



Investigating The Relations Proposed for The Dynamic Impact Factor in The Railway (In Terms of Velocity Parameter of The Railway Vehicle)

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ARTICLE INFO	ABSTRACT
<p>Article History: Received 7 May 2023 Received in revised form 16 July 2023 Accepted 17 September 2023 Available online 18 September 2023</p>	<p>Railway systems are subject to complex vertical dynamic forces, which arise due to the movement of trains and the presence of structural irregularities or defects within both the track infrastructure and rolling stock. Accurately evaluating these dynamic forces is crucial for ensuring the safety and longevity of railway components, yet the process is often time-consuming and computationally demanding when dynamic effects are fully considered. As a practical alternative in design applications, these forces are typically approximated as quasi-static. In this approach, the static load defined as the total weight of a vehicle divided by the number of wheels is adjusted by a dynamic impact factor to account for additional loads generated during motion. Various researchers and transportation authorities have proposed different formulas for calculating this impact factor, many of which incorporate the influence of train speed. Among the most commonly referenced models, Talbot's equation recommends conservative dynamic amplification at speeds exceeding 44 km/h, indicating a precautionary design strategy. Conversely, the formulation introduced by Mir Mohammad Sadeghi predicts the lowest dynamic load increases at speeds above 84 km/h, suggesting potential for more optimized design parameters. This comparative analysis underscores the importance of selecting an appropriate dynamic impact factor based on vehicle speed and operational conditions.</p>
<p>Keywords: Impact Factor, Quasi-Static Force, Static Force, Dynamic Force, Velocity of Railway Vehicles</p>	

1. INTRODUCTION

Train-track interactions during providing service create significant forces on the railroad. Such forces are relatively large and transient in nature and are called impact (dynamic) loads. Considerable research attention has been devoted to vertical static and dynamic forces because they are the main source of problems in railway tracks where trains are active at variable velocities and constant axial loads [1]. The nature of the forces acting on railroads is dynamic. Two main sources are influential in the emergence of these dynamic forces; First, the transient nature of

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the load of the wheels of railway vehicles and second, the impacts caused by the movement of the wheels on the uneven surfaces of the worn and destroyed rails. Other factors influencing the emergence of these dynamic effects can be mentioned as follows [2]:

1. Horizontal and vertical asperities of the railroad.
2. Unequal hardness in different sections of the railroad caused by variable characteristics and uneven settlements of the ballast and the bed.
3. Railroad discontinuity at welds, joints, branches and intersections.
4. Wave-shaped irregularities on the rail surface (corrugation).
5. Natural vibrations and hunting movement of railway vehicles.
6. Faults of the wheel profile, such as the deviation from the shape of a complete circle, chamfering of the wheel, local cuts and similar things.
7. Railroad failures such as joint opening, fractured welds, rail surface burns, broken sleeper under the rail and other types of failures that affect the rail support surface or wheel-rail contact geometry.
8. Unequal distribution of the weight of the locomotive and wagons between axles or wheels due to the difference in height along the track.
9. Uneven distribution of the axial load in the arches, which is often compensated by super elevation.
10. Braking which leads to increase in the load of front axles of the locomotive while decreasing the load in other axles.

Considering these dynamic effects in the analysis and design of railroads is important, but accurate prediction of dynamic forces on railroads is difficult and requires a lot of time. On the other hand, it is necessary to create as much ease as possible in the process of analysis and design of railroads. Therefore, the vertical static force from the wheels of railway vehicles is multiplied by a coefficient called the dynamic impact factor for design purposes and gives the quasi-static force used in the design of railroads and is used in calculations, according to Eq.1, [3]:

$$P_d = \emptyset P_s \quad (1)$$

Where:

P_d :Quasi-static force of the wheel

P_s : Static force of the wheel

\emptyset :Dimensionless dynamic impact factor which is always greater than unit.

It is commonly understood that moving railway vehicles create a dynamic impact on railroad structures, resulting in an increase in the static load effect [4]. The dynamic effects on railway structures caused by moving vehicles is a crucial and persistent topic in the design and evaluation of railway tracks, drawing the attention of numerous researchers and engineers [5,6]. The dynamic impact factor, widely accepted for calculating the impact of railway vehicles on railway tracks, has been a crucial parameter [7].

A large number of railroads currently in operation were designed for lower velocities, which warrants the need for extensive assessment and measurement to update the current velocity limits in order to ensure railway track safety [8,9]. Furthermore, high-speed and modern trains pose significant challenges for designing and maintaining railway structures due to the dynamic load they exert. Consequently, the task of determining the precise value of the dynamic impact factor becomes increasingly complex [10-13].

The dynamic impact factor depends on the following parameters [2,14]:

1. Features of the railroad, including railroad geometry, quality, hardness and its components.
2. Operating characteristics and conditions (passenger, cargo and high-velocity traffic), gross tonnage, train length, etc.
3. The characteristics of the railway vehicle, including the type of wheels and the intensity and magnitude of the wheel load.
4. Velocity, braking, increasing and decreasing the acceleration of the train.

There is still no consensus on the evaluation of dynamic impact factors. According to numerous studies, this process is complex owing to the coefficient's susceptibility to numerous parameters and is linked to uncertainty [4, 5, 15]. The effect factor bears a probabilistic nature, without a doubt, due to the uncertainty in the interaction of railway vehicles and infrastructure [16]. There are varied forms and values for dynamic impact factors in railway track design [17]. Field tests indicate overestimation of dynamic impact factors during design, while others have shown underestimation [5]. It is not possible to simultaneously include all effective factors, such as those related to the quality and geometric conditions of the railroad and railway vehicle conditions, in the calculation of the dynamic impact factor. This is due to the difficulty in obtaining information about the quality and geometric conditions of the railroad during the design and construction stages, as well as predicting future conditions during operation. Similarly, predicting the values of parameters that indicate the quality and geometry of railroad or railway vehicles will always involve a significant margin of error [2].

Various institutions and researchers in the rail transportation industry have presented several relationships to compute the dynamic impact factor. These relationships are based on the factors previously mentioned. These relationships are based on various factors, including velocity, wheel diameter, rail bed modulus (track modulus), railroad and transport equipment quality, rail support system quality, geometric quality of the track, rail failures, and wheel surface wear [2]. In the following section, we examine the proposed relationships for the dynamic impact factor, in which only the velocity of the railway vehicle affects the determination of their values.

2. INVESTIGATING THE EFFECT OF VELOCITY IN CALCULATION OF THE DYNAMIC IMPACT FACTOR

The speed of a train has a significant impact on its impact factor. As the speed of the rail vehicle increases, the impact factor value increases significantly [18-20]. Furthermore, according to Mir Mohammad Sadeghi [2], velocity is the most crucial parameter in determining the dynamic impact factor.

Several theories have been proposed to demonstrate the relationship between the dynamic impact factor and the speed of the rail vehicle. This section presents the crucial equations for computing the dynamic impact factor, which rely exclusively on the speed of the train. The relationship of German Railway Research (DB) was proposed by Schramm [21] where two separate relationships have been provided for $V \leq 100$ km/h and $100 < V \leq 200$ km/h, respectively as Eq.2 and Eq.3:

$$\phi = 1 + \frac{V^2}{30000} \text{ For } V \leq 100 \text{ km/h [21]} \tag{2}$$

$$\phi = 1 + \frac{4.5V^2}{10^5} - \frac{1.5V^3}{10^7} \text{ For } 100 \text{ km/h} < V \leq 200 \text{ km/h [21]} \tag{3}$$

In Fig.1, a graph has been drawn by the researchers for the dynamic impact factor based on DB relations for concerned velocities.

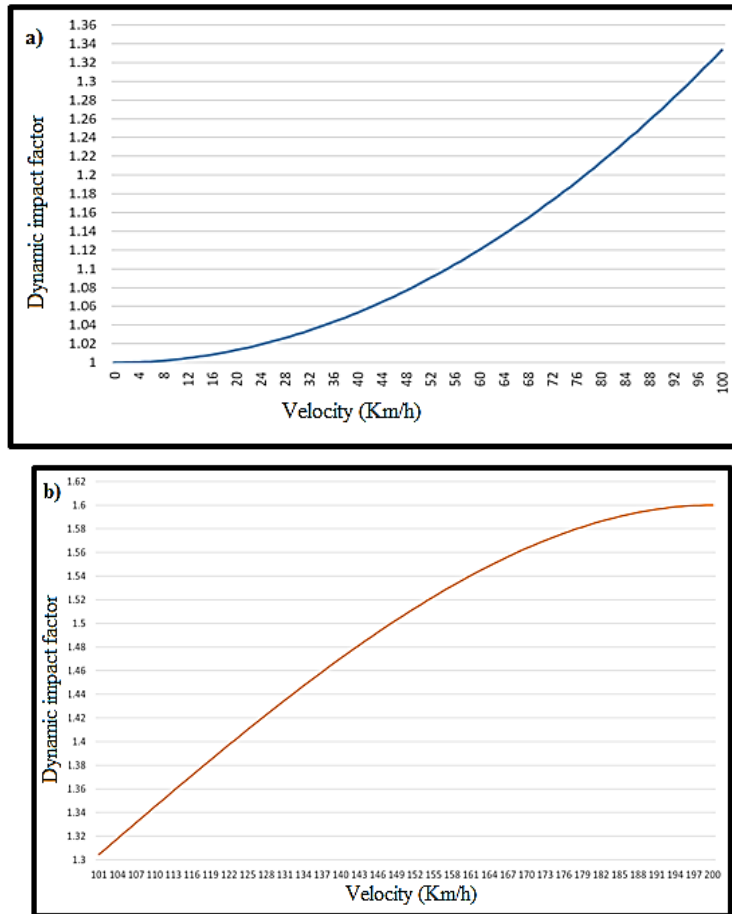


Fig.1. Values of the dynamic impact factor obtained from the Schramm relations a) Based on Eq.2 for $V \leq 100$ km/h and b) Based on Eq.3 for $100 < V \leq 200$ km/h

The relationship proposed by Driessen [22] for the Dutch railways is akin to the one posited by the German railways regarding velocities below 100 km/h (Eq. 4). However, Driessen conducted experiments for velocities ranging between 60 km/h and 90 km/h and suggested altering the denominator of the fraction once velocities exceed 100 km/h. If the assumed velocity of the train is 160 km/h, then the dynamic impact factor will be 1.85. However, the value appears to be overestimated for locomotives that maintain and repair wheel profiles well and travel on high-quality railroads according to [2].

$$\phi = 1 + \frac{V^2}{30000} \quad [22] \quad (4)$$

In the relation of the United States of America railway proposed by Talbot [23] (Eq.5), the relationship between the dynamic impact factor and the velocity of the railway vehicle is linear while the dynamic impact factor proposed by German railway (for velocities less than 100 km/h) and Dutch railways, it was proportional to the second power of the velocity of the railway vehicle. The United States railway relationship is provided for velocities greater than 8 km/h, and its general equation is as follows:

$$\phi = 1 + 0.0062(V - 8) \quad [23] \quad (5)$$

In Fig.2, a graph has been drawn by the researchers for the dynamic impact factor based on the USA relation for $8 \text{ km/h} < V < 200 \text{ km/h}$.

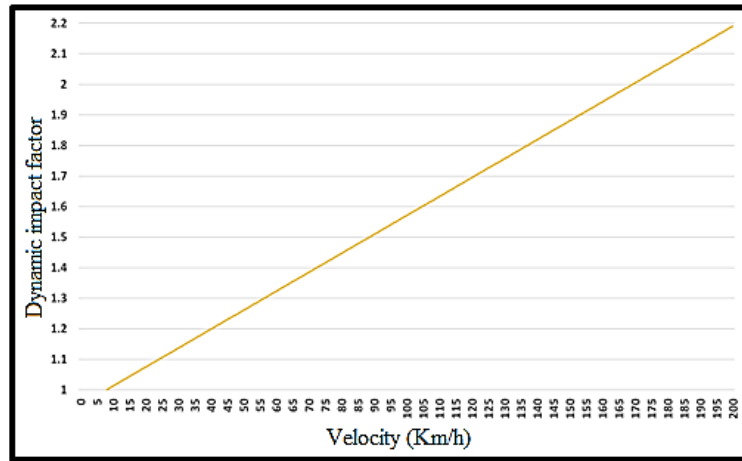


Fig. 2. Values of the dynamic impact factor obtained from the Talbot relation

Another relation is the relationship proposed by Mir Mohammad Sadeghi [24] after conducting theoretical studies for Australian railways (Eq.6). As can be seen, this relationship is a quadratic equation. In Fig.3, a graph has been drawn by the researchers for the dynamic impact factor based on the Australian railway relationship for velocities up to 200 km/h.

$$\phi = (10^{-6}V^2) + (0.0008V) + 1.098 \quad [24] \quad (6)$$

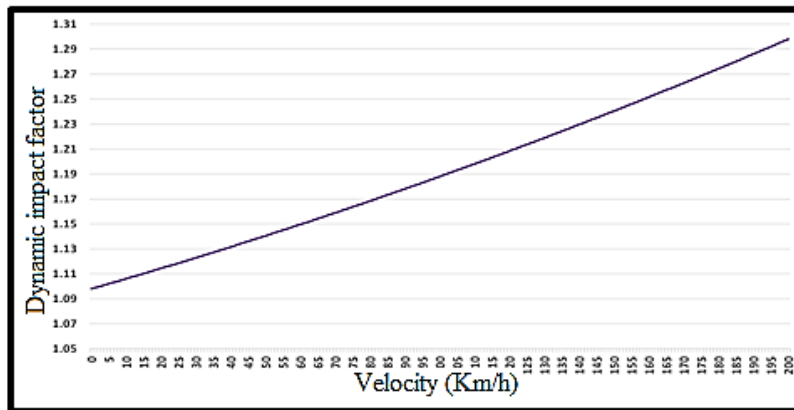


Fig.3. Values of the dynamic impact factor obtained from the Mir Mohammad Sadeghi relation

The Washington Metropolitan Area Transit Authority (WMATA) recommends the following relationship to calculate the dynamic impact factor [25] (Eq.7). In Fig.4, a graph has been drawn by the researchers for the dynamic impact factor based on the WMATA relation for velocities up to 200 km/h.

$$\phi = (1 + 3.86 \times 10^{-5}V^2)^{0.67} \quad [25] \quad (7)$$

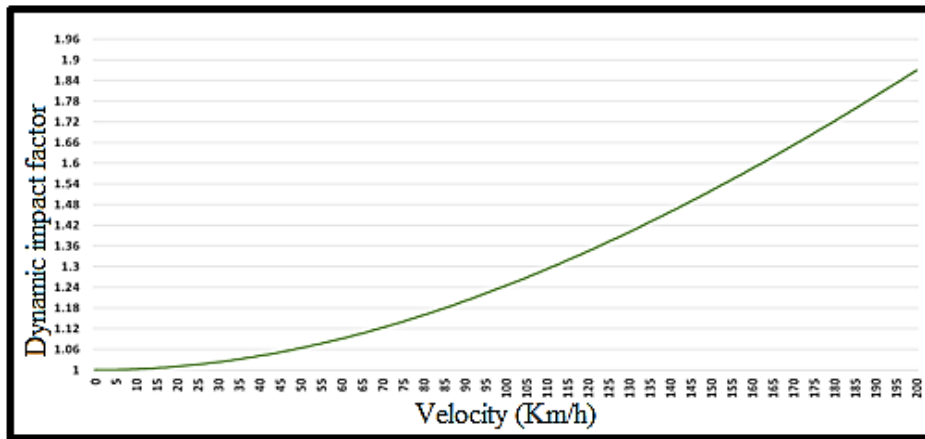


Fig. 4. Values of the dynamic impact factor obtained from the WMATA relation

Mir Mohammad Sadeghi and Youldashkhan [26] suggested the following relationship (Eq.8) to calculate the dynamic impact factor based on the conditions of the Iranian railways. In Fig. 5, a graph has been drawn by the researchers for the dynamic impact factor based on the Iranian railways for velocities up to 200 km/h.

$$\phi = -3.6(10^{-11})V^4 + 3.6(10^{-8})V^3 - 6(10^{-6})V^2 + 6(10^{-4})V + 1.2 \quad [26] \quad (8)$$

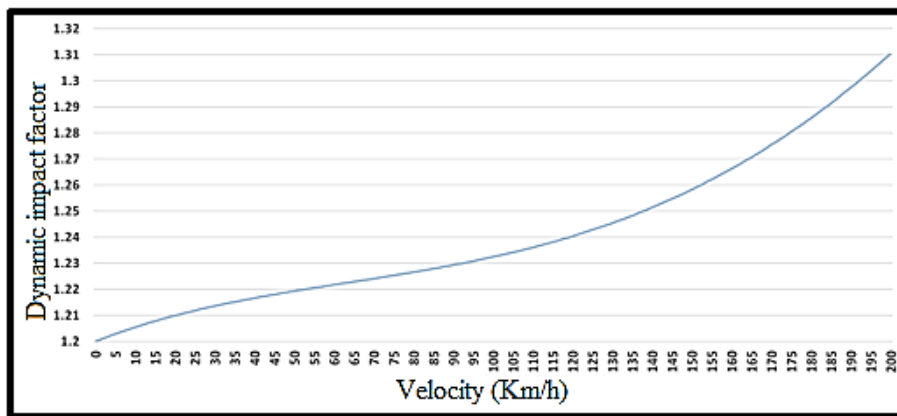


Fig. 5. Values of the dynamic impact factor obtained from the Mir Mohammad Sadeghi and Youldashkhan relation

3. CONCLUSION

Accurately assessing the value of the dynamic impact factor ensures safe and cost-effective design for new railroads, while also providing valuable information for evaluating the condition and management of existing ones. Table 1 presents a summary of the relationships described by the researchers in the preceding section.

Table 1. Relationships proposed for calculation of dynamic impact factor

Relation	Proposed by
$\phi = 1 + \frac{V^2}{30000} \text{ For } V \leq 100\text{km/h}$	Schramm [21]
$\phi = 1 + \frac{4.5V^2}{10^5} - \frac{1.5V^3}{10^7} \text{ For } 100 \text{ km/h} < V \leq 200\text{km/h}$	

$\phi = 1 + \frac{V^2}{30000}$	Driessen [22]
$\phi = 1 + 0.0062(V - 8)$	Talbot[23]
$\phi = (10^{-6}V^2) + (0.0008V) + 1.098$	Mir Mohammad Sadeghi [24]
$\phi = (1 + 3.86 \times 10^{-5}V^2)^{0.67}$	Washington Metropolitan Area Transit Authority (WMATA) [25]
$\phi = -3.6(10^{-11})V^4 + 3.6(10^{-8})V^3 - 6(10^{-6})V^2 + 6(10^{-4})V + 1.2$	Mir Mohammad Sadeghi and Youldashkhan [26]

In Fig.6, the diagram of the dynamic impact factor values based on the velocity-based relationships of the railway vehicle has been drawn for velocities up to 200 km/h. By carefully examining the statistical data and comparing the values of the dynamic impact factors obtained from the different relationships in the previous section, the following results have been concluded:

1. In these relations, the values of the dynamic impact factor are ranged between 1 and 2.2.
2. Approximately, most values of the dynamic impact factor obtained by these relationships are in the range of 1 to 1.6.
3. Compared to other relations, Talbot’s relation recommends more conservative values for the dynamic impact factor at velocities greater than 44 km/h.
4. Compared to other relations, Mir Mohammad Sadeghi’s relation suggests the lowest values for the dynamic impact factor for velocities greater than 84 km/h.

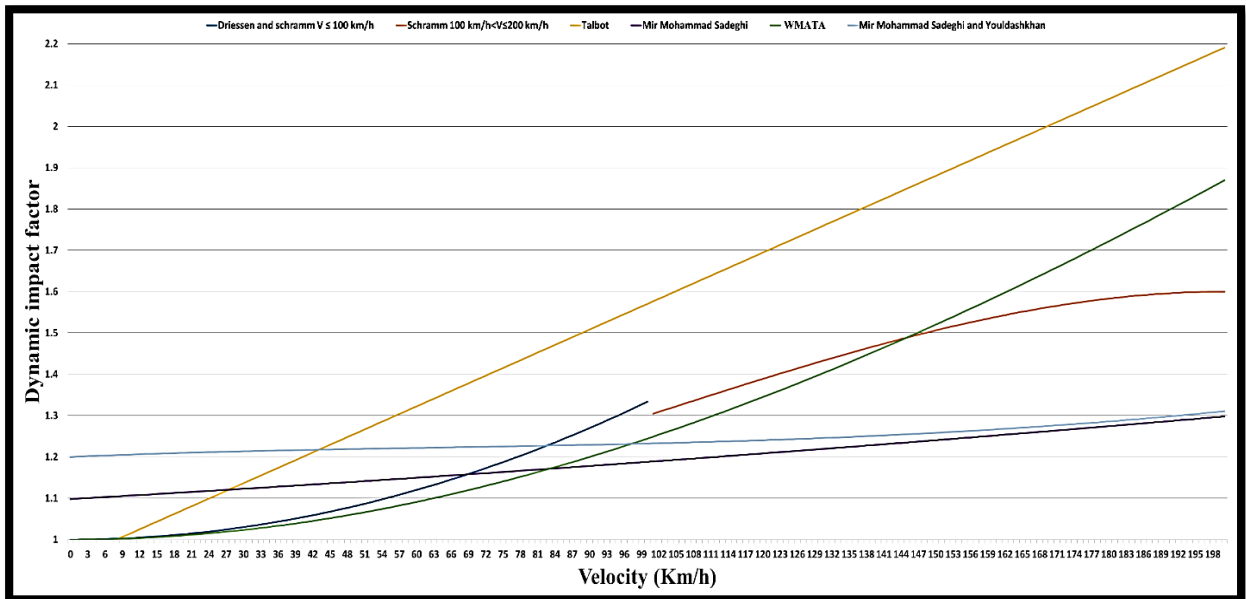


Fig. 6. Comparison of dynamic coefficient values based on relationships based on velocity of the railway vehicle

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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Appendix

Values of the dynamic impact factor based on the mentioned relationships have been provided in Table 1.

Table 2. Values of the dynamic impact factor based on the mentioned relationships

Velocity (km/h)	$1 + \frac{V^2}{30000}$ For $V \leq 100 \text{ km/h}$	$1 + \frac{4.5V^2}{10^5} - \frac{1.5V^3}{10^7}$ For $100 \text{ km/h} < V \leq 200 \text{ km/h}$	$1 + 0.0062(V - 8)$	$(10^{-6}V^2) + (0.0008V) + 1.098$	$(1 + 3.86 \times 10^{-5}V^2)^{0.67}$	$-3.6(10^{-11})V^4 + 3.6(10^{-8})V^3 - 6(10^{-6})V^2 + 6(10^{-4})V + 1.2$
0	1			1.098	1	1.2
1	1.000033333			1.098801	1.000025862	1.200594036
2	1.000133333			1.099604	1.000103445	1.201176287
3	1.0003			1.100409	1.000232745	1.201746969
4	1.000533333			1.101216	1.00041375	1.202306295
5	1.000833333			1.102025	1.000646447	1.202854478
6	1.0012			1.102836	1.000930819	1.203391729
7	1.001633333			1.103649	1.001266843	1.203918262
8	1.002133333		1	1.104464	1.001654494	1.204434285

9	1.0027		1.0062	1.105281	1.002093743	1.204940008
10	1.003333333		1.0124	1.1061	1.002584556	1.20543564
11	1.004033333		1.0186	1.106921	1.003126895	1.205921389
12	1.0048		1.0248	1.107744	1.003720721	1.206397462
13	1.005633333		1.031	1.108569	1.004365987	1.206864064
14	1.006533333		1.0372	1.109396	1.005062645	1.207321401
15	1.0075		1.0434	1.110225	1.005810643	1.207769678
16	1.008533333		1.0496	1.111056	1.006609924	1.208209097
17	1.009633333		1.0558	1.111889	1.007460428	1.208639861
18	1.0108		1.062	1.112724	1.008362092	1.209062173
19	1.012033333		1.0682	1.113561	1.009314848	1.209476232
20	1.013333333		1.0744	1.1144	1.010318624	1.20988224
21	1.0147		1.0806	1.115241	1.011373347	1.210280395
22	1.016133333		1.0868	1.116084	1.012478939	1.210670895
23	1.017633333		1.093	1.116929	1.013635316	1.211053938
24	1.0192		1.0992	1.117776	1.014842395	1.21142972
25	1.020833333		1.1054	1.118625	1.016100087	1.211798438
26	1.022533333		1.1116	1.119476	1.017408299	1.212160285
27	1.0243		1.1178	1.120329	1.018766936	1.212515456
28	1.026133333		1.124	1.121184	1.0201759	1.212864144
29	1.028033333		1.1302	1.122041	1.021635088	1.213206542
30	1.03		1.1364	1.1229	1.023144395	1.21354284
31	1.032033333		1.1426	1.123761	1.024703713	1.213873229
32	1.034133333		1.1488	1.124624	1.02631293	1.214197899
33	1.0363		1.155	1.125489	1.027971932	1.214517039
34	1.038533333		1.1612	1.126356	1.029680602	1.214830836
35	1.040833333		1.1674	1.127225	1.031438818	1.215139478
36	1.0432		1.1736	1.128096	1.033246457	1.21544315
37	1.045633333		1.1798	1.128969	1.035103392	1.215742038
38	1.048133333		1.186	1.129844	1.037009496	1.216036327
39	1.0507		1.1922	1.130721	1.038964635	1.2163262
40	1.053333333		1.1984	1.1316	1.040968676	1.21661184
41	1.056033333		1.2046	1.132481	1.043021481	1.216893429
42	1.0588		1.2108	1.133364	1.04512291	1.217171147
43	1.061633333		1.217	1.134249	1.047272821	1.217445175
44	1.064533333		1.2232	1.135136	1.049471069	1.217715693
45	1.0675		1.2294	1.136025	1.051717508	1.217982878
46	1.070533333		1.2356	1.136916	1.054011988	1.218246908
47	1.073633333		1.2418	1.137809	1.056354356	1.218507959
48	1.0768		1.248	1.138704	1.05874446	1.218766209
49	1.080033333		1.2542	1.139601	1.061182143	1.219021831
50	1.083333333		1.2604	1.1405	1.063667246	1.219275
51	1.0867		1.2666	1.141401	1.066199611	1.219525889

52	1.090133333		1.2728	1.142304	1.068779073	1.21977467
53	1.093633333		1.279	1.143209	1.07140547	1.220021515
54	1.0972		1.2852	1.144116	1.074078636	1.220266594
55	1.100833333		1.2914	1.145025	1.076798402	1.220510078
56	1.104533333		1.2976	1.145936	1.079564599	1.220752134
57	1.1083		1.3038	1.146849	1.082377056	1.220992932
58	1.112133333		1.31	1.147764	1.085235601	1.221232638
59	1.116033333		1.3162	1.148681	1.088140059	1.221471419
60	1.12		1.3224	1.1496	1.091090253	1.22170944
61	1.124033333		1.3286	1.150521	1.094086008	1.221946866
62	1.128133333		1.3348	1.151444	1.097127144	1.22218386
63	1.1323		1.341	1.152369	1.100213482	1.222420585
64	1.136533333		1.3472	1.153296	1.10334484	1.222657204
65	1.140833333		1.3534	1.154225	1.106521036	1.222893878
66	1.1452		1.3596	1.155156	1.109741887	1.223130766
67	1.149633333		1.3658	1.156089	1.113007207	1.223368028
68	1.154133333		1.372	1.157024	1.116316812	1.223605822
69	1.1587		1.3782	1.157961	1.119670514	1.223844308
70	1.163333333		1.3844	1.1589	1.123068127	1.22408364
71	1.168033333		1.3906	1.159841	1.126509462	1.224323975
72	1.1728		1.3968	1.160784	1.129994329	1.224565469
73	1.177633333		1.403	1.161729	1.133522539	1.224808275
74	1.182533333		1.4092	1.162676	1.137093901	1.225052547
75	1.1875		1.4154	1.163625	1.140708224	1.225298438
76	1.192533333		1.4216	1.164576	1.144365316	1.225546098
77	1.197633333		1.4278	1.165529	1.148064984	1.225795679
78	1.2028		1.434	1.166484	1.151807036	1.22604733
79	1.208033333		1.4402	1.167441	1.155591278	1.226301201
80	1.213333333		1.4464	1.1684	1.159417516	1.22655744
81	1.2187		1.4526	1.169361	1.163285557	1.226816194
82	1.224133333		1.4588	1.170324	1.167195204	1.22707761
83	1.229633333		1.465	1.171289	1.171146265	1.227341832
84	1.2352		1.4712	1.172256	1.175138543	1.227609007
85	1.240833333		1.4774	1.173225	1.179171844	1.227879278
86	1.246533333		1.4836	1.174196	1.183245972	1.228152787
87	1.2523		1.4898	1.175169	1.187360732	1.228429677
88	1.258133333		1.496	1.176144	1.191515928	1.228710089
89	1.264033333		1.5022	1.177121	1.195711364	1.228994163
90	1.27		1.5084	1.1781	1.199946846	1.22928204
91	1.276033333		1.5146	1.179081	1.204222177	1.229573857
92	1.282133333		1.5208	1.180064	1.208537162	1.229869753
93	1.2883		1.527	1.181049	1.212891607	1.230169865
94	1.294533333		1.5332	1.182036	1.217285315	1.230474328

95	1.300833333		1.5394	1.183025	1.221718093	1.230783278
96	1.3072		1.5456	1.184016	1.226189744	1.231096848
97	1.313633333		1.5518	1.185009	1.230700076	1.231415174
98	1.320133333		1.558	1.186004	1.235248893	1.231738387
99	1.3267		1.5642	1.187001	1.239836003	1.232066618
100	1.333333333		1.5704	1.188	1.24446121	1.2324
101		1.30449985	1.5766	1.189001	1.249124324	1.232738662
102		1.3089988	1.5828	1.190004	1.25382515	1.233082732
103		1.31349595	1.589	1.191009	1.258563497	1.23343234
104		1.3179904	1.5952	1.192016	1.263339173	1.233787613
105		1.32248125	1.6014	1.193025	1.268151986	1.234148678
106		1.3269676	1.6076	1.194036	1.273001746	1.234515659
107		1.33144855	1.6138	1.195049	1.277888264	1.234888682
108		1.3359232	1.62	1.196064	1.282811348	1.235267872
109		1.34039065	1.6262	1.197081	1.28777081	1.23565335
110		1.34485	1.6324	1.1981	1.292766463	1.23604524
111		1.34930035	1.6386	1.199121	1.297798117	1.236443663
112		1.3537408	1.6448	1.200144	1.302865586	1.236848738
113		1.35817045	1.651	1.201169	1.307968683	1.237260587
114		1.3625884	1.6572	1.202196	1.313107222	1.237679327
115		1.36699375	1.6634	1.203225	1.31828102	1.238105078
116		1.3713856	1.6696	1.204256	1.32348989	1.238537954
117		1.37576305	1.6758	1.205289	1.32873365	1.238978074
118		1.3801252	1.682	1.206324	1.334012117	1.239425552
119		1.38447115	1.6882	1.207361	1.339325109	1.239880503
120		1.3888	1.6944	1.2084	1.344672444	1.24034304
121		1.39311085	1.7006	1.209441	1.350053942	1.240813276
122		1.3974028	1.7068	1.210484	1.355469423	1.241291324
123		1.40167495	1.713	1.211529	1.360918709	1.241777293
124		1.4059264	1.7192	1.212576	1.366401622	1.242271294
125		1.41015625	1.7254	1.213625	1.371917984	1.242773438
126		1.4143636	1.7316	1.214676	1.377467619	1.24328383
127		1.41854755	1.7378	1.215729	1.383050353	1.243802581
128		1.4227072	1.744	1.216784	1.38866601	1.244329796
129		1.42684165	1.7502	1.217841	1.394314417	1.24486558
130		1.43095	1.7564	1.2189	1.399995401	1.24541004
131		1.43503135	1.7626	1.219961	1.405708791	1.245963279
132		1.4390848	1.7688	1.221024	1.411454415	1.2465254
133		1.44310945	1.775	1.222089	1.417232105	1.247096506
134		1.4471044	1.7812	1.223156	1.42304169	1.247676698
135		1.45106875	1.7874	1.224225	1.428883003	1.248266078
136		1.4550016	1.7936	1.225296	1.434755877	1.248864743
137		1.45890205	1.7998	1.226369	1.440660146	1.249472795

138		1.4627692	1.806	1.227444	1.446595645	1.25009033
139		1.46660215	1.8122	1.228521	1.452562209	1.250717447
140		1.4704	1.8184	1.2296	1.458559676	1.25135424
141		1.47416185	1.8246	1.230681	1.464587882	1.252000806
142		1.4778868	1.8308	1.231764	1.470646668	1.25265724
143		1.48157395	1.837	1.232849	1.476735872	1.253323634
144		1.4852224	1.8432	1.233936	1.482855336	1.254000083
145		1.48883125	1.8494	1.235025	1.489004901	1.254686678
146		1.4923996	1.8556	1.236116	1.49518441	1.255383509
147		1.49592655	1.8618	1.237209	1.501393707	1.256090668
148		1.4994112	1.868	1.238304	1.507632636	1.256808244
149		1.50285265	1.8742	1.239401	1.513901044	1.257536326
150		1.50625	1.8804	1.2405	1.520198776	1.258275
151		1.50960235	1.8866	1.241601	1.52652568	1.259024354
152		1.5129088	1.8928	1.242704	1.532881606	1.259784475
153		1.51616845	1.899	1.243809	1.539266403	1.260555446
154		1.5193804	1.9052	1.244916	1.545679922	1.261337352
155		1.52254375	1.9114	1.246025	1.552122014	1.262130278
156		1.5256576	1.9176	1.247136	1.558592532	1.262934304
157		1.52872105	1.9238	1.248249	1.56509133	1.263749513
158		1.5317332	1.93	1.249364	1.571618263	1.264575985
159		1.53469315	1.9362	1.250481	1.578173185	1.265413801
160		1.5376	1.9424	1.2516	1.584755955	1.26626304
161		1.54045285	1.9486	1.252721	1.591366429	1.267123779
162		1.5432508	1.9548	1.253844	1.598004467	1.267996097
163		1.54599295	1.961	1.254969	1.604669927	1.268880069
164		1.5486784	1.9672	1.256096	1.611362671	1.269775771
165		1.55130625	1.9734	1.257225	1.618082559	1.270683278
166		1.5538756	1.9796	1.258356	1.624829456	1.271602663
167		1.55638555	1.9858	1.259489	1.631603224	1.272534
168		1.5588352	1.992	1.260624	1.638403727	1.273477362
169		1.56122365	1.9982	1.261761	1.645230832	1.274432818
170		1.56355	2.0044	1.2629	1.652084405	1.27540044
171		1.56581335	2.0106	1.264041	1.658964313	1.276380297
172		1.5680128	2.0168	1.265184	1.665870424	1.277372458
173		1.57014745	2.023	1.266329	1.672802609	1.278376991
174		1.5722164	2.0292	1.267476	1.679760736	1.279393962
175		1.57421875	2.0354	1.268625	1.686744679	1.280423438
176		1.5761536	2.0416	1.269776	1.693754307	1.281465483
177		1.57802005	2.0478	1.270929	1.700789496	1.282520163
178		1.5798172	2.054	1.272084	1.707850118	1.283587541
179		1.58154415	2.0602	1.273241	1.71493605	1.284667679
180		1.5832	2.0664	1.2744	1.722047165	1.28576064

181		1.58478385	2.0726	1.275561	1.729183343	1.286866484
182		1.5862948	2.0788	1.276724	1.73634446	1.28798527
183		1.58773195	2.085	1.277889	1.743530394	1.28911706
184		1.5890944	2.0912	1.279056	1.750741026	1.29026191
185		1.59038125	2.0974	1.280225	1.757976236	1.291419878
186		1.5915916	2.1036	1.281396	1.765235905	1.29259102
187		1.59272455	2.1098	1.282569	1.772519916	1.293775393
188		1.5937792	2.116	1.283744	1.779828152	1.294973052
189		1.59475465	2.1222	1.284921	1.787160496	1.29618405
190		1.59565	2.1284	1.2861	1.794516833	1.29740844
191		1.59646435	2.1346	1.287281	1.80189705	1.298646275
192		1.5971968	2.1408	1.288464	1.809301032	1.299897606
193		1.59784645	2.147	1.289649	1.816728668	1.301162484
194		1.5984124	2.1532	1.290836	1.824179845	1.302440958
195		1.59889375	2.1594	1.292025	1.831654454	1.303733078
196		1.5992896	2.1656	1.293216	1.839152382	1.30503889
197		1.59959905	2.1718	1.294409	1.846673523	1.306358443
198		1.5998212	2.178	1.295604	1.854217767	1.307691782
199		1.59995515	2.1842	1.296801	1.861785006	1.309038953
200		1.6	2.1904	1.298	1.869375135	1.3104