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SCIENTOMETRIC ANALYSIS OF INDIAN PHYSICS LITERATURE DURING 2004-2018

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ABSTRACT

The paper deals with the Indian physics literature published in resources as reflected in Web of Science (WOS) during the period 2004-2018. The study analyses India's performance based on its publication output in physics, few Scientometric indices, such as the number of publications, number of citations, activity index, relative growth rate, doubling time, patterns of communication in national and international journals, are considered for portraying the different dimensions, Most prolific scientists and Institutions, and national & international collaboration from India were also considered. It was examined that during 2004-2018 there was a substantial increase in yearly output of Indian physics literature, compared to the global output ratio. The study reveals that the literature in the field of physics is gradually increasing and there is an upward trend, however there is some fluctuation in trends of publications with mean growth rate of 0.220 and average doubling time is 3.714. Among the subfields Materials Science has the largest number of publications amounting to 31.30% of the overall publications. Journal of Applied Physics has published highest number of papers i.e. 3097 with 12.5 average citations per paper. Among the Research Institutes, Indian Institute of Technology (IIT), Delhi, has published highest number of publications i.e. 19931 among the physics research institutes in India. However the publication trends indicates that there is greater scope for higher research in physics in India.

Key Words: Scientometrics, Physics, Web of Science, Relative Growth Rate, Doubling Time, Impact Factor and Activity Index.

1. INTRODUCTION

Physics is a pivotal and all inclusive of the sciences, and has had a comprehensive impact on all scientific and societal development. In fact, physics is the present day equivalent of what used to be called natural philosophy, from which most of our modern sciences arose. Physics represents the rational analysis and accounting of the world we live in. lt forms an essential part of human culture. Physics allows us to explore the world from the smallest to the largest objects (Sinatra, R 2015)[11]. The application of physics is responsible for most of the basis of modern society and civilization, Physics works on a global scale, dependent on the interaction of groups of physicists in different countries and regions. Developments in many areas, including medicine, transport, communications, information technology and even the arts, have benefited directly from physics discoveries, and its methods will be necessary to solve many problems including those of the environment (Takeda, G 2009)[12].

Therefore, the progress of research in physics will have a profound impact on the development of other disciplines leading to the progress of a nation and its economy. On the other hand, Scientometrics assessment is a key important aspect of research and development activity. One of the most prominent productivity indices is the number of publications contributed by the Authors, countries, and institutions. Scientometric studies help researchers, scientists, and policymakers to provide appropriate facilities and proper guidance by providing insight into different dimensions of research and development activities. Hence Scientometrics is a indispensable tool used to examine the quality and quantity of literature published across disciplines within a particular geographical area. In this paper, an attempt is made on the Scientometric analysis of physics literature published in India and the world during 2004-2018 from various dimensions.

2. OBJECTIVES

The major objectives of this study are to examine the research performance of India in physics research at the national and global context, as reflected in the web of science database during 2004-2018. In specific, the study defined the following objectives:

1. To study the growth of publications and doubling time;
2. To find out the source of publications, and impact factor;

3. To study most prolific authors in physics;
4. To study the Institution wise research productivity and International collaborations;
5. To study the country- wise collaborative sharing of publications
6. To identify the subject and discipline activity indicator of physics and sharing of publications among sub-domains; and
7. To find out the highly cited publications and the journals selected or approved by the authors.

3. METHODS AND MATERIALS USED

For this study the data was retrieved from the Web of Science (WOS) (www.isiknowledge.com) database which is maintained by Thomson Reuters (now Clarivate Analytics) provides an exhaustive citation search, by using keywords SU=Physics AND CU=India on physics for 15 years period i.e.2004-2018. For interpreting the data, MS-Excel and SPSS-Statistical software have been used. The Relative Growth Rate (RGR), Doubling Time (Dt) and Activity Index (AI) have been calculated.

3.1Relative Growth rate (GR): Relative Growth Rate is the growth rate relative to the size of the population. It is also called the exponential growth rate, or the continuous growth rate calculated from the following equation suggested by Mahapatra (1985)[8].

Relative Growth Rate (GR) is the increase in the number of publications per unit time. The formula for calculating the mean R

$$\mathbf{R = W2- W1/T2 – T1}$$

Where:

R = mean relative growth rate over the specific period of intervals;

W1 = Log W1 (natural log of initial number of publication);

W2 = Log W2 (natural log of final number of publication);

T2 – T1 = the unit difference between the initial and final time

3.2 Doubling Time (Dt.) The doubling time is the given period required for a quantity to double in size or value. This can be calculated, using the following formula calculated from the following equation suggested by Mahapatra (1985)[8].

Doubling time Dt = 0.693/R

3.3 Activity Index (AI)

In the present study, Activity Index (AI) for India has been calculated for various years to see how India's performance regularly changed during various years. For this, the author has used the Activity Index for the years 2004-2018.

The Activity Index (AI) characterizes the relative research effort of a country in the given subjects. It is defined as:

$$AI = \frac{\text{given field's share in the country' s publication output}}{\text{given field's share in the world's publication output}}$$

Mathematically

$$AI = \frac{nij/nio}{noj/noo} * 100$$

Where: nij - Indian output of papers in particular field

nio - Total Indian output on all subjects

noj - World output of papers in particular field

noo - Total World output on all subjects

4. DATA ANALYSIS AND INTERPRETATION

4.1 Growth of publications of world and India in Physics

Table 1 shows that global productivity in physics by the scientist is accounted for 1963841. The publications on physics gradually increased from 109210 to 1506160 with variations found during the period from 2004 to 2018. Indian scientist publications are increased from 3619 in 2004 to 10471 in 2018. Table 1 indicates the share of India is collaborating with the global level.

Table 1: Growth of publications of world and India in Physics

Year	World TP	India TP	%TP Share
2004	109210	3619	3.31
2005	113175	4026	3.56
2006	119501	4404	3.69

2007	121419	4778	3.94
2008	125890	5371	4.27
2009	124572	5569	4.47
2010	124173	5972	4.81
2011	131739	6214	4.72
2012	132806	6344	4.78
2013	138739	7155	5.16
2014	139300	7963	5.72
2015	142817	8378	5.87
2016	144050	8834	6.13
2017	145833	9634	6.61
2018	150616	10471	6.95
2004-2008	589195	22198	3.77
2009-2013	652029	31254	4.79
2014-2018	722616	45280	6.27
2004-2018	**1963840**	**98732**	**5.03**

Note: TP= Total Publications

4.2 Relative Growth Rate and Doubling time

Table 2 indicates that Relative Growth Rate (RGR) and Doubling Time (Dt.) in physics research publications are one of the major aspects of the discussion. Physics was found through the Web of Science (WOS) database fifteen years period (2004-2008).

Relative Growth Rate mean values for global and India is 0.066 and 0.220. In 2004 the physics research publication was 109210 and 3619, increase to 150616 and 10471 in the year 2018. Doubling Time mean values for global and India is 9.496 and 3.714. Assume for this table its authentication that doubling time of publications 10210 to 150616 and 3619 to 10471 publications in physics research in the fifteen years (2004-2018) period.

Table 2 World v/s India Relative Growth Rate (RGR) and Doubling Time (Dt.)

Year	World TP	RGR	Dt.(P)	India TP	RGR	Dt.(P)
2004	109210			3619		
2005	113175	0.099	7.027	4026	0.748	0.927
2006	119501	0.095	7.330	4404	0.455	1.523
2007	121419	0.088	7.902	4778	0.334	2.075
2008	125890	0.083	8.302	5371	0.277	2.502
2009	124572	0.076	9.087	5569	0.224	3.096
2010	124173	0.071	9.811	5972	0.195	3.557
2011	131739	0.070	9.920	6214	0.169	4.099
2012	132806	0.066	10.531	6344	0.147	4.702
2013	138739	0.064	10.759	7155	0.144	4.822
2014	139300	0.061	11.407	7963	0.139	4.990
2015	142817	0.059	11.811	8378	0.128	5.419
2016	144050	0.056	12.400	8834	0.119	5.815
2017	145833	0.054	12.937	9634	0.116	5.996
2018	150616	0.052	13.208	10471	0.112	6.181
Mean Value		**0.066**	**9.496**		**0.220**	**3.714**

Note: RGR=Relative Growth Rate, Dt.(P)= doubling Time

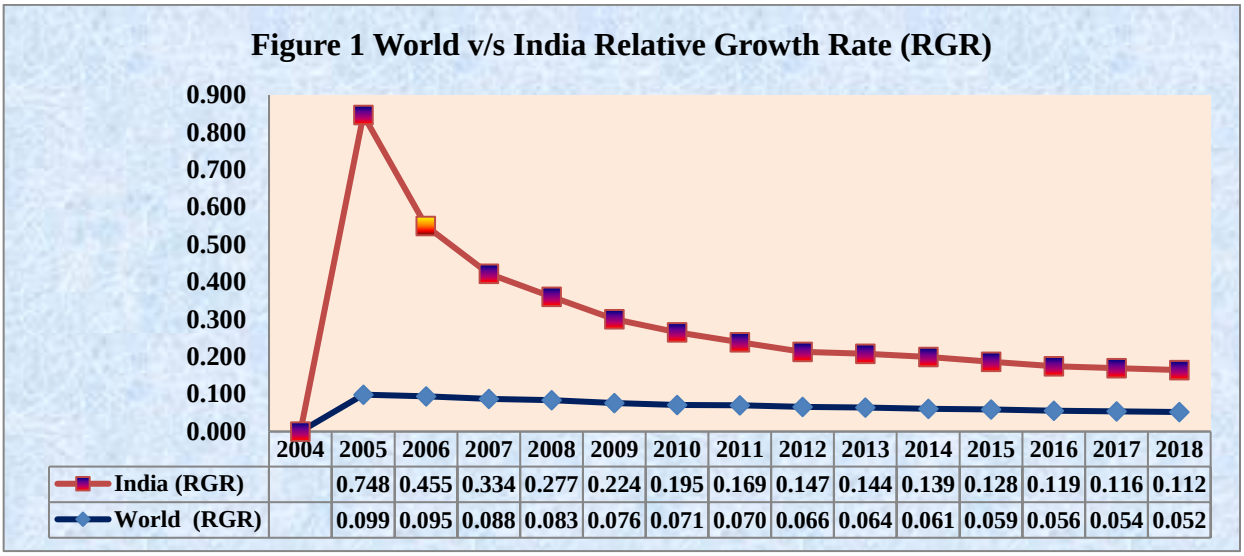


Figure 1 World v/s India Relative Growth Rate (RGR)

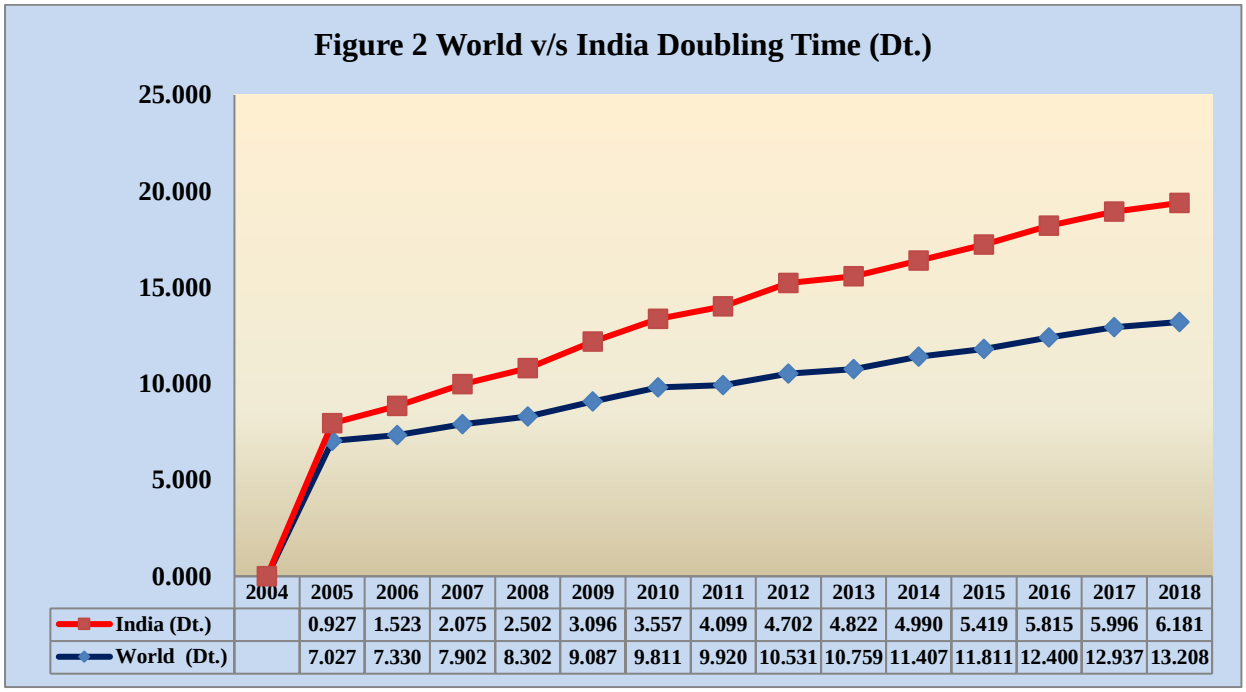


Figure 2 World v/s India Doubling Time (Dt.

4.3 Sub-fields of research priority in Physics research in India

Out of 20 sub-fields related, only five sub-fields verified an increase in their activities from 2004-2011 to 2012–2018. Out of 20 sub-fields of physics more than 25,000 publications are published in one domain is Materials Science, however, more than 15000 papers are published under the domain Chemistry, and among other three domains more than 5000 papers have been published under Engineering, Science Technology other subfields and Astronomy Astrophysics each and other subjects contributed 4000 and less than 3000 papers (Table 3) respectively.

As per the sub-fields cumulative output in Indian physics research during 2004-2018, the maximum research priority (i.e. 27,343 publications with 31.30% share) is contributed by Materials Science in India during 2004-2018, followed by Chemistry(i.e.17,910 publications with 20.50% share),Engineering (i.e. 9,354 publications with 10.71% share), Science and Technology other subfields(i.e.7857 publications with 9.00% share), Astronomy Astrophysics (i.e.5,673 publications with 6.49% share),Optics (i.e. 4,628 publications with 5.30% share), Instruments Instrumentation (i.e. 3,276 publications with 3.75% share),Nuclear Science Technology (i.e.2,290 publications with 2.62% share) and Mechanics (i.e.1,962 publications with 2.25% share) followed by others.

Table 3: Subjective distribution of Indian Contributions

Sl.No	Subject	No. of publications	%	Cumulative	Cum.%
1	Materials Science	27343	31.30	27343	31.30
2	Chemistry	17910	20.50	45253	51.81
3	Engineering	9354	10.71	54607	62.52
4	Science Technology other Topics	7857	9.00	62464	71.51
5	Astronomy Astrophysics	5673	6.49	68137	78.01
6	Optics	4628	5.30	72765	83.30
7	Instruments Instrumentation	3276	3.75	76041	87.06
8	Nuclear Science Technology	2290	2.62	78331	89.68
9	Mechanics	1962	2.25	80293	91.92
10	Mathematics	1630	1.87	81923	93.79
11	Crystallography	1073	1.23	82996	95.02
12	Polymer Science	872	1.00	83868	96.02
13	Electrochemistry	786	0.90	84654	96.92
14	Energy Fuels	622	0.71	85276	97.63
15	Thermodynamics	497	0.57	85773	98.20
16	Computer Science	492	0.56	86265	98.76
17	Metallurgy Metallurgical Engineering	416	0.48	86681	99.24
18	Spectroscopy	360	0.41	87041	99.65
19	Education Educational Research	172	0.20	87213	99.85
20	Biochemistry Molecular Biology	135	0.15	87348	100
	Total	**87348**	**100**		

4.4 Ranking of top 20 most preferred journals of Indian professional and their impact factor in physics.

Table 4 depicts that the total research output of the physics for the study period 2004-2018, in different journals. The impact factor for a journal is generally calculated on the basis of a 3 years period, and can be the average number of times published research papers are cited up to 2 years after publication. Impact factor of the physics journals are discussed in the table 4, based on the average citations per paper the journal has Physical Review Letters, published from USA (49.75), followed by Physical Review D, published from USA (19.34),

Physical Review C, USA (18.23), Physical Review B, USA (18.1), Applied Physics Letters, USA (17.28), Journal of High Energy Physics, (17.22) and Applied Surface Science, Netherlands (15.76).

The Journal Physical Review Letters published from the USA has highest impact factor (8.839), followed by Journal of High Energy Physics, published from Germany (5.541), Applied Surface Science, Netherlands (4.439), Physical Review D, USA (4.394), Physical Chemistry Chemical Physics, England (3.906), Physical Review B, USA (3.836) and Applied Physics Letters, USA (3.495).

Table 4: Ranking of top 20 most preferred journals of Indian professional and impact factor

Sl. No.	Source/Journal	Country	TP	TC	ACPP	Impact Factor
1	Journal of Applied Physics	USA	3097	38703	12.5	2.176
2	Physical Review D	USA	3007	58166	19.34	4.394
3	Journal of Materials Science Materials in Electronics	Germany	2581	12724	4.93	2.324
4	Physical Review B	USA	2372	42934	18.1	3.836
5	Pramana Journal of Physics	India	1921	7262	3.78	0.520
6	Journal of Molecular Liquids	Netherlands	1813	17696	9.76	3.929
7	Applied Surface Science	Netherlands	1804	28437	15.76	4.439
8	Physical Review E	USA	1780	19282	10.83	2.366
9	Applied Physics Letters	USA	1776	30691	17.28	3.495
10	Materials Letters	Netherlands	1735	26534	15.29	2.687
11	Physica B Condensed Matter	Netherlands	1682	18224	10.83	1.453
12	Indian Journal of Pure Applied Physics	India	1650	7938	4.81	0.582
13	Journal of Nanoscience and Nanotechnology	USA	1627	12971	7.97	1.354
14	Journal of Magnetism and Magnetic Materials	Netherlands	1604	20328	12.67	3.046
15	Physical Chemistry Chemical Physics	England	1560	18586	11.91	3.906
16	Journal of High Energy Physics	Germany	1556	26801	17.22	5.541
17	Physical Review C	USA	1522	27747	18.23	3.304
18	Physical Review Letters	USA	1464	72828	49.75	8.839
19	Indian Journal of Physics	India	1423	5069	3.56	0.988
20	Journal of Chemical Physics	USA	1380	18388	13.32	2.843

Note: TP= Total Publications, ACPP= Average Citations per Publications

4.5 Most Productive Authors in India in the field of physics

Table 5 shows highly productive authors based on number of publications, irrespective of disciplines during period of 2004-2018 appeared in web of science. The author Amit Kumar, of Shoolini University, Bajhol, Himachal Pradesh is the most productive author, he has the contributed 3097 publications and received 68695 citations, and 22.18 average citation per publication, followed by Satish Kumar, DRDO, Solid State Physics Laboratory, New Delhi, has published 2415 papers and received 33213 citations with 13.75 average citations per publication, Rohit Kumar, Indian Institutes of Science Education and Research, Pune Maharashtra, contributed

1964 publications and received 35987 citations with 35987 citations with 18.32 average citation per publication, and Subhajit Das Indian Institute Of Engineering Science And Technology (IIEST), Shibpur, West Bengal contributed 1886 publications and received 53240 citations followed by others.

Table 5: Highly Productive Authors in India in the field of physics

Sl. No.	Authors	Affiliation	No. of Publications	TC	ACP	H-Index
1	Kumar, Amit	Shoolini University, Bajhol, Himachal Pradesh	3097	68695	22.18	101
2	Kumar, Satish	DRDO, Solid State Physics Laboratory, New Delhi,	2415	33213	13.75	70
3	Kumar, Rohit	Indian Institutes of Science Education and Research, Pune, Maharashtra	1964	35987	18.32	73
4	Das, Subhajit	Indian Institute Of Engineering Science And Technology (IIEST), Shibpur, West Bengal	1886	53240	28.23	98
5	Ghosh Sayandeep	Indian Institute of Technology (IIT), Guwahati, Assam	1695	33500	19.76	72
6	Sharma, Alfa	Indian Institute of Technology (IIT), Indore, Madhya Pradesh	1505	36401	24.19	79
7	Kumar, Virendra	Indian Institute of Science Education and Research (IISER), Bhopal, Madhya Pradesh.	1328	33.31	24.87	78
8	Sharma, Shweta	Shoolini University, Bajhol, Himachal Pradesh	1326	42131	31.77	91
9	Bhattacharya, Soumyadeep	Jawaharlal Nehru Centre for Advanced Scientific Research¸ Bangalore, Karnataka,	1317	35804	27.19	79
10	Sarkar, Sudipta	Indian Institute of Technology Gandhinagar, Gujarat	1313	61648	46.95	84
11	Bhatnagar, Vipin	Panjab University, Chandigarh, Punjab	1154	51355	44.5	99
12	Jain, Sonal	Madhav Institute of Technology and Science, Gwalior, Madhya Pradesh	1091	47532	43.57	96
13	Ranjann K	University of Delhi, New Delhi	1042	46520	44.64	92
14	Choudhury, Samiran	S. N. Bose National Centre for Basic Sciences, Kolkata, West Bengal	1027	45298	44.11	97
15	Dutta, Srimonti	Saha Institute of Nuclear Physics (SINP), Kolkata, West Bengal,	1019	42655	41.86	91
16	Kaur, Maninder	I. K. Gujral Punjab Technical University, Jalandhar¸ Punjab	1012	44593	44.06	93
17	Khan, Amzad	CSIR, Indian Institute of Petroleum, Dehradun, Uttarakhand	999	44148	44.19	95
18	Sharma, Vivek.	Lovely Professional University, Phagwara, Punjab	996	51474	51.8	92
19	GaganMohanty	Tata Institute of Fundamental Research, Mumbai , Maharashtra	988	45455	46.01	95
20	Gupta, Rajesh	CSIR National Environmental Engineering Research Institute, Nagpur, Maharashtra	983	48631	49.47	106

Note: TP= Total Publications, TC= Total Citations, ACPP= Average Citations per Publications

4.6 Ranking of Indian organizations / Instructions based on number of publications in the field of physics literature

Table 6 shows the ranking list of top 20 productive of organization / institutions in India, which have published papers in physics during the period 2004-2018. According to web of science database Indian Institute of Technology (IIT), Delhi (19931 publications), produced the highest number of publications to the field of physics, i.e. (19931 publications), followed by Department of Science Technology , New Delhi (7463 publications), Council of Scientific Industrial Research (CSIR) New Delhi (6929 publications), Bhabha Atomic Research Center (BARC), Mumbai (5784 publications),Indian Institute of Science (IISC), Bangalore (5269 publications), Tata Institute of Fundamental Research (TIFR), Mumbai (5080 publications), Saha Institute of Nuclear Physics, Kolkata (353 publications) (Table 6).

The average citation received per publications for a total publication of these 20 top organizations varies from 9.59 to 52.19 with a average citation per publication during 2004-2018 is 18.93. Only eight organizations registered higher average citations per publication than the average of 20 organizations. Which include Central Electricity Authority Of India (CEA), New Delhi 52.19 citations per publication, followed by Center National De La Recherche Scientifique (CNRS), New Delhi (38.65 citations per publication), Panjab University, Chandigarh (30.44 citations per publication),Tata Institute of Fundamental Research (TIFR), Mumbai (28.17 citations per publication), Saha Institute of Nuclear Physics, Kolkata (18.52 citations per publication),Banaras Hindu University , Varanasi (16.96 citations per publication) (Table 6).

The average h-index of 20 organizations varies from 51 to 140, with the average value of h-index during 2004-2018. Only 16 out of 20 organizations have scored higher h-index values than the average values of 20 organizations. These are Centre National De La Recherche Scientifique (CNRS), New Delhi with h-index 140, followed by Central Electricity Authority of India (CEA), New Delhi (137), Panjab University, Chandigarh (129), Tata Institute of Fundamental Research (TIFR), Mumbai (128), Department of Science Technology , New Delhi (108), Bhabha Atomic Research Center (BARC), Mumbai (107), Council of Scientific Industrial Research (CSIR) New Delhi (103), Saha Institute of Nuclear Physics, Kolkata (101),Institute of Technology (IIT), Bombay(95), Indian Institute of Science (IISC), Bangalore (93), Banaras Hindu University , Varanasi (73) Indian Institute of Technology (IIT), Madras (69) (Table 6).

Table 6: Organizational / Institution productivity in the field of physics literature

Sl. No.	Organizations-Enhanced	TP	TC	ACP	H-Index
1	Indian Institute of Technology (IIT), Delhi	19931	NA	NA	NA
2	Department of Science Technology , New Delhi	7463	115329	15.45	108
3	Council of Scientific Industrial Research (CSIR) New Delhi	6929	104495	15.08	103
4	Bhabha Atomic Research Center (BARC), Mumbai	5784	96297	16.65	107
5	Indian Institute of Science (IISC), Bangalore	5269	75704	14.37	93
6	Tata Institute of Fundamental Research (TIFR), Mumbai	5080	143118	28.17	128
7	Saha Institute of Nuclear Physics, Kolkata	3538	65531	18.52	101
8	Centre National De La Recherche Scientifique (CNRS), New Delhi	3471	134171	38.65	140
9	Indian Institute of Technology (IIT), Bombay	3213	57173	17.79	95
10	Panjab University, Chandigarh	3110	94665	30.44	129
11	Indian Institute of Technology (IIT), Madras	2860	36109	12.63	69
12	Indian Institute of Technology (IIT), Kanpur	2833	31943	11.28	62
13	Indian Institute of Technology (IIT), Kharagpur	2821	35245	12.49	66
14	Indian Association for the Cultivation Of Science (IACS), Jadavpur	2614	36719	14.05	67
15	Indian Institute of Technology (IIT), Delhi	2441	28732	11.77	61
16	Central Electricity Authority of India (CEA), New Delhi	2402	125360	52.19	137
17	University of Delhi, Delhi	2353	24563	10.44	54
18	Jadavpur University , Jadavaur	2113	20271	9.59	51
19	National Physics Laboratory India (PUSA) New Delhi	2101	27964	13.31	63
20	Banaras Hindu University , Varanasi	2049	34760	16.96	73

Note: TP= Total Publications, ACPP= Average Citations per Publications

4.7 International collaboration

Collaborative research has become the most prominent element in the field of science including physics. It is observed that there is a consistently increasing trend towards collaboration among different branches of physics which leads o collaborative authorship in literature.

Table 7 reveals the international collaborative papers of India with top 20 countries during 2004-018. The share of international publications in the India is physics research output was among the various collaborative countries the USA ranked first with 9235 publications and 2,64,225 citations (28.61 ACP and 176 H-index), followed by Germany which ranked second with 6640 publications and 2,13,319 citations (32.13 ACP and 166 H-index), South Korea ranked third with 4880 publications and 1,58,787 citations (32.54 ACP and 148 H-index). France4628 and Japan3854 publications ranked fourth and fifth respectively followed by other countries, as shown in the table 7.

Table 7: International collaboration among research institution in India

Rank by Collaborative Papers	Country	TP	TC	ACP	H-Index
1	USA	9235	264225	28.61	176
2	Germany	6640	213319	32.13	166
3	South Korea	4880	158787	32.54	148
4	France	4628	175116	37.84	157
5	Japan	3854	137158	35.59	141
6	England	3814	152389	39.96	151
7	China	3758	154665	41.16	154
8	Russia	3687	167830	45.52	162
9	Italy	3480	130758	37.57	135
10	Poland	2753	108118	39.27	142
11	Spain	2696	118650	44.01	130
12	Switzerland	2555	117948	46.16	133
13	Taiwan	2527	83228	32.94	117
14	Brazil	2517	105495	41.91	140
15	Czech Republic	2381	92612	38.9	134
16	Austria	1803	66091	36..66	112
17	Canada	1711	79733	46.6	103
18	Mexico	1678	81791	48.74	106
19	Sweden	1672	82618	49.41	115
20	Hungary	1627	79658	48.96	125

Note: TP= Total Publications, ACPP= Average Citations per Publications

4.8 Subject-wise productivity in India

Table 8 and figure 3 indicate the subject-wise productivity of India in physics research. Materials Science, Chemistry, Engineering, Science Technology Other Topics, Astronomy Astrophysics, Optics, Instruments Instrumentation, Nuclear Science Technology¸ Mechanics¸ Mathematics, were considered on the basis of the total number of publications. During 2004-2018 Materials Science is ranked first with 27343 (5.44%) publications, followed by Chemistry with 17910 (3.56%) publications, Engineering with 9354 (1.86%) publications, Science Technology subjects with 7857 (1.56%) publications, Astronomy Astrophysics with 5673 (1.13%) publications, Optics with 4628 (0.92%) publications, Instruments Instrumentation with 3276 (0.65%) publications, Nuclear Science Technology with 2290 (0.46%) publications, Mechanics 1962 (0.39) publications and Mathematics 1630 (0.32) publications Similarly the table 9and figure 4 indicate the subject wise productivity of world physics literature.

Table 8: Subject wise productivity in India

Year	Materials Science	Chemistry	Engineering	Science Technology Other Topics	Astronomy Astrophysics	Optics	Instruments Instrumentation	Nuclear Science Technology	Mechanics	Mathematics	Total
2004	783	530	143	172	235	141	118	132	28	44	**2326**
2005	925	585	174	123	246	186	99	111	63	86	**2598**
2006	1037	705	193	177	255	178	185	210	61	61	**3062**
2007	1128	779	215	277	268	276	165	141	77	64	**3390**
2008	1293	814	267	330	303	251	222	196	100	73	**3849**
2009	1400	919	276	390	320	272	170	139	114	154	**4154**
2010	1485	918	404	368	337	300	191	143	146	100	**4392**
2011	1632	1174	375	548	365	249	212	163	134	137	**4989**
2012	1602	1174	366	559	441	296	219	149	122	125	**5053**
2013	1973	1423	656	711	440	346	247	147	162	100	**6205**
2014	2228	1504	731	759	443	386	236	150	121	107	**6665**
2015	2603	1749	1077	955	479	381	290	148	154	128	**7964**
2016	2694	1740	1244	821	488	448	305	160	192	116	**8208**

2017	3102	1824	1549	797	509	385	283	154	217	163	**8983**
2018	3458	2072	1684	870	544	533	334	147	271	172	**10085**
Total	**27343**	**17910**	**9354**	**7857**	**5673**	**4628**	**3276**	**2290**	**1962**	**1630**	**81923**

Table 9: Subject wise productivity in World

Year	Materials Science	Chemistry	Engineering	Science Technology Other Topics	Astronomy Astrophysics	Optics	Instruments Instrumentation	Nuclear Science Technology	Mechanics	Mathematics	Total
2004	23218	14725	8297	4709	4839	6228	4867	3384	2281	2404	**74952**
2005	24380	14969	9243	5492	4686	6962	4832	3069	2467	2855	**78955**
2006	25931	17031	9329	6642	4892	6944	5162	3266	2611	2577	**84385**
2007	26685	16276	9850	7369	4663	7764	5476	3907	3026	3005	**88021**
2008	27687	18217	9571	8771	5442	7879	4640	2220	3170	3513	**91110**
2009	26705	18376	10076	8968	5423	7781	4680	2815	3447	4299	**92570**
2010	28821	19413	9930	11007	5410	8390	4973	2420	3670	3060	**97094**
2011	32606	23215	10717	12626	5708	8628	5692	2924	3596	3363	**109075**
2012	32781	23244	10962	13000	5974	8857	5094	2129	3665	3672	**109378**
2013	35668	25062	12079	13678	5758	9037	5691	2826	3615	3389	**116803**
2014	37901	25906	12133	15220	6132	8954	5242	2422	3929	3114	**120953**
2015	41496	28592	13969	17497	6124	9085	5458	2501	3801	3093	**131616**
2016	43228	28247	14640	18312	6276	9549	5794	2317	3968	3045	**135376**
2017	46256	29418	14786	18440	6063	9065	4902	2294	4028	3405	**138657**
2018	49475	33222	14589	20160	6230	9529	5225	2069	4109	3651	**148259**
Total	**502838**	**335913**	**170171**	**181891**	**83620**	**124652**	**77728**	**40563**	**51383**	**48445**	**1617204**

Figure 3 Subjectwse productivity in India

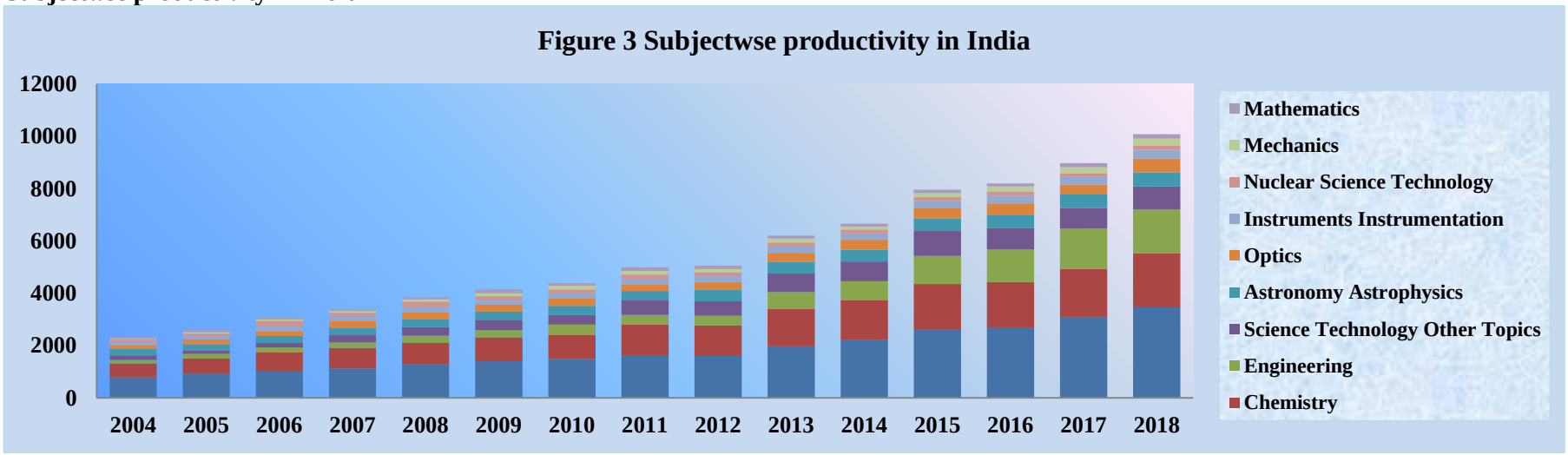
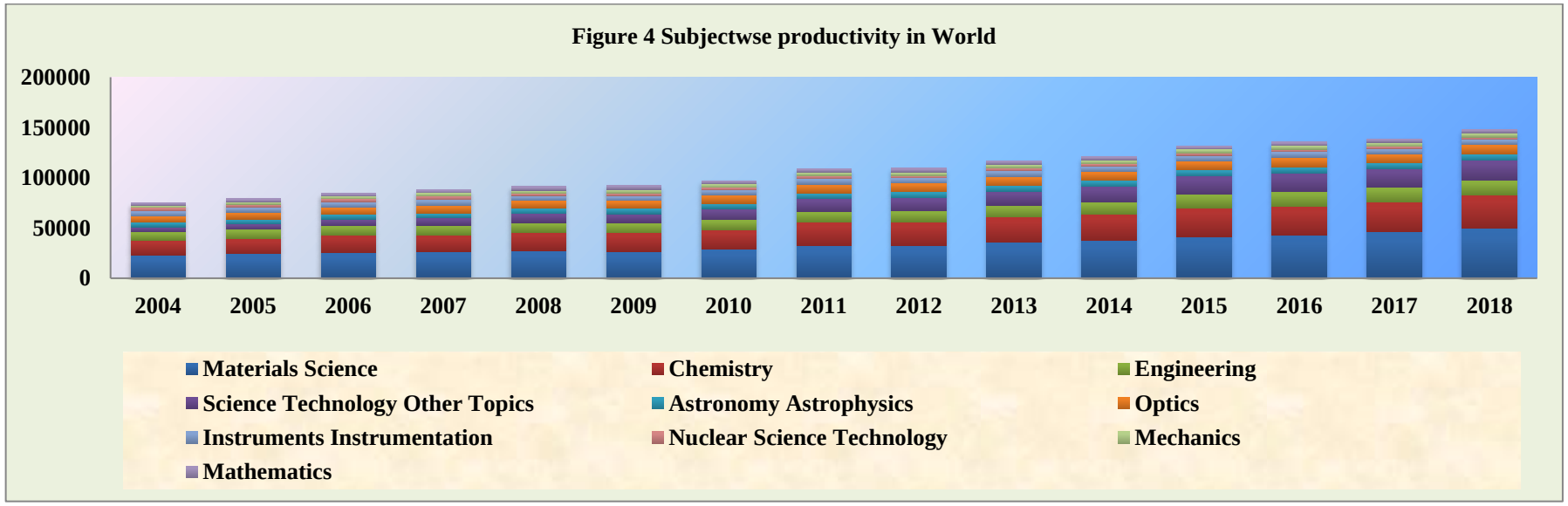


Figure 4 Subjectwse productivity in World



4.9 Activity Index (AI)

Activity index characterizes the relative research efforts of a country in a given subject field and takes into consideration the effect of the size of the country as well as the size of the field. Activity Index (AI) for India has been calculated for various years to see how India's performance gradually changed during different years. For this the authors have used the Activity Index. The Activity Index is used for Indian physics research output in table 10.

The table depicts the highest AI in various subject categories as follows: Materials Science (116.83) in 2009, Chemistry (124.27) in 2007, Engineering (169.69) in 2018, Science Technology other subjects (117.70) in 2004, Astronomy Astrophysics (159.79) in 2012, Optics (92.30) in 2007, Instruments Instrumentation (113.25) in 2008, Nuclear Science Technology (208.99) in 2008, Mechanics (96.96) in 2018, and Mathematics (91.54) in 2005. It is observed from the data that India's research efforts in these subjects correspond to the world's average.

Table 10: Activity Index for Sub-fields of Physics Literature

Year	Materials Science	Chemistry	Engineering	Science Technology Other Topics	Astronomy Astrophysics	Optics	Instruments Instrumentation	Nuclear Science Technology	Mechanics	Mathematics
2004	108.67	115.98	55.54	117.70	156.49	72.95	78.13	125.69	39.56	58.98
2005	115.31	118.77	57.21	68.06	159.54	81.19	62.27	109.92	77.61	91.54
2006	110.21	114.08	57.01	73.44	143.65	70.64	98.77	177.20	64.38	65.23
2007	109.76	124.27	56.67	97.60	149.23	92.30	78.24	93.70	66.07	55.30
2008	110.55	105.77	66.03	89.06	131.80	75.41	113.25	208.99	74.67	49.19
2009	116.83	111.45	61.04	96.91	131.50	77.90	80.95	110.04	73.70	79.83
2010	113.91	104.54	89.94	73.91	137.71	79.05	84.91	130.63	87.95	72.25
2011	109.43	110.56	76.50	94.89	139.80	63.10	81.43	121.88	81.47	89.06
2012	105.78	109.33	72.27	93.08	159.79	72.34	93.06	151.49	72.06	73.69
2013	104.13	106.88	102.23	97.85	143.84	72.07	81.70	97.92	84.36	55.54
2014	106.68	105.36	109.34	90.50	131.10	78.23	81.70	112.39	55.89	62.36
2015	103.67	101.09	127.42	90.20	129.26	69.31	87.81	97.80	66.96	68.39

2016	102.79	101.60	140.15	73.95	128.25	77.38	86.82	113.89	79.81	62.83
2017	103.51	95.70	161.70	66.71	129.58	65.56	89.11	103.62	83.16	73.89
2018	102.75	91.69	169.69	63.44	128.37	82.23	93.97	104.45	96.96	69.26
Average AI	**108.26**	**107.81**	**93.52**	**85.82**	**139.99**	**75.31**	**86.14**	**123.97**	**73.64**	**68.49**

4.10 Highly Cited Papers/ Publications from India in Physics

Table11 reveals highly cited publications from the field of physics in India. 20 highly cited papers are identified which have received 993 to 5,574 citations during the period 2004 to 2018 of these 20 publications and received 2531.15 citations per paper.

These 20 highly cited papers were published in 11 journals including 4 papers in Physics Letters B Journal, 3 papers in Physical Review Letters,2 papers in Chinese Physics, C, 2 papers in Journal of Physics G-Nuclear And Particle Physics, 2 papers in Nuclear Physics A , 2 papers in Reviews of Modern Physics, 1 paper each in Archives of Nano Letters, Advanced Materials, Annual Review of Fluid Mechanics, Nature Materials and Journal of Physical Chemistry A. Citations received by these top 20 cited papers accumulated to 50,623 (4.31%) of all citations. Most of the publications are having multiple authors (Three or more authors).

The top cited paper was ‘Review of Particle Physics Particle Data Group, authored by Olive, K. A.; Agashe, K.; Amsler, C.; et al. published in Chinese Physics C in the year 2014and this paper received 5574 citations, followed by ‘Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC, authored by Chatrchyan, S.; Khachatryan, V.; Sirunyan, A. M.; et al.. published in Physics Letters B in the year 2012, and this paper received 5376 citations, ‘Review of particle physics’ authored by Amsler,C.; Doser, M.; Antonelli, M.; et al. published in Physics Letters B in the year 2008 and this paper received 4525 citations, ‘Review of Particle Physics’ authored by Nakamura,K.; Hagiwara,K.; Hikasa, K.; et al. published in Journal of Physics G-Nuclear And Particle Physics in the year 2010 this paper received 4430. This indicates that more research is being conducted in the newly developing subjects.

Table 11: Twenty highly cited papers from India

Sl. No.	No. of Citations Received	Title	Authors	Source	Publisher	Year of Publication
1	5574	Review of Particle Physics Particle Data Group	Olive, K. A.; Agashe, K.; Amsler, C.; et al.	Chinese Physics C	IOP Publishing on behalf of the Chinese Physical Society, China	2014
2	5376	Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC	Chatrchyan, S.; Khachatryan, V.; Sirunyan, A. M.; et al.	Physics Letters B	Elsevier, Netherlands	2012
3	4525	Review of particle physics	Amsler,C.; Doser, M.; Antonelli, M.; et al.	Physics Letters B	Elsevier, Netherlands	2008
4	4430	Review of Particle Physics	Nakamura,K.; Hagiwara,K.; Hikasa, K.; et al.	Journal of Physics G-Nuclear And Particle Physics	IOP Publishing, United Kingdom	2010
5	3994	Review of particle physics	Yao, W-M; Amsler, C.; Asner, D.; et al.	Journal of Physics G-Nuclear And Particle Physics	IOP Publishing, United Kingdom	2006
6	3836	Review of particle physics	Eidelman,S; Hayes, KG; Olive, KA; et al.	Physics Letters B	Elsevier, Netherlands	2004
7	3605	Review of particle physics Particle Data Group	Patrignani,C.; Agashe,K.; Aielli, G.; et al.	Chinese Physics C	IOP Publishing on behalf of the Chinese Physical Society, China	2016
8	3199	Observation of Gravitational Waves from a Binary Black Hole Merger	Abbott, B. P.; Abbott, R.; Abbott, T. D.; et al.	Physical Review Letters	American Physical Society, USA	2016
9	2200	Experimental and theoretical challenges in the search for the quark-gluon plasma: The STAR Collaboration's critical assessment of the evidence from RHIC collisions	Adams,J; Aggarwal,MM; Ahammed, Z; et al.	Nuclear Physics A	Elsevier, Amsterdam, Netherlands	2005
10	2017	Formation of dense partonic matter in relativistic nucleus-nucleus collisions at RHIC: Experimental evaluation by the PHENIX Collaboration	Adcox,K; Adler, SS; Afanasiev, S; et al.	Nuclear Physics A	Elsevier, Amsterdam, Netherlands	2005

11	1616	GW170817: Observation of Gravitational Waves from a Binary Neutron Star Inspiral	Abbott,B.P.; Abbott,R.; Abbott, T. D.; et al.	Physical Review Letters	American Physical Society, USA	2017
12	1373	GW151226: Observation of Gravitational Waves from a 22-Solar-Mass Binary Black Hole Coalescence	Abbott,B.P.; Abbott,R.; Abbott, T. D.; et al.	Physical Review Letters	American Physical Society, USA	2016
13	1261	Colloquium: Nonequilibrium dynamics of closed interacting quantum systems	Polkovnikov,Anatoli; Sengupta, Krishnendu; Silva, Alessandro; et al.	Reviews of Modern Physics	American Physical Society, USA	2011
14	1185	Graphene Quantum Dots Derived from Carbon Fibers	Peng, Juan; Gao, Wei; Gupta, Bipin Kumar; et al.	Nano Letters	American Physical Society, USA	2012
15	1151	Hydrodynamics of soft active matter	Marchetti, M. C.; Joanny, J. F.; Ramaswamy, S.; et al.	Reviews of Modern Physics	American Physical Society, USA	2013
16	1113	Synthesis, Structure, and Properties of Boron- and Nitrogen-Doped Graphene	Panchokarla,L.S.; Subrahmanyam, K. S.; Saha, S. K.; et al.	Advanced Materials	Wiley-VCH, Germany	2009
17	1085	Vortex-induced vibrations	Williamson,CHK; Govardhan, R.	Annual Review of Fluid Mechanics	Annual Reviews, California, USA	2004
18	1058	Biological synthesis of triangular gold nanoprisms	Shankar,SS; Rai,A; Ankamwar, B; et al.	Nature Materials	Nature Publishing Group, United Kingdom	2004
19	1032	Review on Modified TiO2 Photocatalysis under UV/Visible Light: Selected Results and Related Mechanisms on Interfacial Charge Carrier Transfer Dynamics	Kumar, S. Girish; Devi, L. Gomathi	Journal of Physical Chemistry A	American Chemical Society, USA	2011
20	993	Ferromagnetism as a universal feature of nanoparticles of the otherwise nonmagnetic oxides	Sundaresan, A.; Bhargavi, R.; Rangarajan, N.; et al.	Physical Review B	American Physical Society , USA	2006

5. CONCLUSION

In this paper, an attempt has been made to investigate research trends in the field of Physics. Physics envisages different natural phenomenon and we can say that our world is ruled by physics. Physics governs many products like refrigerators, cars, escalators, and microwave, etc. Therefore, the developments in physics research and their application have a direct impact on the national economy. The present study analyses the growth of literature in physics by the researchers in India during 2004-2018 based on the data extracted from the Web of Science (WOS).

The study reveals that the literature in the field of physics is gradually increasing and there is an upward trend, however there is some fluctuation in trends of publications with mean growth rate of 0.220 and average doubling time is 3.714. Among the subfields Materials Science has the largest number of publications accounting 31.30% of the overall publications. Journal of Applied Physics has produced highest number of papers i.e. 3097 with 12.5 average citations per paper. Among the Research Institutes, Indian Institute of Technology (IIT), Delhi, has published highest number of publications i.e. 19931 among other physics research institutes in India. Indian researchers have their highest collaboration with USA in terms of physics research with a total of 9235 papers and the average citations per paper are 28.61.

However, the results of the study are limited to only Web of Science (WOS) database which includes only the peer reviewed journals, Inclusion of some of the other reputed Indian Journals would give a better view of research in Physics and its allied fields in India. This Study can be helpful to forecast the trends of Indian research in Physics and its allied fields in the near future.

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