JN	
	Hibrbl_ dhgkljmdpbb hkgh\guo ebgbc i_j_^Zqb L \hegu	
	DhZdkbZevgZy b ^\moijh\h^gZy EI	
	lh dZdbf djbl_jbyf \Zu[ohZxdkbZevguo ebgbc "	HID
	JZagh\b^ghklb dhgkljmdpbc ihehkdh\uo ebgbc	D lhehkdh\
	Fbdjhihehkdh\u_ ebgbb DhfieZgZjgu_ ebgbb	
	>Zcl_ kjZ\gbl_evgmx oZjZdl_jbklbdm iZjZf_hjhD\ dhZdkbZe ^\moijh\h^ghc ebgbc	
	DZdb_ ^hklhbgkl\Z bf__l ^\moijh\h^gZy ebgbc iZju^a"	HlyD\ \h^_ ©\b

	DZdb_ hkh[_gghklb bf_xl fgh]hk\yagu_ ebgbb	
	>ey dZdbo jZ^bhl_ogbq_kdbo p_e_c bkihevhmDxlkyA dhZdk dZ[_eb k oZjZdl_jbklbq_kdbf khijhlb\e_gb_f b Hf"	
	MdZ‘bl_ hkgh\gu_ jZagh\b^ghklb b h[eZklv HjlDf_gA gby fgh]hk\yaguo EI	
	DZdb_ hlebqby bf_xl j_]meyjgu_ b g_j_]meyjgu_ ebgbb"	
	GZ dZdb_ lbiu fh‘gh jZa^_eblv ebgbb i_j_^ZdqD ihAdhebq_ g_aZ\bkbfuo ijh\h^ysbo ih_joghkl_c"	
	>Zcl_ kjZ\gbl_evgmx oZjZdl_jbklbdm iZjZf_HjlD\ ehAgbc i_ hkgh\guo deZkkh\	
	Q_f h[mkeh\e_g \u[hjokljZgh^ZjlogU^ebg \heg ^eyD<HAKl" HI	
	Q_f h]jZgbqb\Z_lky fhsgZhklvhk^bjgZh \ H<" HID A	
	>Zcl_ hij_^_e_gb_ b mdZ‘bl_ h[eZklv agZq_gbc DK< b D	
	lhq_fm g_‘_eZl_evgh lihyq\ec gWF<k\ ebgbb" HID	
	>Zcl_ oZjZdl_jbklbdm madhihehkghfm b rbjHlDihe Ahkghfm kh]eZkh\Zgbx	
	Hkgh\gu_ ihgylby j_ne_dlhf_ljbb lhykgbl_ HjlDgpbA jZ[hlu j_ne_dlhf_ljZ	
	DZd hljZ‘_gby WF< hl]_g_jZlhjZ b gZ]jmadHlDebyAxl gZ oZjZdl_jbklbdb EI"	
	DeZkkbnbdZpby g_j_]meyjghkl_c k ihfhsvx j_ne_dlhf_ljZ	
	lhbkd g_bkijZ\ghkl_c \ EK lhykgbl_ dZd hHlD[gZjm‘Ab\Zxl f_klhjZkiheh‘_gb_ dZ[_ey k\yab	
	FZl_fZlbq_kdZy fh\^b_ejZkikjehkljZg_gby WF< \HID M h^ghk\yaguo \hegh\h^Zo	
	FZl_fZlbq_kdb_ fh^_**eb** g \bijh\fhm]hevghf \hegh\h^_M >bZiZahg jZ[hqbo qZklhl AZlmoZgb_	
	FZl_fZlbq_kdb_ fh^_hebgl bidhj\m]ehf \hegh\h^_HID M >bZiZahg jZ[hqbo qZklhl AZlmoZgb_ jZaebqguo lbih\ \h	
	AZibrbl_ nhjfmeu ^ey \uqbke_gby \hegh\h]hHlDmijhMb\e_gb ebgbc i_j_^Zqb L \hegu hkgh\guo lbih\	
	JZkkqblZlv iZjZf_lju \aZbfgh]h \ebygby kbff_HlDbqgM]h dZ Bkoh^gu_ ^Zggu_ dhwnnbpb_gl aZlmoZgby . gZ gZb\ukr aZ^Zggh]h ^bZiZahgZ wg_j]_lbq_kdbc ihl_gpbZe ZiiZjZl mkeh\gh ijbgylv 6 ^;	
	JZkkqblZlv i_j_^Zlhqgu_ oZjZdl_jbklbdb hilHlbqD_kdM]h dZ[kl_deh\hehdgZ khhlghr_gb_ dhwnnbpb_glh\ ij_ehfe_gby ¤ qbkeh fh^ jZkijhkljZgyxsboky \ k_lh\h^_ 1 ghjfbjh\Zggmx qZklhlm djblbq_kdmx qZklhlm lR b djblbq_kdmx ^ebgm \hegu R dhwnnbpb_gl ih]ehs_gby \ k_lh\h^_ . \hegh\h_ khijhlb\e_gb_ =\ nZah\mx kdhjhklv #n	
	Baf_jblv hkgh\gu_ iZjZf_lju ^\moijh\h^ghc pHlDb M Hij_^_e_gby oZjZdl_jZ g_bkijZ\ghklb \ ^\moijh\h^ghc Hij_^_e_gby jZkklhygby ^h g_bkijZ\ghklb \ \ha^mrguo dZ[_evguo ebgbyo ljbf_g_gby f_lh^h\ aZsblu h[hehq_d dZ[_ey hl dhjjhab Kbff_ljbjh\Zgby gbadhqZklhlguo dZ[_e_c	
	Baf_jblv hkgh\gu_ iZjZf_lju ^\moijh\h^ghc p_ib	

	Hij_^_eblv oZjZdl_j g_bkijZ\ghklb \ ^\moijh\h^ghc p_ib	
	Hij_^_eblv jZkklhygbj_Z\ghklb\ \ha^mrguo dZ[_evguo ebgbyo	bHID M
	H[hkgh\Zlv ijbf_g_gb_ b ijbf_gblv h^bg ba h[hehq_d dZ[_ey hl dhjjhabb	HfI_Dh^M\ aZsb
	<uihegblv kbff_ljbjh\Zgb_ gbadhqZklhlgh]h dZ[_ey	
	ljbf_gblv hkgh\gu_ ijb_fu h[jZ[hldb wdki_jbk ^Zgguo ^ey \uy\e_gby jmkejZ\b_cgbyZ\ lhemqblv b kjZ\gblv oZjZdl_jbklbdb oZjZdl_jbklbdb h^gh b fgh]hfh^h\uo H<"	HI_gIZMevguo
	JZkkqblZlv hkgh\gu_ \b^u ^bki_jkbb \ H< mf_gvr_gby ^bki_jkbb \ <HEK	>HZID v jMdhf_g^
	KjZ\gbl_ klZlbklbq_kdb_ oZjZdl_jbklbdb <HEK oZjZdl_jbklbdZfb EI ^jm]bo deZkkh\	HEKD k M
	>Zcl_ oZjZdl_jbklbdb kbklZlbjv \ H<	HID M
	JZ[hqZy ^ebgZ \hegu ihl_jv fZl_jbZeZ k_j^p_\bgu WJ/ jZaghklv ihdZaZl_e_c ij_ehfe_gby fZl_jbZeh\ k_j^p_\bgu b h[hehqdb ¤Q Q Q ^bZf_lj k_j^p_\bgu GF \ fdf lbi \hegu fh^Z lhkljhblv]jZnbdb qZklhlghc aZ\ebkbf#mklku.q_jlblv ihi_j_qguc jZaj_a hilbq_kdh]h dZ[_ey k mdZaZgb_f _]h dhgkljmdlb\ we_f_glh\ \ fZkrlZ[_ mdZaZlv _]h fZjdm	ZgS_gkfdmf]elZ ^bwe_dljbq_kdb HIDbc
	JZajZ[hlZcl_ ijbgpbibZevgmx ko_fm b jZkkqblZcl_ 'imibg dZ[_ey	HIDZcl_<
	ljbf_gbl_ ^bZ]jZffm KfblZ <hevi_jlZ ^ey j_rHgby aZ^Zqb ijh_dlbjh\Zgby \ ^bZiZahg_ jZ^bhqZklhl	HIDy dhgdj_lg
	ljb_^bl_ ijZdlbq_kdb_ ijbf_ju bkihevah\Zgby ljZgknhjfZpbb khijhlb\e_gbc	HIDy\e<gby
	JZkkqblZcl_ kh]eZkh\Zgb_ EI k]_g_jZlhjhf hkgh\gu_ djbl_jbb kh]eZkh\Zgby	HIDgZ]j<madhc
	lhykgbl_ \ujZ'_gb_ ^ey bfi_^ZgkZ k_joijh\ $Z = \sqrt{\frac{}{0}}$ $Z_S = \sqrt{\frac{}{0\ 0}}$ $Z_{ЭФ} = Z\frac{+R}{-R}$	HI^Dgbd<
	lhykgbl_ \ujZ'_gb_ ^ey ^h[jhlghklv k_joijh fbdjhihehkdh\hc ebgbb $Q = \frac{5\ H_k}{,\ R_k}$ $Q = \frac{-\frac{X_S}{k\ d}}{WJ/\frac{R_S}{k\ d}}$	HI^Dys_<
	lhykgbl_ ijhihjpbhgZevghklv baf_g_gby dhZdkbZevghc p_ib $\frac{k}{\sqrt{f}}$ $q\sqrt{f}$ klhlhlc l	HI^Dbpb<_glZ a
	Hij_^_eblv ^bgZfbq_kdbc ^bZiZahg j_ne_dlhf_ljZ	
	Hij_^_eblv 'f_jl\mx ahgm“ j_ne_dlhf_ljZ"	
	H[tykgblv fh'gh eb k ihfhsvx j_ne_dlhf_ljZ mqZklhd H< gZoh^ysbcky ih^ f_oZgbq_kdbf gZijy'_gb_f'	HIJ_^_eblv
	H[tykgblv fh'gh eb k ihfhsvx j_ne_dlhf_ljZ	hij_^_eblv

	aZlmoZgb_ H<"	
	H[tykgblv ijbgpbibZevgu_ jZaebqby j_ne_dlHhfDljbkb ^ey dhZdkbZevghc El b H<"	

l_j_q_gv l_f ^ey dmjkh\h]h ijh_dlbjh\Zgby \uZhelu_gb ij_^klZ\e_gu \ lZ[ebp_

LZ[ebpZ – l_j_q_gv l\hf]h^eiyh dhljkjh\Zgby b\uidmejkhg\hc jZ[hlu

i i	ljbf_jguc i_j_q_gv l_f ^ey dmjkh\h]h ijh_dlbjh\Z dmjkh\hc jZ[hlu
	Mq_[guf ieZghf g_ ij_^mkfhlj_gh

<hijhku ^ey ijh_^_gby ijhf_'mlhqghc Zll_klZpZgby\ ij_^klZ\e_gu \ lZ[ebp_

LZ[ebpZ – ljbf_jguc i_j_q_gv \hijhkh\ ^ey l_klh\

i i	ljbf_jguc i_j_q_gv \hijhkh\ ^ey l_klh\	Dh^ bg^bdZlhjZ
	G_ ij_^mkfhlj_gh	

l_j_q_gv l_f dhgljhevguo jZ[hl ih ^bkpbiebgc hlmfuZxs h[mq_gby ij_^klZ\e_gu \ lZ[ebp_

LZ[ebpZ – l_j_q_gv dhgljhevguo jZ[hl

i i	l_j_q_gv dhgljhevguo jZ[hl
	<ZjbZgl < dZdhf qZklhlghf ^ibZiZahgl_kybk\moijh\h\ gdZyq_ekblgby gZijZ\eyxs_c kj_^u" H\l\f_lljh\hf \ kZglbf_\jh\hf hilbq_kdhf < dZdhf ^bZiZahg_ qZklhl \ dZq_kl_ gZiajZ\elkxs_c kj \hehdhggh hilbq_kdbc dZ[_ev"÷Hl\F=up ÷dF=pp=p =÷p L=p ÷ L=p=p DZdhc lbi \heg jZkijhkljZgy_lky ih dhZdkbZevghfmL d lbHE lbEH lbi K dZdhc p_evx hilbfbabjmxlky]_hf_ljbq_kedvg_h]ihZjZf_l dZ[_ey" Hl_lu k p_evx m_ebq_gby ijhikmpkdZvxfhc fh mf_gvr_gby \ghkbfuo ihl_jv k p_evx m_ebq_gby \ghkbfuo ihl_jyf DhZdkbZevguc dZ[_ev h[eZ^Z_l fbgbfZehgu_gb ihl_jyf ^bZf_ljh\ _]h ijh\h^gbdHl_jZu\gh ' G ' G G ' G
	<ZjbZgl K dZdhc p_evx bkihevamxlky dhZdkbZehgu_ dZ[_eb l m_ebq_gghc bg^mdlb\gunklvx^"eyHlm_ebq_gdbyjhkZlah\hc k ^ey mf_gvr_gby \ghkbfuo^ehyl_mf_gvr_gby \j'^f_gbyijhoh kb]gZeZ ^ey m_ebq_gby ihehku qZklhl lmibgbaZpby dhZdkbZevgh]h dZ[_ey ijb\hgbk d ke_^m ^bZiZahgZ qZklhl Hl_lu ^bZiZahg qZklhl ^bZiZahg qZklhl m_ebqb\Z_lky ^bZiZahg qZklhl mf_gvrZ_lky l_j_qbkebl_ iZjZf_lju \aZbfgh]h \ebygbyHf_'^um p_5yfb / & *αf_lα^bwœebae P U N J < dZdbo gZijZ\eyxsbo kj_^Zo bkihevam_bkgy_ahZdhg ih hljZ'_gby" Hl_lu dhZdkbZevguc dZ[_ev hilbhqe_hkdbhc\

dZ[_ev k_lh\h^

DhZdkbZevguc dZ[_ev h[eZ^Z_l fZdkbfZekvlgxc ijkeimk hlghr_gb_ ^bZf_ljh\ gphdhjhjZh\gh Hl_lu " G ' G ' G

Qbkeh\Zy Zi_jlmjZ \hehdgZ hilbq_kdh]hmeZ[c_ehl\ujZ‘

$$S_{ij} = \quad VLQ_{ПРОД} = \sqrt{\frac{n}{n}} \qquad VLQ_{ПРОД} = \frac{n}{n} \qquad VLQ_{ПРОД} = \sqrt{n - n}$$

$$VLQ_{ПРОД} = \frac{0}{0}$$

DZdb_ ba i_j_qbke_gh[eZm^Zkjhc aZbfghklvx" Hl_l ljhcgbdb fhklu pbjdmeylhju _glbeb]bjZlhj

Dhwnnbpb_gl aZlmoZgby \ dhZdkbZevghc mhjifmeh‘gh

Hl_lu $\frac{0}{Q\left(\frac{D}{d}\right)}$ $\sqrt{\frac{L}{C}}$ $\frac{R}{}\sqrt{\frac{C}{L}} + \frac{G}{}\sqrt{\frac{L}{C}}$

?keb \ gZijZ\eyxs_c kj_^_ pbebg^jbq_kdh]h \b^Z _d we_dljhfZ]gblgh]h ihey jZkiheh‘_gu dZd gZZ_jkykmlgid_ lh \hegu" Hl_lu 7 (PQ*HE* +PQ

?keb \ gZijZ\eyxs_c kj_^_ pbebg^jbq_kdh]h \b^Z _d we_dljhfZ]gblgh]h ihey jZkiheh‘_gu dZd gZZ_jkykmlgid_ lh \hegu" Hl_lu 7 (PQ*HE* +PQ

<ZjbZgl

?keb \ gZijZ\eyxs_c kj_^_ pbebg^jbq_kdh]h \b^Z _d we_dljhfZ]gblgh]h ihey jZkiheh‘_gu dZd gZZ_jkykmlgid_ lh \hegu" Hl_lu 7 lbi (lb*EH* +*HE*bi

<ujZablv q_j_a we_f_[$\dot{S}$]lu\ fZhkjbfhu_ qZklhlguf nbevljhf

hkeZ[e_gb_ kb]gZeZ \ G= H O\J l u L = O|SJ|
|S|

$L[\partial Б] = |S| \qquad L[\partial Б] = |S| +$

Qlh[u j_Zebah\Zlv \ f_ljh\hf ^bZiZahg_ \heg ihke_^h dhglmj dZdhc ^ebgu ke_^m_l \u[jZlv DA h'ljahd ^\moij

l<— l= λ l< λ l= λ

Qlh[u j_Zebah\Zlv \ f_ljh\hf ^bZiZahg_ \heg ihke_^h dhe_[Zl_evguc dhglmj kdeZ^mc_^ebugjuZlv DAmhlijhahd ^\c

El" Hl_lul<— l= λ l< λ l= λ

Qlh[u j_Zebah\Zlv \ f_ljh\hf ^bZiZahg_Zhhecg ^begb^gmudlb

ke_^m_l \u[jZlv DA hlj_ahd ^\moijh\hl^g-hc E=l" Hl_lu

l< λ l= λ

<ZjbZgl

Qlh[u j_Zebah\Zlv \ f_ljh\hf ^bZiZahg_ebgegkefdhmklv

	\u[jZlv DA hlj_ahd ^\moijh\h^ghc E-l" Hl_lO l O l O ljb dZdhf hlghr_gbb dhwnnbpb_glZ ij_nehfeh_[ghehkdb^_ n \ <HD gZ[ex^Z_lky ihegh_ \gmlj_gg__nhljnZ`_gb_ Hl\ n n n !n ljb dZdhc ^ebg_ \hegu_jh_afZhq`Z we_dljhfZ]gb<HD \he Hl_lu KP ! KP KP Hlghkbl_evgh_ agZq_gb_ ihdZaZl_ey ijehdfeZ_gb<HDil n n hij_^_ey_lky ih nhjfme_ Q_fm fh`_l [ulv jZ\gh ^Zggh_ n Hl\_lu ' ' ' ' < \hehdhggh hilbq_kdhf \hegh\h^_ kms_gh\mhxl GjZ hd dZdhc ^ebg_ \hegu \hafh`gh _Ohdgh"fdHfl\O_lu fdf O
	<ZjbZgl < \hehdhggh hilbq_kdhf \hegh\h^_ kms_gh\mhxl GjZ hd dZdhc ^ebg_ \hegu \hafh`gh _Ohdgh"fdHfl\O_lu fdf O fdf < \hehdhggh hilbq_kdhf \hegh\h^_ kms_gh\mhxl GjZ hd dZdhc ^ebg_ \hegu \hafh`gh _Ohdgh"fdHfl\O_lu fdf O fdf DZdZy gZijZ\eyxsZy kj_^Z gZau\Z_lky ^bkvj_j]bjmxs_ aZ\bkbl hl qZkvjhlgu_ aZ\bkbl hl qjZkbhelvguc hl_l DZdbf kbf\hehf fSZ¾ ijhp`ugh hibkZlv k\hckl\h kh]eZkh\Zg fgh]hihexkgbdZ" HS\_lS $S_{ij}$ $S_{ji}$ $S_{ii}$ $S_{jj}$ $S_{ii}$ DZdbf kbf\hehf fSZ¾ ijhp`ugh hibkZlv k\hckl\h jZa\yadb fgh]hihexkgbdZ" HS_lS S_{ij} S_{ji} S_{jj} S_{ij}

F_lh^bq_kdb_ fZl_jbZeu hij_^_eyxsb_ ijhp_^m
bg^bdZlhjh\ oZjZdl_jbamxsbo wlZiu nhjfbjh\Z`gb_ yZlkdyhfi_l_
ehdZevguo ghjfZlb\guo ZdlZo =M:l j_]eZf_glbjhmpx_s^bmojmih
ijh_^_gby l_dms_]h dhgljhey mki_\Z_fhklblZbpbjhfh_[mqZxsbo
=M:l

F_lh^bq_kdb_ mdZaZgby ^ey h[mqZxsboky ih hk\h_g

F_lh^bq_kdb_ mdZaZgby ^ey h[mqZxsboky ih hk
fZl_jbZeZ
Hkgh\gh_ gZagZq_gb_ e_dpbhggh]h fZl_jbZekZbk±_fghh]bq
]em[hdh_ b ykgh_ baeh`_gb_ mq_[gh]h fZlf_jbZeZ eGZpabZc
jZfdZo ^bkpbiebgu g_ \ lhf qlh[u ihemqblv f\kx Zbg nhkfZ_bgx
nmg^Zf_glZevguo ijh[e_f ^bkpbiebgu f_lh^h\ ggZ_mqrbo]h
^hklb`_gbc gZmqghc fukeb < mq_[ghf ijhp_klh^_hee_hdbbqy k\dum
hj]ZgbaZpbhggmx b bgnhmjmZgpdbhbgbgmEx_dpby jZykbjcugZ_c lZihgZjZl

dhgdj_lghc h[eZklb agZgby _z ijh[e_fu ^gZb_l hp_ehkghbieibg
ihdZau\Z_l \aZbkfh^kjhyabvfb ^bkpbiebgZfb

leZgbjm_fu_ j_amevlZlgubijbh[hkhqhZxsbfbky e_dpbhgghh]h fZ

– ihemq_gb_ kh\j_f_gguo p_ehklguo \aZbfhk\gvaZgg
dhlhjuo hij_^_ey_lky p_e_\hc mklZgh\dhc d dZ‘^hc dhgdj_lgl

– ihemq_gb_ hiulZ l\hjq_kdh\c_kZgh\u ij_ih^Z\Zl_e_f

– jZa\blb_ ijhn_kkbhgZevgh ^_eh\uo dZq_kl\ ex[\b
kZfhklhyl_evgh]h l\hjq_kdh]h fure_gby

– ihy\e_gb_ g_h[oh^bfh]h bgl_j_kZ g_h[oh^bfh]h [h\u kZ

– ihemq_gb_ agZgbc h kh\j_f_gghf mjh\g_ jZabblhby g
ijh]gha_ bo jZa\blby gZ [eb‘Zcrb_]h^u

– gZmqblvky f_lh^bq_kdbv hfZ\Z_[jZbZe\Zl\u^_eylv u]keeZb\ghu_
iheh‘_gby ijboh^blv d dhgdj_lguf \u\h^Zf ih\hgjuv
nhjfmebjh\dZo

– ihemq_gb_ lhqgh]h ihgbfZgby \k_o g_h[oh^bfuo l_jfbg

E_dpbhgguc fZl_jbZe fh‘_l khijh\h‘^Zlvky ^_fhbgkljZ
bkihevah\Zgb_f jZa^Zl_jbZe fh‘_l ijh_^_gbb dhgjmkbbc ^h[
hkh[_gghklyo ijbf_g_gby hl^_evguo l_fZlbd ih ^bkpbiebg_

Kljmdlmjz ij_^hklZ\e_gby e_dpbhggh]h fZl_jbZeZ

– ZgZeba l_hj_lbq_kdh]h fZl_jbZeZ
– ijhjZ[hldZ e_dpbhggh]h fZl_jbZeZ
– \uiheg_gb_ ijZdlbq_kdbo aZ^Zgbc

F_lh^bq_kdb_ mdZaZgby ^ey h[mqZxsboky ih[mqZklb
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F_lh^bq_kdb_ mdZaZgby ^ey h[mqZxsboky ihbijhoh
aZgylbc

IjZdlbq_kdh_ aZgylb_ y\ey_lky h^ghc ba hlbgh\gu[bgh]hj
ijhp_kkZ aZdexqZxsZyky \ \uiheg_gbb h[mq\Zxsij_bky\Zi\hZ^_eny
dhfie_dkZ mq_[guo aZ^Zgbc k p_evx mk\h_ghbkygh\Zmqq_h[glh
^bkpbiebgu ijbh[j_l_gby mf_gbc b gZ\udh_ehvghZklb\hjq_kdhc

P_evx ijZdlbq_kdh]h aZgylby ^ey h[mqZxs_h[mkqZxsbfky
mf_gbc b gZ\udh\ ijZdlbq_kdhc ^_yl_evghkbg_ih bamqZ_fhc ^

leZgbjm_fu_ j_amevlZlgubijbh[hkhqhZxsbfky ijZdlbq_kdbo aZ

– aZdj_ie_gb_ m]em[e_gb_ jZkrbj_gb_ b ^_lZebaZpb
dhgdj_lguo aZ^Zq

– jZa\blb_ ihagZ\Zl_evguo kihkh[ghkl_c kZfhkylhyl_
l\hjq_kdhc Zdlb\ghklb

– h\eZ^_gb_ gh\ufb f_lh^Zfb b f_lh^bdZfb bamqh_gby
^bkpbiebgu

– \ujZ[hldZ kihkh[ghklb eh]bq_kdh]h hkfuke_gb^yeyihen
\uiheg_gby aZ^Zgbc

– h[_ki_q_gb_ jZpbhgZevgh]h khq_lZgby dhehc dhh\jghc
h[mq_gby

Lj_[h\Zgby d ijh_^_gbx ijZdlbq_kdbo aZgylbc

>ey hnhjfe_gby ^hdmf_glZpbb ih ijZdlbq_kdhkfy aZgylbyf j

hagZdhfblvky kh klZg^Zjlhf hj]ZgbaZpbb Z\dlbqkkbbhon
aZgylbc

agZlv =HKLu \ qZklb mkeh\guo h[hagZq_gbfh^meixhn_k

mq_klv j_dhf_g^Zpbb ij_ih^Z\Zl_ey ih jZajZ[hldb \ dhgki_dlb_ebgZ jk_Zdhf_g^m_fhcl_mjZ[hld

h[jZah\Zgby“ b 'H fh^mevgh j_clbg]h\hc kbkmhgf_[ghp_ijZdhlc
klm^_glh\ \ =M:l“

F_lh^bq_kdb_ mdZaZgby ^ey h[mqZxsboky ihghjch‘
Zll_klZpbb
Ijhf_‘mlhqgZy Zll_klZpby h[mqZxsboky ij_^mkfZljb
ijhf_‘mlhqguo b hdhgqZl_evguo j_amevlZlh_h[hmqZxsgbky ihgjch‘
k_[y ^bnn_j_gpbjh\Zgguc aZq_l – wlh nhjfZgghupo_ghdlhmqaZgxZsgbky
ijb bamq_gbb ^bkpbiebgu ijb \uiheg_gbb dhm\jukch\juZo[hijh_gdZhm\
bkke_^h\Zl_evkdbo jZ[hl b ijhoh‘^_gbb ijZdlpb_dgdkhcZl1h_kelZqgh
'ohjhrh“ 'm^h\e_l\hjbl_evgh“ 'g_m^h\e_l\hjbl_evgh“
Kbkl_fZ hp_ghd ijb ijh_^_gbb ijhf_‘mlhqghceyZll_klZpb
khhl_lkl\bb k lj_[h\Zgbyfb lheh‘_gbc 'H l_dmZs_fhkldbhgbjh
ijhf_‘mlhqghc Zll_klZpbb klm^_glh\ =M:l h[mfquZx\sbky ih
h[jZah\Zgby“ b 'H fh^mevgh j_clbg]h\hc kbkmhgf_[ghp_ijZdhlc
klm^_glh\ \ =M:l“

Ebkl \g_k_gby baf_g_gbc \ jZ[hqmx ijh]jZffm ^bkpb

>ZlZ \g_k_gby baf_g_gbc b ^hiheg_gbc lh^ibkv \g_kr_]h baf_g_gby	Kh^_j‘Zgb_ baf_g_gbc b ^hiheg_gbc	>ZlZ b ijhlhdheZ aZk_^Zgby dZn_^ju	lh^ibkv aZ\ dZn_^jhc