Physics PhD's ...whence ...whither ...when?

The rate of production of physics doctorates in the United States—stationary at 500 per year for almost a decade—is now rising with a rate of increase of approximately 7% per year. Lindsey R. Harmon, director of research of the National Academy of Sciences—National Research Council, reports here on some of the geographic, educational, and sociological characteristics of the new PhD's in physics. The NAS-NRC studies complement those of the US Office of Education and the American Institute of Physics in reporting the extent to which the nation is meeting the critical need for highly educated manpower in physics.

By ***L. R. Harmon***

DURING most of the decade of the 1950's, the production of physics doctorates was on a plateau at about 500 per year. Recent evidence is that it has begun to climb again, at about the long-term rate of an increase of 7% per annum. The data on physics doctorate output, shown in Table 1 and in Figure 1, come from the Doctorate Records

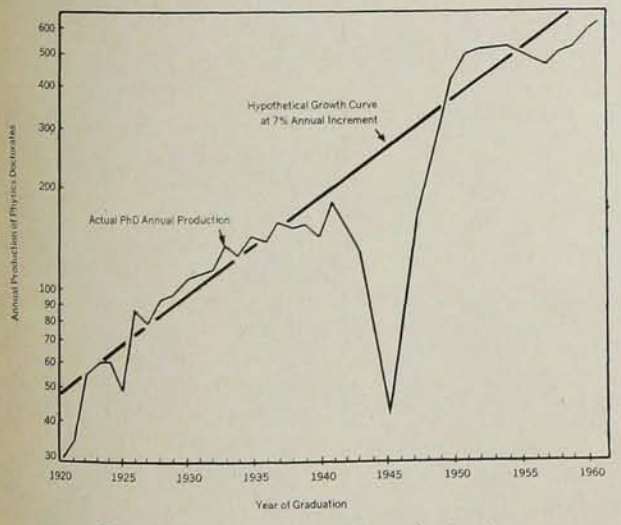

Fig. 1. Annual production of physics doctorates (1920–61) by US universities.

Table 1. **Physics PhD's From US Universities, 1920 through 1961**

1920	31	1934	126	1948	224
1921	37	1935	145	1949	319
1922	56	1936	140	1950	422
1923	61	1937	159	1951	501
1924	62	1938	154	1952	519
1925	50	1939	156	1953	523
1926	87	1940	144	1954	527
1927	80	1941	186	1955	506
1928	93	1942	155	1956	484
1929	97	1943	130	1957	463
1930	106	1944	63	1958	505
1931	112	1945	43	1959	522
1932	115	1946	71	1960	574
1933	136	1947	148	1961	602

File of the Office of Scientific Personnel of the National Academy of Sciences—National Research Council. Figure 1 is plotted on semilogarithmic paper so that a given percentage rate of increase will appear as a straight line. For the last four years, the increase each year has come very near to the 7% per annum rate of increase, which, over many decades, tends to characterize doctorate output in all fields combined.

In recent years, more detailed data have become available through the procedures of the Doctorate

Table 2. Fine Field Breakout of PhD's in Physics, 1957–1961

	1957		*1958*		*1959*		*1960*		*1961*	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
Total	460	*100.0*	505	*100.0*	522	*100.0*	574	*100.0*	602	*100.0*
Solid State	86	*18.7*	101	*20.0*	116	*22.2*	135	*23.5*	124	*20.6*
Electricity & Magnetism	12	*2.6*	7	*1.4*	7	*1.4*	10	*1.8*	20	*3.3*
Optics	2	*0.4*	3	*0.6*	9	*1.7*	6	*1.0*	7	*1.2*
Acoustics	5	*1.1*	16	*3.2*	10	*1.9*	8	*1.4*	9	*1.5*
Mechanics & Heat	6	*1.3*	1	*0.2*	4	*0.8*	1	*0.2*	4	*0.7*
Atomic & Molecular	50	*10.9*	57	*11.3*	57	*10.9*	51	*8.9*	64	*10.6*
Nuclear	142	*30.9*	142	*28.1*	140	*26.8*	173	*30.1*	193	*32.1*
Theoretical	63	*13.7*	76	*15.0*	91	*17.5*	107	*18.6*	110	*18.3*
Thermal Phenomena*	—	—	—	—	—	—	2	*0.4*	2	*0.3*
Fluids*	—	—	—	—	—	—	7	*1.2*	25	*4.1*
General	43	*9.3*	44	*8.7*	32	*6.1*	21	*3.7*	4	*0.7*
Other	42	*9.1*	39	*7.7*	35	*6.7*	38	*6.6*	12	*2.0*
Astronomy	9	*2.0*	19	*3.8*	21	*4.0*	15	*2.6*	28	*4.6*

* New category added in 1960.

Table 3. Regional Distribution, At Various Career Stages, of Physics PhD's, 1958 Through 1961

		Birth				*High School*				*BA*		
		1958	*1959*	*1960*	*1961*	*1958*	*1959*	*1960*	*1961*	*1958*	*1959*	*1960*
Total		505	455	567	602	505	455	567	602	505	455	567
New Engl.	*N*	26	31	25	40	35	32	33	46	70	67	76
	%	*5.2*	*6.8*	*4.4*	*6.6*	*6.9*	*7.0*	*5.8*	*7.6*	*13.9*	*14.7*	*13.4*
Mid. Atl.	*N*	142	127	137	129	142	116	131	138	127	99	116
	%	*28.1*	*27.9*	*24.2*	*21.4*	*28.1*	*25.5*	*23.1*	*22.9*	*25.1*	*21.8*	*20.5*
E. No. Cent.	*N*	93	68	87	103	80	60	86	103	92	62	90
	%	*18.4*	*15.0*	*15.3*	*17.1*	*15.8*	*13.2*	*15.2*	*17.1*	*18.2*	*13.6*	*15.9*
W. No. Cent.	*N*	26	35	45	45	22	26	39	38	25	31	39
	%	*5.1*	*7.7*	*7.9*	*7.5*	*4.4*	*5.7*	*6.9*	*6.3*	*5.0*	*6.8*	*6.9*
South Atl.	*N*	26	26	48	38	37	41	57	44	38	38	53
	%	*5.1*	*5.7*	*8.5*	*6.3*	*7.3*	*9.0*	*10.1*	*7.3*	*7.5*	*8.4*	*9.3*
E. So. Cent.	*N*	17	12	10	13	16	13	12	13	15	12	13
	%	*3.4*	*2.6*	*1.8*	*2.2*	*3.2*	*2.9*	*2.1*	*2.2*	*3.0*	*2.6*	*2.3*
W. So. Cent.	*N*	38	20	39	30	36	23	40	31	34	23	33
	%	*7.5*	*4.4*	*6.9*	*5.0*	*7.1*	*5.1*	*7.0*	*5.1*	*6.7*	*5.1*	*5.8*
Mtn.	*N*	17	16	25	17	8	14	24	17	9	10	21
	%	*3.4*	*3.5*	*4.4*	*2.8*	*1.6*	*3.1*	*4.2*	*2.8*	*1.8*	*2.2*	*3.7*
Pacific	*N*	27	29	42	47	28	36	56	55	42	68	66
	%	*5.4*	*6.4*	*7.4*	*7.8*	*5.6*	*7.9*	*9.9*	*9.1*	*8.3*	*14.9*	*11.6*
Foreign	*N*	87	84	105	124	65	78	79	99	51	45	60
	%	*17.2*	*18.5*	*18.5*	*20.6*	*12.9*	*17.1*	*13.9*	*16.4*	*10.1*	*9.9*	*10.6*
Unknown	*N*	6	7	4	16	36	16	10	18	2	0	0
	%	*1.2*	*1.5*	*0.7*	*2.7*	*7.1*	*3.5*	*1.8*	*3.0*	*0.4*	*0*	*0*

Table 4. **Geographic Location of US Physics Doctorates of 1958–1961 at Various Career Stages**

	Birth		*High School*		*BA*		*PhD*		*Job*	
Region	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
New England	122	*7.2*	146	*8.5*	294	*15.6*	307	*14.4*	104	*8.7*
Middle Atlantic	535	*31.6*	527	*30.5*	471	*25.0*	532	*25.0*	319	*26.6*
E. No. Central	351	*20.7*	329	*19.0*	347	*18.4*	428	*20.1*	183	*15.2*
W. No. Central	151	*8.9*	125	*7.2*	125	*6.7*	120	*5.6*	43	*3.6*
South Atlantic	138	*8.1*	179	*10.4*	168	*8.9*	220	*10.3*	146	*12.2*
E. So. Central	52	*3.1*	54	*3.1*	52	*2.8*	39	*1.8*	35	*2.9*
W. So. Central	127	*7.5*	130	*7.5*	120	*6.4*	97	*4.6*	42	*3.5*
Mountain	75	*4.4*	63	*3.7*	55	*2.9*	42	*2.0*	76	*6.3*
Pacific	145	*8.5*	175	*10.1*	250	*13.3*	344	*16.2*	252	*21.0*

PhD				*Job*			
958	*1959*	*1960*	*1961*	*1958*	*1959*	*1960*	*1961*
505	455	567	602	278	319	394	363
79	71	79	78	20	28	26	30
5.6	*15.6*	*13.9*	*13.0*	*7.2*	*8.8*	*6.6*	*8.3*
118	133	123	158	74	82	88	75
3.4	*29.2*	*21.7*	*26.2*	*26.6*	*25.7*	*22.3*	*20.7*
119	78	116	115	33	45	51	54
3.6	*17.1*	*20.5*	*19.1*	*11.9*	*14.1*	*12.9*	*14.9*
23	28	37	32	9	8	16	10
4.5	*6.2*	*6.5*	*5.3*	*3.2*	*2.5*	*4.1*	*2.7*
54	40	65	61	35	28	38	45
0.7	*8.8*	*11.5*	*10.1*	*12.6*	*8.8*	*9.6*	*12.4*
9	10	10	10	9	9	13	4
1.8	*2.2*	*1.8*	*1.7*	*3.2*	*2.8*	*3.3*	*1.1*
28	19	25	25	5	11	14	12
5.5	*4.2*	*4.4*	*4.2*	*1.8*	*3.4*	*3.6*	*3.3*
8	6	16	12	13	21	24	18
1.6	*1.3*	*2.8*	*2.0*	*4.7*	*6.6*	*6.1*	*5.0*
67	70	96	111	40	54	82	76
3.3	*15.4*	*16.9*	*18.4*	*14.4*	*16.9*	*20.8*	*20.9*
—	—	—	—	16	13	18	20
—	—	—	—	*5.8*	*4.1*	*4.6*	*5.5*
—	—	—	—	24	20	24	19
—	—	—	—	*8.6*	*6.3*	*6.1*	*5.2*

Survey of the Office of Scientific Personnel. Table 2 gives the breakout of the subfields of physics for each year since 1957. Perhaps the outstanding feature of these is the relative constancy of the percentages in the various subfields from one year to the next. Field classification here is largely accomplished by the doctorate-holders themselves, although a few of the graduates could not be reached at the time of the survey, and the classification had to be made on the basis of a dissertation title. The number of such cases has declined; this is reflected also in the decrease in the numbers in the "other" and "general" categories.

The origins of the physics doctorates have been a matter of continuing interest for many years. It is now possible to provide, from the data of the Doctorate Survey, a more comprehensive picture of where these people were born, where they went to high school, college, and graduate school, and where their first postdoctoral jobs were located. Table 3 gives comprehensive data on this question by geographic regions of the United States, for all foreign areas combined, and for the small number whose earlier locations and area of postdoctoral employment could not be ascertained. Table 4 and Figure 2 are derived from this table, but with a revision to eliminate the "foreign" and "unknown" categories. This was done because these data relate to United States doctorates only, and the presence of "foreign" and "unknown" categories in all but the PhD column would have caused

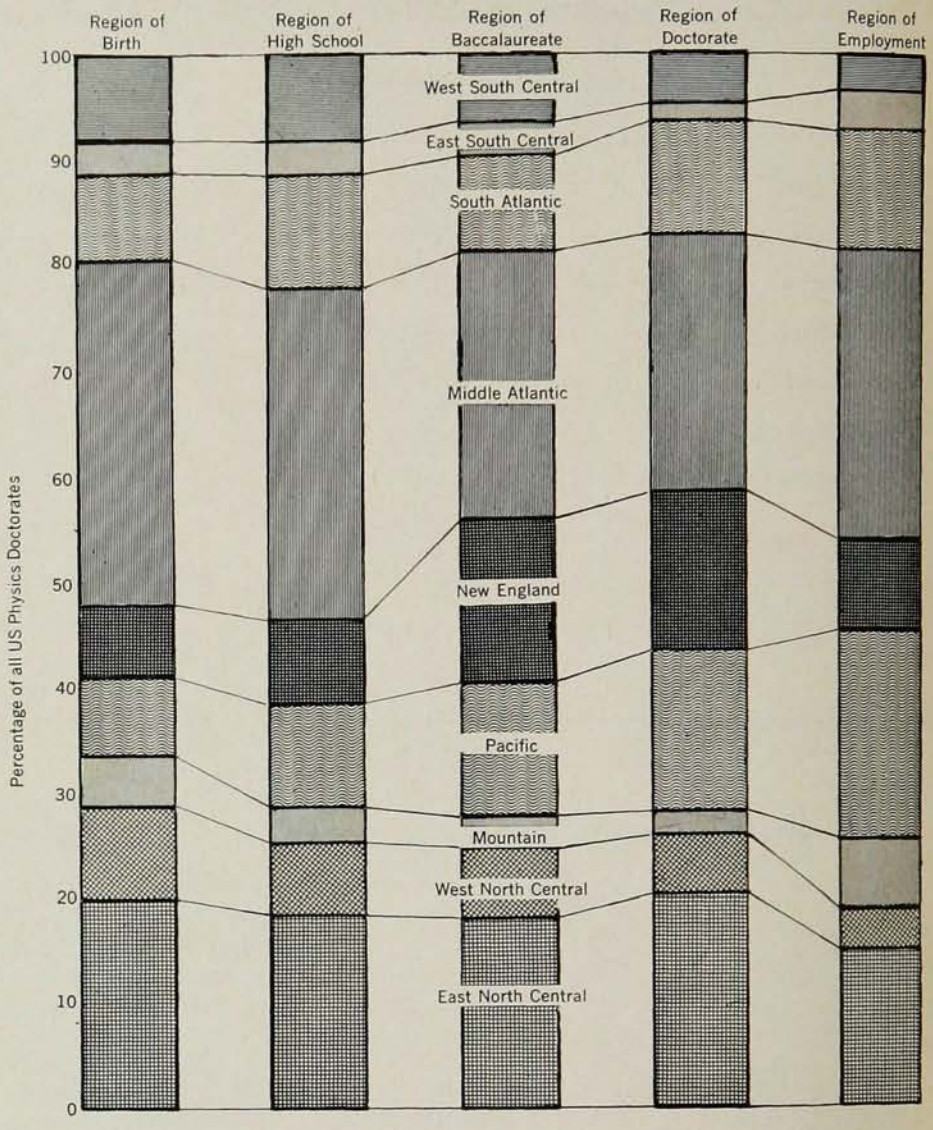

Fig. 2. Geographic location of physics doctorates of 1958–61 at various career stages.

a visual distortion in Figure 2 that would make it difficult to distinguish the really significant trends.

There are in Figure 2 several noteworthy trends. Most prominent, perhaps, is the continual expansion of the Pacific Coast sector at each career stage. This is undoubtedly a function in part of the phenomenal growth in California population over the period here concerned, so that migration in that direction is characteristic of all population segments, including physicists. This is accompanied by a corresponding decline in the West Central region, both North and South, at each career stage. New England shows a marked expansion at the college and graduate-school stages, but returns, in the "employment" phase, to approximately the percentage that characterizes the first two phases. Apparently a great deal of the New England increase during the higher education phase comes from students from the Middle Atlantic region who go north for their college and university training. It is interesting, too, that the two smallest regions (in terms of number of physics doctorates), the East South Central and the Rocky Mountain states, gain back at the "employment" level a percentage that is larger than their "origins" percentage at any earlier career stage.

The states represented by each of these geographic regions are as follows:

New England: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut.

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above 1.5 Mev	decreasing to not less than 10 μa at 2.0 and 0.5 Mev	—	1 to 250 μa
below 0.75 Mev			1 to 250 μa
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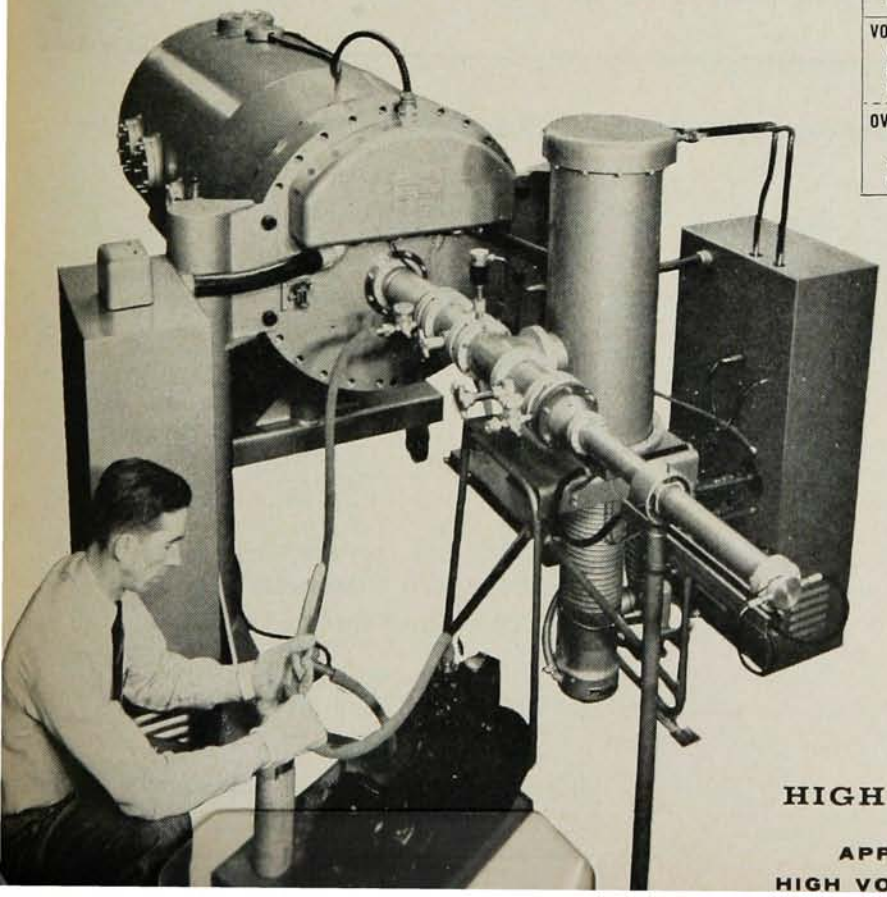
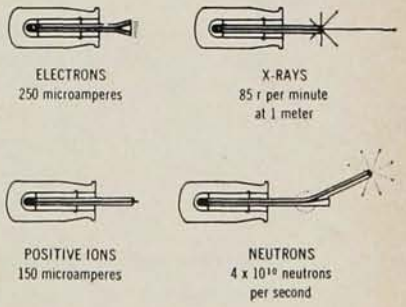
Drift	±20 Kv	±20 Kv	±40 Kv
OVERALL VOLTAGE STABILITY with stabilizing magnet	±2 Kv	—	—





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One of the factors that has come increasingly to attention in recent years is the time that is required for graduate education, and the age of the scientists at the time they attain the doctorate. This is of concern both because of the fact that a number of studies have shown that the youngest years are the period of greatest creativity and because the younger the scientists are at the time their professional careers begin, the longer time they will have for productive work. Fellowship programs have aimed not only at increasing the number of scientists who complete their training, but also at reducing the time required for graduation. Table 5 provides data on age at three career stages. It is apparent here that there is little age spread at the time of high-school graduation; physicists, like people in other fields, are predominantly 17 or 18 years old. There is a slight difference in favor of the physicists; by a small margin they are the youngest group among all who eventually attain the PhD. At the time of the bachelor's degree, they are about 23 years old—about the average for physical scientists—and younger than bioscientists, social scientists, or humanities scholars. The spread in ages has also increased, the standard deviation of ages at this stage being 2.2 years, as against 0.9 years at high-school graduation. At the time of the doctorate, the age of the average physicist is about 30.5 years, but the spread of ages has increased still further, the standard deviation now being 4.3 years. Table 5 shows the data for 1958; a comparison with other years, not shown, indicates no significant changes in later years in age at PhD.

A somewhat more analytical picture is afforded by Table 6, which gives the time lapse between the BA and PhD degrees for the physics doctorates of 1958, 1959, and 1961, and also the distribution of years of predoctoral professional experience—one of the items that helps to account for the BA-to-PhD time lapse. (Data for 1960 are lacking for these variables.) It is evident that there has been a slight, probably insignificant, increase in time lapse, together with a marked drop in years of predoctoral professional experience. This leaves an increasing portion of the time since the baccalaureate unaccounted for—apparently devoted either to studies or to nonprofessional work experience needed for financial support, or to both. Could it be that the effect of a massive fellowship program has been chiefly that of "holding the line" against an increasing workload, academic or other, for the physics graduate student?

The family situation of these students does not accord with the old-fashioned stereotype of the single student in the garret. We are concerned here principally with the male physicists of United States citizenship, as this group comprises approximately five-sixths of

Table 5. Distribution of Ages at Various Career Stages of 1958 Physics PhD's

High-School Graduation			*BA*			*PhD*		
Age	*N*	*%*	**Age**	*N*	*%*	**Age**	*N*	*%*
15 and below	13	*3.07*	Up to 17	1	*0.20*	16–19	0	—
16	27	*6.37*	18–19	13	*2.60*	20–23	0	—
17	134	*31.60*	20–21	144	*28.80*	24–27	156	*31.20*
18	214	*50.47*	22–23	238	*47.60*	28–31	206	*41.20*
19	29	*6.84*	24–25	65	*13.00*	32–35	88	*17.60*
20	6	*1.42*	26–27	21	*4.20*	36–39	33	*6.60*
21	1	*0.24*	28–29	8	*1.60*	40–43	10	*2.00*
22	0	—	30–31	7	*1.40*	44–47	7	*1.40*
23	0	—	32–33	3	*0.60*	48–51	0	—
24	0	—	34+	0	—	52+	0	—
Unknown	81	*19.10*	**Unknown**	5	*1.00*	**Unknown**	5	*1.00*
Mean Age		18.07*	**Mean Age**		23.00**	**Mean Age**		30.45**
Standard Deviation		0.90	**Standard Deviation**		2.22	**Standard Deviation**		4.28
Known *N*		424	*N*		500	*N*		500

* Youngest of any field.
** Average for physical science.

Table 6. BA to PhD Time Lapse and Years of Predoctoral Professional Experience For Physics Doctorates of 1958, 1959, and 1961

A. Time Lapse in Years, BA to PhD*

	1958			1959			1961		
Years	*N*	%	Cum. %	*N*	%	Cum. %	*N*	%	Cum. %
0–2	0	—	—	0	—	—	2	0.3	0.3
3	6	1.2	1.2	7	1.5	1.5	11	1.9	2.2
4	54	10.8	12.0	41	9.0	10.5	49	8.3	10.5
5	98	19.6	31.6	77	17.0	27.5	106	18.0	28.5
6	84	16.8	48.4	79	17.4	44.9	100	17.0	45.5
7–8	120	24.0	72.4	104	22.9	67.8	133	22.5	68.0
9–10	74	14.8	87.2	81	17.8	85.6	85	14.4	82.4
11–12	25	5.0	92.2	30	6.6	92.2	57	9.7	92.1
13–14	12	2.4	94.6	13	2.9	95.1	24	4.1	96.2
15–16	12	2.4	97.0	13	2.9	98.0	8	1.4	97.6
17–18	8	1.6	98.6	3	0.7	98.7	5	0.8	98.4
19–20	3	0.6	99.2	4	0.9	99.6	5	0.8	99.2
21+	4	0.8	100.0	2	0.4	100.0	5	0.8	100.0
Total	500	100.0		454	100.0		590	100.0	
Mean	7.51			7.69			7.74		

B. Years of Predoctoral Professional Experience*

	1958			1959			1961		
Years	*N*	%	Cum. %	*N*	%	Cum. %	*N*	%	Cum. %
0	50	9.9	9.9	53	11.6	11.6	64	11.3	11.3
Less than 1	74	14.6	24.5	74	16.3	27.9	99	17.5	28.8
1–1.9	94	18.6	43.1	66	14.5	42.4	85	15.1	43.9
2–2.9	61	12.1	55.2	75	16.5	58.9	73	12.9	56.8
3–3.9	55	10.9	66.1	38	8.3	67.2	64	11.3	68.1
4–5.9	44	8.7	74.8	59	13.0	80.2	78	13.8	81.9
6–7.9	33	6.5	81.3	28	6.2	86.4	45	8.0	89.9
8–9.9	14	2.8	84.1	20	4.4	90.8	20	3.5	93.4
10–14.9	19	3.8	87.9	12	2.6	93.4	28	5.0	98.4
15+	61	12.1	100.0	30	6.6	100.0	9	1.6	100.0
Total	505	100.0		455	100.0		565	100.0	
Mean	4.68			3.92			3.46		

*The "Unknown" category has been eliminated; therefore the totals do not agree with those of other tables.

the whole population, and the segment of the group upon which any program at the undergraduate or graduate levels would have the greatest effect. There is a sharp contrast in marriage rate between this group and others. Among noncitizens, (approximately 15% of the total) and among women (2% or 3%) whether citizens or not, the marriage rate is about 50%. Among the male US citizens, it is half again as high, varying from 71.5% in 1958 to 76% in 1961 (the increase may not be statistically significant). For those who are married, age at doctorate is 30.7 years for the 1961 PhD's while for the bachelors it is 29.1 years. Of the married men, 29% are beyond age 31, while only 14% of the bachelors are that old. Almost half of the bachelors (43%) are under 28 when they attain the doctorate; only 26% of the married men are that young. About two out of three of the married men have children; 40% have two or more children prior to the doctorate. No data are presently available regarding time trends in number of dependents; it seems improbable that there has been any significant change over the four years we are concerned with here. It is quite apparent that there is a relationship between age at doctorate and number of dependents. Whether the relationship is causal—or in the direction of causality—cannot be determined from these data alone.

A matter of general interest to physicists is the kind of jobs they enter upon completing the doctorate. A limited amount of information on this question is afforded by the Doctorate Survey. Table 7 gives the plans and prospects for employment for these graduates as of the time they complete their Doctorate Survey forms—typically just before graduation. Data are available for four years, 1958 through 1961. Part A of Table 7 tabulates the answers to the request "Indicate

Table 7. Plans and Prospects For Professional Future Physics Doctorates of 1958–1961

A. Category of Plans

	1958		1959		1960		1961	
	N	%	*N*	%	*N*	%	*N*	%
Am seeking employment	30	*5.9*	26	*5.7*	36	*6.3*	41	*6.8*
Am negotiating with specific employer(s)	45	*8.9*	50	*11.0*	56	*9.9*	55	*9.1*
Have made definite commitment (other than categories below)	278	*55.1*	268	*58.9*	316	*55.7*	278	*46.2*
Returning to predoct. employment	70	*13.9*	51	*11.2*	77	*13.6*	85	*14.1*
Military service—active duty	3	*0.6*	6	*1.3*	10	*1.8*	23	*3.8*
Plan further study	43	*8.5*	36	*7.9*	64	*11.3*	98	*16.3*
Other, and no data available	36	*7.1*	18	*4.0*	8	*1.4*	22	*3.7*
Total	505	*100.0*	455	*100.0*	567	*100.0*	602	*100.0*

B. Employer Categories, For Those With Definite Job Commitments*

	1958		1959		1960		1961	
	N	%	*N*	%	*N*	%	*N*	%
US college or university	167	*48.0*	167	*52.3*	193	*49.0*	184	*50.8*
Other educational institution	5	*1.4*	4	*1.3*	1	*0.3*	2	*0.6*
US government, federal civilian employee	35	*10.0*	38	*11.9*	34	*8.6*	33	*9.1*
Foreign, governmental or private	4	*1.2*	3	*0.9*	16	*4.0*	20	*5.5*
US state, local, or other government	1	*0.3*	1	*0.3*	1	*0.3*	3	*0.8*
Nonprofit organization (other than above)	15	*4.3*	15	*4.7*	16	*4.0*	23	*6.3*
Industry or business	114	*32.8*	87	*27.3*	131	*33.2*	97	*26.6*
Self-employed	2	*0.6*	0	*0*	1	*0.3*	0	*0*
Other	5	*1.4*	4	*1.3*	1	*0.3*	1	*0.3*
Total	348	*100.0*	319	*100.0*	394	*100.0*	363	*100.0*

* Categories 2 and 3 from Part A.

your prospects and arrangements for your professional future (please check only one)". It is apparent that the vast majority have made definite commitments prior to graduation; only about one in fifteen is still seeking an opening at the time the questionnaires are filled out. The most significant time trend in the resulting data is the increase over these four years in the percentage planning further study. It has approximately doubled, from 8.5% in 1958 to 16.3% in 1961. Possibly significant also, in spite of the small numbers involved, is the increase in those going into military service. The drop in 1961 in those indicating a definite commitment is probably not significant, as the data here do not include the "laggard" returns, as they do for previous years; when such delayed responses are in, the percentage with definite commitments usually rises slightly.

The employers of these doctorate-holders are indicated in Part B of Table 7 for those people who indicated definite job commitments—either a contract signed with a new employer or a return to predoctoral employment. No time trend is apparent in these data; approximately half will be in colleges or universities, and industry will absorb most of the remainder—between a fourth and a third of the total. The United States government typically recruits about one in ten, with about the same number going to all other categories of employers.

As is almost inevitable with data regarding education and employment, the information of these tables is incomplete. Important questions remain unanswered; many of them cannot be answered by recourse to questionnaires such as that of the Doctorate Survey. Some information will be afforded in the future by questions included in the Survey in late 1961 and by others added in 1962, such as an indication of employment status in the year immediately preceding the doctorate, and information on functions to be performed in the immediate postdoctoral job. A collation of the data from the Doctorate Survey with other information relating to fellowships held should also, in the future, provide useful information. Other studies, done quite independently and relating to the sources of support for graduate students, will help to clarify some of the unanswered questions regarding the long and possibly lengthening time lag between the BA and PhD degrees. An examination by the physicists themselves, however, of the nature of the doctorate training, and perhaps undergraduate education as well, is needed in order to answer some of the questions only touched upon by the present report.