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Physics Research in India: A Study of Institutional Performance based on Publications Output

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ABSTRACT

The study examines the broad characteristics of India's physics publications output, its subject areas of strength and also the extent to which country's research pursuits have technological orientation. The study is based on contributions by Indian institutions and scientists as indexed in *INPSEC*-Physics 1998. The study finds that India's physics-related contribution is significantly high (86 per cent) in Science Citation Index (SCI)-covered journals, of which 26.4 per cent was in high-impact journals (IF = 1.5). Its contributions in condensed matter physics and materials science are significantly strong and also have technological orientation. The study also shows that there are wide differences in the quantity and quality of publications output across various broad and narrow subject fields under physics. The physics research activity is led by a select number of institutions in the country. Out of 435 institutions participating in physics research, just 20 had accounted for 50 per cent of the total output. The academic sector, being the biggest of all the sectors in terms of participating institutions, made the largest contributions to the physics output, followed by R&D sector, industrial sector, and government sector. However, the share of academic sector in high-impact journals was at second rank; the R&D sector topping the list. R&D sector also exceeds all other sectors in terms of publication output per institution.

Keywords: Physics, physics industry, physics research, institutional performance

1. INTRODUCTION

Physics is known to have made severall contributions to the economy of many nations. It has been harbinger of the change, but it has failed, till date, to get the acknowledgement it deserves for its role and contributions. This might be because physics has never been instrumental in bringing about any industrial activity directly or in generating any industry on its own. There is no industry like 'physics industry' in the economy of any nation. Physics has always served as a bridge between knowledge creation and wealth generation, particularly in high-tech industry. The explosive growth of information technology (IT), microelectronics, and telecommunications has its roots in condensed matter physics, materials physics, semiconductor physics, and fibre optics. The knowledge of physics has been instrumental in the development of enabling technologies for IT hardware, information processing, information transmission, and storage. The semiconductor industry, effectively utilises the knowledge of solid-state physics, chemical physics, plasma physics, materials physics for several applications. Many other industries are equally dependent on the developments in physics[1-2].

By utilising knowledge in physics, some industries have been able to make landmark contributions to the national economy of the country, influencing especially its prosperity and human life in meeting its needs. For example, condensed matter physics finds applications in medicine (x-rays, MRI), shelter (composites in construction materials), security (weapon systems), entertainment (films, radio, television-flat panel display), communications (pervasive-transistor, integrated circuits, lasers, fibres), transportation (smart cars, levitating trains, supersonic aircraft), and energy (solar cells and fuel cells)[1-2].

Physicists continue to apply physics knowledge in other areas for studies on technological developments. For example physics has been applied in biology and medicine for exploring the properties of DNA, understanding the way proteins are configured, and making improvements in medical imaging (imaging lungs using laser-polarised noble gases)[1-2].

1.1 Physics Research in India

India has more than a century old tradition of creating and nurturing physics at the highest level. The country has produced physicists of world fame known for their landmark contributions. Over the years, it has been able to establish and enrich its academic and research institutions, their infrastructural and research facilities, computing and network facilities, put up a strong teaching and research community and establish national and international linkages[3].

This has been possible because physics research in India is basically an institutional activity, pursued countrywide with funding coming from several sectors including academic, R&D, government, and industry. The academic sector constitutes universities, institutions of higher learning, and colleges. The R&D sector includes scientific agencies/departments and its constituents including Department of Science and Technology (DST), Department of Atomic Energy (DAE), Council of Scientific and Industrial Research (CSIR), Department of Space (DoS), Defence Research and Development Organisation (DRDO), Department of Electronics (DoE), Department of Ocean Development (DOD), and Department of Biotechnology (DBT).

These scientific agencies/departments though survive on government funds, but they are autonomous by character. The government sector includes several ministries/departments under the state/central government such as Ministry of Information Technology, Ministry of Non-Conventional Energy Resources, etc., and research organisations under them. The industrial sector includes private and public undertakings. By far, the organisations/ institutions belonging to academic and R&D sectors have been contributing the largest share (90 per cent or more) to the country's total output in physics. The remaining 10 per cent share is contributed by organisations under government sector, industrial sector, and others including private, non-profit and international organisations.

There are nearly 435 physics-based research institutions in country employing more than 5000 PhDs and several thousands Masters' engaged in research programmes in the major areas of physics. A large number of universities are engaged in postgraduate teaching and research and doctoral programme. As a result, around 700 PhDs are awarded each year in physics. India also has bilateral and multilateral programmes in S&T with several different countries including the USA, France, Russia, Germany, China, the European Union, and the CIS countries. India also has collaboration programmes with UN agencies like UNESCO, UNDP, etc. Many of these collaborative programmes are focusing on different aspects of physics research.

Even though physics institutions are spread throughout India, but research activity in physics is confined mainly to select few institutions only in the country. These institutions are regarded as R&D leaders in this area. Characteristically, these institutions are relatively better placed as they possess highly qualified and skilled manpower; endowed with strong network linkages, command superior research and technical infrastructure and the state-of-the-art research facilities.

These institutions are known to corner major share of R&D funds given by Government of India to support physics research in the country. This is evident from the extramural funding data for 1998-99: The Indian Institute of Science, Bangalore, received 11 research projects with a funding of Rs 430.29 lakh. It was followed by National Aerospace Laboratories, Bangalore (10 projects, Rs 58.30 lakh); IIT, Kanpur (7 projects, Rs 86.61 lakh); IIT, Delhi (6 projects, Rs 61.31 lakh); IIT, Mumbai (6 projects, Rs 26.11 lakh); National Physical Laboratory, Delhi (5 projects, Rs 27.65 lakh); Jadvapur University, Kolkata (4 projects, Rs 18.07 lakh); Roorkee University (3 projects, Rs13.07 lakh); Pune University (3 projects, Rs 17.45 lakh); Osmania University, Hyderabad (3 projects, Rs 23.92 lakh); Jawaharlal Nehru University, Delhi (3 projects, Rs 12.08 lakh); IIT, Kharagpur (3 projects, Rs 14.99 lakh); Delhi University (3 projects, Rs 31.17 lakh); and Cochin University of S&T (3 projects, Rs 21.95 lakh)[4].

The scientific academies of the country namely Indian Academy of the Sciences, Bangalore, Indian National Science Academy, Delhi, and the National Academy of Sciences, Allahabad also play significant role in catalysing and promoting physics research. They are known for organising seminars, conferences, discussions and dissemination of information through research journals. In addition, there are several other associations/societies created exclusively for serving the cause of physics in the country. These include Indian Physics Association, Indian Physical Society, Optical Society of India, Indian Vacuum Society, Ultrasonic Society of India, Acoustical Society of India, Metrology Society of India, and Materials Research Society of India. Indian Physics Association also actively celebrated in 2005 International Year of the Physics in India, by organising several activities by promoting physics education and research at various levels and its utilisation in industry. India publishes nearly 50 journals in physics and physics related areas, brought out by academic/professional societies, research and academic organisations, and private publishers.

The funding support pursuit is regulated directly by scientific agencies/departments. These agencies/departments also sponsor research as well as offer extramural funding in the higher education system including universities and colleges, deemed universities, and institutes of national importance. The extramural funding is also provided even to national laboratories. Besides, funds are provided for collaborative research under the bilateral, regional or multilateral programme.

During 1998-99, the R&D funding agencies/ departments funded 199 projects in physical sciences. The Department of Science & Technology funded 60 projects with an allocation of Rs 1168.88 lakh. It was followed by the University Grants Commission with 57 projects (Rs 25.39 lakh); Defence Research & Development Organisation, 30 project (Rs 199.56 lakh); Department of Atomic Energy, 21 projects (Rs 2234.55 lakh); Council of Scientific and Industrial Research, 20 projects (Rs 142.73 lakh); Indian Space Research Organisation, six projects (Rs 25.39 lakh); All India Council of Technical Education, four projects (Rs 37.19 lakh); and Department of Ocean Development, one project (Rs 6.90 lakh)[4].

Evidently India commands a strong infrastructural base for physics research. Its R&D institutions are well equipped to lead India in physics research, in developing physics-based technologies directed at economic development of the country and at influencing the quality of human life. In this paper, publications output of India has been studied at the institutional level with a view to map India's contributions to physics, its areas of strength and weakness in physics research, and their technological orientation.

2. METHODOLOGY

The study is based on India's contributions in physics as indexed in INSPEC–Physics database for the year 1998. INSPEC is published by the Institution of Electrical Engineers (IEE), UK. It is the most comprehensive and leading bibliographic database providing access to the world's S&T literature in physics, electrical engineering, electronics, communications, control engineering, computers and computing, and information technology. Over 3500 S&T journals and some 1500 conference proceedings, and numerous other publications are scanned each year by IEE for inclusion in the database.

The database now contains over seven million bibliographic records. It is growing at the rate of 350000 records per year. This database has four sections: Section A: Physics; Section B: Electrical & Electronics Engineering; Section C: Computers and Control; and Section D: Information Technology. The INSPEC–Physics database classifies physics literature under 10 main subject fields and 60 sub-fields (*Appendix I*). For studying the impact of physics papers, impact factor (IF) data of the reporting journals were used.

The data on IF were taken from Journal Citation Reports (JCR) brought by Institute for Scientific Information. India contributed more than 25 per cent papers in journals having IF =1.5 in 1998. I

India's contributions were categorised into three groups: (i) high impact-those published in journals having IF =1.5, (ii) medium impact-those published in journals having IF = 0.5 and < 1.5, and (iii) low impact-those published in journals having IF = 0.5.

3. RESULTS

3.1 Broad Characteristics of Publications Output in Physics

3.1.1 Publications Size

The world output in physics has shown positive growth in publications during 1990-1998. As reflected in the INSPEC-database the world output in physics was 156367 papers in 1990, 158220 in 1994, and 193251 in 1998. The publications output posted 1.19 per cent growth between 1990 and 1994, and 22.14 per cent between 1994 and 1998. Contrary to the world trend, India's publications output in physics posted negative growth during the same periods. India published 4552 papers in 1990, 4211 in 1994, and 4480 in 1998, respectively. India's world share in physics output was also on the declining curve: contributing 2.91 per cent in 1990, 2.66 per cent in 1994, and 2.32 per cent in 1998. Evidently, India's publications output did not keep pace with the growth in the world output in physics, rather it showed negative growth during 1990-1998. It is indeed a matter for concern and serious debate.

3.1.2 Pattern of Communication

Of the 4480 contributions in physics made by Indian authors, 4183 were in journals (93 per cent) and 297 in conference proceedings (7 per cent). The 'journals' seem to be the preferred channel of communication of Indian authors. Indian papers were published in 516 journals: 485 foreign journals (83.6 per cent), and 31 local Indian journals (16.4 per cent). The countrywise breakup of foreign journals was: USA (143); UK (140); the Netherlands (74); Germany (29); Switzerland (27); and other foreign countries (72).

Of the 4,183 contributions in 516 journals, 3618 (86 per cent) were in SCI-covered journals (having impact factor in the range of 0.012~28.933) and the remaining 565 (14 per cent) in non-SCI-covered journals. Of the 3,618 papers in the SCI-covered journals: (i) 26.4 per cent were published in high impact factor journals (IF = 1.5), (ii) 47.1 per cent in medium impact factor journals (IF = 0.5 and < 1.5), and (ii) the remaining 26.4 per cent in low impact journals (IF < 0.5). Out of 516 journals covered, only 31 were from India. Among these 31 Indian journals, only 15 were covered by the JCR; their impact factor was between 0.056 and 0.515; depicting low value journal impact (Table 1). India's publication profile in foreign journals form USA, UK, the Netherlands, Switzerland, and Germany is as follows:

- USA: 24 per cent publications were in 143 journals. Of these, 105 journals had the IF range as 0.115 ~ 1.499, and 38 had IF range as 1.5 ~ 13.439.
- UK: 19 per cent publications were in 140 journals. Of these, 109 journals had the IF range as 0.012 ~ 1.499, 18 had IF range as 1.5 ~ 28.933, and 13 were non SCI-covered journals.
- The Netherlands: 16 per cent publications were in 74 journals. Of these, 52 journals had the IF range as 0.139 ~ 1.499, 15 had the IF range as 1.5~5.631, and 7 were non SCI-covered journals.
- Switzerland: Eight per cent publications were in 27 journals. Of these, 20 journals had the IF range as 0.160 ~ 1.499, and only 1 had the IF as 1.503, and 6 were non SCI-covered journals.
- Germany: 4 per cent publications were in 29 journals. Of these 22 journals had the IF range as 0.107 ~ 1.423, and 7 had the IF range as 1.5 ~ 3.295.

3.1.3 Publication Productivity Pattern

In all, 435 research institutions across the country contributed to physics research in 1998. Of these, 20 institutions account for 50 per cent of the total publications output by India, 55 for 75 per cent output, and 94 for 85 per cent output. The size of their contributions varied widely from 1 paper to 272 papers per institution. Based on their contributions per paper, the 435 institutions were categorized in three groups (Table 2 and Fig. 1).

3.1.4 Geographic Spread of Physics Research

Geographically, the physics research activity is spread across 26 Indian states and union territories. However, publications output is not evenly distributed across the states. It comparatively high in 11 states per state contribution ranging from 109 to 769 papers. Collectively these 11 states account 92 per cent share to the country output in physics in 1998. The research activity in eight states was of medium level per state contribution ranging between 22 and 61 papers. Together

Table 1. Top 10 Indian journals reporting Indian output in physics

Journal	Impact factor	Publications	Per cent share in the country's output
Indian Journal of Pure and Applied Physics	0.123	90	2.15
Pramana-Journal of Physics	0.284	66	1.58
Bulletin of Materials Science	0.287	64	1.53
Indian Journal of Physics, Part A	NSCI	59	1.41
Indian Journal of Physics, Part B	NSCI	49	1.17
Indian Journal of Marine Sciences	0.102	43	1.03
Indian Journal of Radio & Space Physics	NSCI	40	0.96
Current Science	0.515	33	0.79
Bulletin of the Astronomical Society of India	NSCI	26	0.62
Proceedings of the Indian Academy of Sciences, Earth and Planetary Sciences	0.136	23	0.55

NSCI = Not covered in the SCI

Table 2. Categorisation of research institutions by productivity per institution

Institution category	Range of contribution	Number of institutions	Publications per cent
High-productivity institutions	≥ 75 papers	15	43.1
Medium-productivity institutions	15 – 74 papers	48	34.0
Low- productivity institutions	>15 papers	372	22.9

these states account for seven per cent to the country output. In seven states, the research activity is of low level, per state contribution ranging between 2 and 12 papers and together

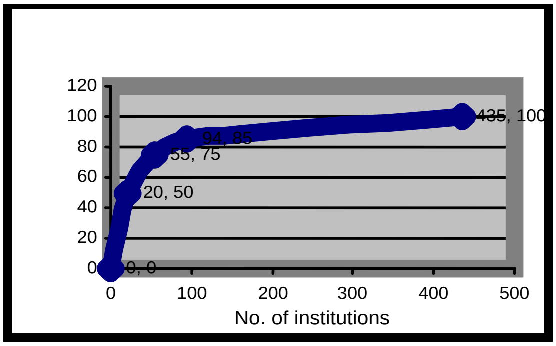

Figure 1. Productivity profile of institutions in physics in 1998.

these states account for just 1 per cent share (Table 3).

3.2 Mapping of India's Contributions by Main Subject fields in Physics

The publications output of Indian scientists in the 10 main fields of physics was grouped under three categories-high productivity fields, medium productivity fields, and low productivity fields-as depicted in Table 3. The country average impact of publications output in physics in 1998 was 1.032. At the subject level it varied from 0.622 to 2.155. The country share in high impact journals (IF=1.5) was 26.4 per cent and across the 10 main fields it ranged between 8.5 per cent and 52.9 per cent (Table 4).

The relative quality index (RQI) quantifies publication share in high impact journal relative to the country average. It highlights the fields in which India is publishing more high quality papers. These are: A1–the physics of elementary particles and fields is 2.0. It implies that impact of papers in this subject was twice that of the country average of 1, A5–fluids, plasmas and electric discharges (1.71), A3–atomic and molecular physics (1.45), A2–nuclear physics (1.4), A0–general physics (1.15), and A9–geophysics, astronomy and astrophysics (1.04).

Interestingly, these fields are not high productivity ones but have shown impact above the country average. It implies quality in such low productivity fields is indeed very high. The specific sub-fields of physics which have contributed to high performance are: A05-statistical physics (91; 1.769); A11–fields and particles theory (52;1.925); A12–particle theories and interaction models (45;1.985); A13–specific reactions and phenomena (52; 2.324); A21–nuclear structure (62;1.817); and A98–stellar systems (84;1.607). In addition two more sub-fields have done exceeding well in terms of impact, A47–fluid

Table 3. Geographical distribution of physics output by productivity range

State category	Range of contribution	States and union territories wise contribution of papers
High-productivity states	≥ 75 papers	Maharashtra (770), West Bengal (739), Karnataka (486), Delhi (431), Uttar Pradesh (408), Tamil Nadu (400), Andhra Pradesh (278), Madhya Pradesh (178), Gujarat (170), Kerala (149), and Orissa (109)
Medium-productivity states	15-74 papers	Assam (61), Chandigarh (52), Bihar (47), Rajasthan (41), Haryana (33), Goa (24), Punjab (24), Meghalaya (22)
Low-Productivity states	> 15 papers	Himachal Pradesh (12), J&K (10), Manipur (9), Pondicherry (8), Arunachal Pradesh (4), Sikkim (2), and Tripura (2)

Table 4. Publications output by subject, impact factor and share of publications in high impact factor journals

Category	Subject field code and name	Publications count	Average impact	Per cent share of high impact papers	Relative quality index
High-productivity subject fields > 500 papers	A6–Condensed matter: structure, thermal and mechanical properties	629	1.002	19.7	0.75
	A7–Condensed matter: electronic structure, electrical, magnetic, and optical properties	896	1.055	22.8	0.86
	A8–Cross-disciplinary physics and related areas of science and technology	807	1.055	9.2	0.35
	A9–Geophysics, astronomy and astrophysics	565	1.089	27.4	1.04
Medium-productivity subject fields 200 - 499 papers	A4–Classical areas of phenomenology	489	0.622	8.5	0.32
	A0–General	331	1.260	30.4	1.15
	A2–Nuclear physics	256	1.327	36.9	1.40
	A3–Atomic and molecular physics	229	1.327	38.4	1.45
Low-productivity subject fields < 200 papers	A1–The physics of elementary particles and fields	149	2.155	52.9	2.00
	A5–Fluids, plasmas and electric discharges	129	1.275	45.2	1.71
	The country average		1.032	26.4	1.0

dynamics (49;1.723); A71–electron states (58;1.508) (Table 5; *Appendix I*). The publications output in A6–condensed matter: structure, thermal and mechanical properties, A7-condensed matter: electronic structure, electrical, magnetic, and optical properties, and A8-cross-disciplinary physics each was more than 500 papers. It was well country average per field (361.8 papers). In A2-nuclear physics the publications output was though of medium range but it published 40 per cent more papers than the country average in high impact journals. These four physics fields possess high potential for technological applications. Given their publications output accounting for 57.7 per cent country share and their RQI, it can be inferred that physics research activity in these four subject fields is indeed very strong.

3.3 Mapping of Contributions by Different Sectors

The academic sector dominates in publications output contributing 60 per cent share to the country output, followed by R&D sector contributing 37 per cent share, followed by industrial sector (2.1 per cent share) and government sector (0.9 per cent share). The productivity per institution is highest (29.2 papers) for the R&D sector, followed by academic sector (8.95 papers per institution), government sector (2 papers per institution) and industrial sector (1.88 papers per institution). The quality index of the R&D sector is 45 per cent greater than the country average. The quality index on academic sector ranked second, followed by industrial sector, and government (Table 6).

3.3.1 Academic Sector

The 300 institutions under this sector comprised 108 universities, 10 institutions of higher learning (IHL), and 182 colleges. The university segment contributed 56 per cent of its papers in SCI journals, followed by IHL (22 per cent) and colleges (8 per cent). The contribution (papers) in high impact journals was the maximum by universities (23 per cent of its total SCI papers), followed by IHL (18 per cent) and colleges (15 per cent). The average output per institution was highest from IHL (66.2 papers) followed by universities (15.74 papers), and colleges (1.62 papers). The leading Indian institutions under academic sector are given in Table 7 along with their individual output and IF values.

Table 5. Distribution of publications output at sub-field level

Category	Low impact (IF Below 0.5)	Moderate impact (IF 0.5 –1.499)	High impact (IF 1.5 and more)
Low-productivity (21–99 papers)	A01 (25, 0.054) A28 (61, 0.346) A37 (37, 0.499) A46 (87, 0.387)	A03 (83, 1.255) A07 (65, 0.566) A25 (82, 1.294) A29 (34, 0.566) A31 (46, 1.438) A32 (24, 1.488) A33 (87, 1.088) A34 (50, 1.307) A43 (43, 0.541) A62 (83, 0.929) A64 (82, 1.203) A65 (31, 0.929) A66 (43, 1.112) A76 (47, 1.027) A77 (91, 0.541) A82 (96, 0.107) A91 (79, 0.917) A94 (84, 0.929) A95 (33, 0.917) A96 (57, 1.374) A97 (64, 1.474)	A05 (91, 1.769) A11 (52, 1.925) A12 (45, 1.985) A13 (52, 2.324) A21 (62, 1.817) A49 (49, 1.723) A71 (58, 1.508) A98 (84, 1.607)
Medium-productivity (100–149 papers)	A86 (120,0.305)	A52 (127, 1.136) A68 (149, 0.935) A72 (139, 1.028) A73 (132, 0.806) A75 (106, 1.042) A87 (112, 0.683) A74 (128, 1.153) A92 (127, 0.883)	
High-productivity (150–499 papers)		A42 (188, 0.742) A47 (160, 0.546) A61 (214, 0.954) A78 (170, 0.814) A81 (479, 0.600)	

(i) Fields which have contributed 20 and more papers were included in the table
(ii) Figures in parentheses are publication output in the sub-field and its average impact

The major areas of research pursued in leading institutions along with their publications output and IF values are given in Table 8.

3.3.2 R&D Sector

The 63 institutions under R&D sector comprised of the following scientific agencies: Department of Atomic Energy (DAE) had participation from nine institutions; Department of Science & Technology (DST) 11 institutions; Council of Scientific & Industrial Research (CSIR) 22 institutions; Department of Space (DoS) seven institutions; Defence Research & Development Organization (DRDO) 12 institutions; Department of Electronics (DoE) one institution; and Indian Council of Agricultural Research (ICAR) one institution. Under the R&D sector, DoS contributed 90 per cent of its papers in SCI–covered journals, followed by DAE (84 per cent), CSIR (81 per cent), DST (78 per cent), and DRDO (65 per cent). However, the contribution to high impact papers was maximum by DAE (42 per cent of its SCI papers), followed by DST (41 per cent), DoS (34 per cent), DRDO (18 per cent) and

Table 6. Sector-wise publications output in physics

Sector	No. of institutions	Publications						
		Total*	Per institution	In journals	In confer. proceedings	In SCI-journals*	In high IF journals*	Relative quality index
Academic	300	2686 (60)	8.95	2538	148	2172 (86)	463 (18.2)	0.85
R&D	63	1656 (37)	26.27	1522	134	1344 (88.3)	472 (31.0)	1.45
Government	21	42 (0.9)	2.0	38	4	27 (63)	5 (13.1)	0.61
Industrial	51	96 (2.1)	1.88	85	11	75 (88.2)	15 (17.6)	0.82
All India	435	4480	10.3	4183	297	3618	955 (21.3)	1.00

** Figures in parentheses denote percentages*

Table 7. Leading institutions in physics in India in 1998

Institution	Output	IF
Indian Institute of Science, Bangalore	272	1.229
Indian Institute of Technology, Madras, Chennai	150	0.709
Indian Institute of Technology Delhi, New Delhi	140	0.745
Indian Institute of Technology, Kanpur	137	0.936
Indian Institute of Technology, Kharagpur	107	0.706
Banaras Hindu University, Varanasi	106	0.802
Indian Institute of Technology, Mumbai	101	0.870
Jadavpur University, Kolkata	77	1.066
Delhi University, Delhi	70	0.908
Poona University, Pune	58	1.409
Calcutta University, Kolkata	56	0.798
Hyderabad University, Hyderabad	49	1.278
Punjab University, Chandigarh	47	1.666
Shivaji University, Kolhapur	43	0.367
Anna University, Chennai	42	0.581

Table 8. Major areas of focus under leading academic institutions

Main Field of Physics	Output	Av. IF
A8–'Cross-disciplinary physics',	317	0.619
A7–'Condensed matter: electronic structure …. ',	311	1.050
A4–'Classical areas of phenomenology'.	220	0.611
A6–'Condensed matter: structure ……..',	201	1.198
A9–'Geophysics, astronomy, astrophysics',	131	0.937

CSIR (18 per cent). The DAE reported the highest average output per institution (84.2 papers), followed by DST (33 papers), DoS (19.3 papers), CSIR (13.8 papers), and DRDO (10.6 papers). The leading institutions under each agency were identified along with the subject fields in which they had contributed significantly [Table 9 (a-f)]. Of the remaining scientific agencies, Physical Research Laboratory, Ahmedabad (76 papers and IF = 1.835), and Vikram Sarabhai Space Research Centre (VSSRC), Trivandrum (31 papers and

Table 9 (a). Leading institutions under department of atomic energy

Institution	Output	Av. IF
Bhabha Atomic Research Centre, Mumbai	169	1.146
Tata Institute of Fundamental Research, Mumbai	151	1.884
Saha Institute of Nuclear Physics, Kolkata	104	1.597
Indira Gandhi Centre for Atomic Research, Kalpakkam	95	0.839
Centre for Advanced Technology, Indore	74	0.866
Institute of Physics, Bhubaneshwar	64	1.639

Table 9 (b). Major areas of focus under DAE

Main field of physics	Output	Av. IF
A7–'Condensed matter: electronic structure…… properties',	137	1.298
A2–'Nuclear physics',	95	1.146
A8–'Cross-disciplinary physics',	87	0.794
A6–'Condensed matter: structure … properties',	86	1.419
A0–'General physics'.	60	1.528
A3–'Atomic and molecular physics',	55	1.513
A1–'Elementary and particle physics',	45	2.483
A9–'Geophysics, astronomy, astrophysics',	44	1.693

Table 9 (c). Leading institutions under DST

Institution	Output	Av. IF
Indian Association for Cultivation of Science, Kolkata	150	1.120
Indian Institute of Astrophysics, Bangalore	51	1.234
Institute for Plasma Research, Gandhi Nagar	33	0.705
Raman Research Institute, Bangalore	33	1.682

Table 9 (d). Major areas of focus under DST

Main field of physics	Output	Av. IF
A9–'Geophysics, astronomy, astrophysics',	59	1.148
A7–'Condensed matter: electronic structure … ',	52	1.436
A6–'Condensed matter: structure ……… ',	38	1.246
A3–'Atomic and molecular physics',	27	1.473
A8–'Cross-disciplinary physics'.	23	0.971

Table 9 (e). Leading institutions under CSIR

Institution	Output	Av. IF
National Physical Laboratory, Delhi	96	0.546
National Chemical Laboratory, Pune	30	1.193
National Geophysical Research Institute, Hyderabad	28	0.923
Regional Research Laboratory, Bhopal	28	0.532
National Institute of Oceanography, Panjim, Goa	20	2.181.

Table 9 (f). Major areas of focus under CSIR

Main field of physics	Output	Av. IF
A9–'Geophysics, astronomy, astrophysics',	69	1.223
A8–'Cross-disciplinary physics',	61	0.497
A7–'Condensed matter: electronic structure……..',	28	0.938
A6–'Condensed matter: structure .. '.	24	0.762

IF = 0.907) were the leading institutions under Department of Space (DoS) contributing in A9–'geophysics, astrophysics, astronomy', and A4–'classical areas of phenomenology'. Defence Metallurgical Research Laboratory (DMRL), Hyderabad (55 papers and IF = 1.084) and Solid State Physics Laboratory (SSPL), Delhi (44 papers and IF = 0.168) were the leading institutions under the DRDO contributing in A7–'condensed matter: electronic structure … ', and A8–'cross-disciplinary physics'.

3.3.3 Government Sector

The 21 institutions under government sector 17 under central government, and 4 under state government) participated in physics research. Their contributions were 65 per cent and 35 per cent, respectively. The central government institutions published 85.71 per cent of their papers in the SCI–covered journals, of which 22.2 per cent were in high impact journals. The state government institutions published 50 per cent of their papers in the SCI-covered journals, of which 14.3 per cent in high impact journals. The average output per institution was higher for state government institutions (3.50 papers) than for central government institutions (1.53 papers).

3.3.4 Industrial Sector

The industrial sector comprising 51 institutions (35 under public sector and 16 under private sector) participated in physics research. Their contributions were 79.2 per cent and 20.8 per cent, respectively. The former published 90 per cent of its output in the SCI–covered journals, of which 23.81 per cent were in high impact journals. The latter published 46.7 per cent of its publications in the SCI–covered journals, but their contribution in high impact journals was negligible. The average output per institutions was higher by institutions under private sector (2.17 papers) than for public sector institutions (1.25 papers).

4. CONCLUSION

India still publishes 86 per cent of its physics output in low impact factor journals, and 26 per cent in high impact journals. Three condensed matter physics fields account for 52 per cent of the country output, the remaining seven physics fields for the 48 per cent output. Only 55 top institutions account for 75 per cent of the country output, and just eleven states account for 92 per cent of the country output. The academic sector and the R&D sector together account for 97 per cent of the country output. These facts demonstrate that physics research in the country is highly skewed in favour of select institutions, select sectors, select subject fields, and select states. India's high publication output in condensed matter physics fields, and nuclear physics, which together account for 57.7 per cent of the country output, does reflect that physics research in India has strong technological orientation.

India's high publication output quality index is low as they publish bulk of research output in low impact journals. Weaknesses of these sorts are common not only to industrial sector and government sector but even to academic sector as well. India's research base in physics, confined to just 435 institutions, is still too small given the geographical size of the country. It needs to be expanded. India needs to focus its attention also on medium ranking institutions across the country for encouraging research output both in terms of quantity and quality especially in physics areas having potential for industrial and societal applications.

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Physics Sub-fields

Sub-field Code	Sub-field Name
A 01	Communication, education, history and philosophy
A 02	Mathematical methods in physics mechanics and fields
A 03	Classical and quantum physics mechanics and fields
A 04	Relativity and gravitation
A 05	Statistical physical physics and thermodynamics
A 06	Measurement science, general laboratory techniques, and………
A 07	Specific instrumentation and techniques of general use in physics
A 11	General theory of fields and particles
A 12	Specific theories and interaction models particle systematics
A 13	Specific reactions and phenomenology
A 14	Properties of specific particles and resonance
A 21	Nuclear structure
A 23	Radioactivity and electromagnetic transactions
A 24	Nuclear reactions and scattering: general
A 25	Nuclear reactions and scattering: specific reactions
A 27	Properties of specific nuclei listed by mass ranges
A 28	Nuclear engineering and nuclear power studies
A 29	Experimental methods and instrumentation for elementary………
A 31	Theory of atoms and molecules
A 32	Atomic spectra and interactions with photons
A 33	Molecular spectra and interactions with photons
A 34	Atomic and molecular collision processes and interactions
A 35	Properties of atoms and molecules instruments and techniques
A 36	Studies of special atoms and molecules
A 41	Electricity and magnetism fields and charged particles
A 42	Optics
A 43	Acoustics
A 44	Heat flow, thermal and thermodynamic processes
A 46	Mechanics, elasticity, rheology
A 47	Fluid dynamics

Sub-field Code	Sub-field Name
A 51	Kinetic and theory of fluids physical properties of gases
A 52	The physics of plasmas and electric discharges
A 61	Structure of liquids and solids crystal …
A 62	Mechanical and acoustics properties of condensed matter
A 63	Lattice dynamics and crystal statistics
A 64	Equations of state, phase equilibria, and phase transitions
A 65	Thermal properties of condensed matter
A 66	Transport properties of condensed matter (non-electronic)
A 67	Quantum fluids and solids liquid and solid helium
A 68	Surfaces and interfaces thin films
A 71	Electron states
A 72	Electronic transport in condensed matter
A 73	Electronic structure and electrical properties of surfaces,
A 74	Superconductivity
A 75	Magnetic properties and materials
A 76	Magnetic properties and materials condensed matter mossbauer effect
A 77	Dielectric properties and materials
A 78	Optical properties and condensed matter spectroscopy and other…..
A 79	Electron and ion emission by liquids and solids impact phenomena
A 81	Materials science
A 82	Physical chemistry
A 86	Energy research and environmental sciences
A 87	Biophysics, medical physics, and biomedical engineering
A 91	Solid earth physics
A 92	Hydrospheric and lower atmospheric physics
A 93	Geophysical observations, instrumentation and techniques
A 94	Aeronomy, space physics, and cosmic rays
A 95	Fundamental astronomy and astrophysics instrumentation and……
A 96	Solar system
A 97	Stars
A 98	Stellar systems galactic and extragalactic objects and systems