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Research Article

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Abstract

In this paper, the effect of resistances on applied force has been studied practically. As per study, the existing Newton's equation ($F=ma$) calculates only net force and does not count the effect of resistances. It has been observed that in every action some part of the applied force is required to overcome the effect of resistances (friction, air resistances, etc.); and when applied force exceeds that amount only then a stationary body accelerate. Hence, a mathematical expression ($F=ma+r$) has been provided by including a factor describing above said resistances.

Keywords: Newton second law of motion ($F=ma$), applied force, net force, effect of friction, effect of air resistance, $F=ma+r$

1. Background

Philosophers in antiquity used the concept of force in the study of stationary and moving objects, but thinkers such as Aristotle retained fundamental errors in understanding this concept of force due to an incomplete understanding of non-obvious force of friction, etc. In observing objects around him, Aristotle noticed that an object required a force to start moving. If that force was removed, the object eventually came to stop. A large force resulted in a large velocity; a small force resulted in a small velocity. He concluded that force was related to velocity. However, in some situations, force resulted in no velocity. We could push and push on a heavy boulder, but it would never budge. To explain these observations, Aristotle added the concept of resistance. Combining the concept of resistance with the idea that force was related to velocity, Aristotle formulated his "second law;"

$$Force = velocity \times resistance[1][2][3][4] \quad (1)$$

14 It looks remarkably like Newton's second law, except that it relates force
 15 to velocity instead of acceleration, and it defines resistance as a property of
 16 the medium, not the object being moved. After Aristotle, John Philoponus
 17 (490-570AD) suggesting that Aristotle's relationship be modified as the ap-
 18 plied force is determined by the increase in velocity taken as a sum to the
 19 resistance, i.e.

$$Force = velocity + resistance[1][2][3][4] \quad (2)$$

20 If the resistance were zero, the object would move with a constant veloc-
 21 ity directly proportional to the force. Thereafter, Avicenna (A.D. 980-1037)
 22 developed a theory of motion in 'The Book of Healing'. His theory of motion
 23 was consistent with the concept of inertia in Newton's first law of motion.
 24 Avicenna also referred to as being proportional to weight times velocity and
 25 that such a moving body would eventually be slowed down by the air re-
 26 sistance around it.[5][6][7] Later on, John Buridan's (1301-1359) explained
 27 the same that "after leaving the arm of the thrower, the projectile would
 28 be moved by an impetus given to it by the thrower, and would continue to
 29 be moved as long as the impetus remained stronger than the resistance, and
 30 would be of infinite duration were it not diminished and corrupted by a con-
 31 trary force resisting it or by something inclining it to a contrary motion".[10]
 32 Buridan also modified Aristotle relationship by replacing resistance with the
 33 weight.

$$Impetus(force) = weight \times velocity[7][8][9][10] \quad (3)$$

34 Thereafter, Galileo (1564-1642) eventually made the mental jump from the
 35 observed to the hypothetical – from motion in everyday experience to motion
 36 without resistance. As going down an incline, he reasoned, a ball accelerates.
 37 If he placed a second incline facing the first, the ball would move up the
 38 second incline almost to the same height from which it had been released on
 39 the first incline. Mentally, Galileo removed friction and concluded that the
 40 ball would continue up the second incline until it reached exactly the same
 41 height from which it had been released. Next, Galileo decreased the angle
 42 of the second incline. Each time, the ball traveled until it almost reached
 43 the same height from which it had been released. At lower inclines, however,
 44 the ball had to travel farther. If the angle of incline were reduced to zero,
 45 Galileo reasoned, the ball would continue moving forever. [11][12][13] Thus,
 46 Galileo, based on such experiments perceived that a moving body maintains
 47 its constant speed in straight line unless no resistances act on it, i.e.

Figure 1: Galileo Experiment

48 “A body moving on a level surface will continue to move in the same
 49 direction at a constant speed unless disturbed.” [14][15][16]

50 Far from these researcher, Isaac Newton (1643-1727) saw things in vac-
 51 uum. He did not add the concept of resistances while calculating applied
 52 force. Newton described in his second law that a force to be equal to change
 53 in momentum (mass times velocity) per change in time.

$$F = ma[14][15][16] \quad (4)$$

54 This relation is only good for objects that have a constant mass. This
 55 equation tells us that an object subjected to an external force will accelerate
 56 and that the amount of the acceleration is proportional to the size of the net
 57 force. The amount of acceleration is also inversely proportional to the mass of
 58 the object; for equal forces, a heavier object will experience less acceleration
 59 than a lighter object.

60 2. Need to Modify Newton’s Second law of Motion

61 In this paper, it has been observed that Sir Isaac Newton’s existing equa-
 62 tion of motion ($F = ma$) calculates only net force but does not calculate
 63 the applied force. Therefore, in this part of the paper, need of applied force
 64 has been explained by analyzing the difference between net force and applied
 65 force.

66 2.1. Applied Force (Vertically)

67 Let a person accelerates 10kg mass at the rate of $3m/s^2$ in the upward
 68 direction (against gravity) on Earth. Here, it seems that 10kg mass needs

69 30N force to accelerate it at the rate of $3m/s^2$ in the upward direction, i.e.

$$\begin{aligned} 70 \quad & F = ma \\ 71 \quad & F = 10\text{kg} \times 3m/s^2 \\ 72 \quad & F = 30\text{N} \end{aligned}$$

73 In above case, 30N is a net force but not applied force. To calculate
74 applied force, we have to understand the concept of applied force, i.e.,

75 Let the boy holds same mass (10kg) in the air on Earth. Here, the boy
76 has to apply 98N (mg) force just to hold it. Therefore, according to the
77 concept, the applied force is the sum of applied force till object is stationary
78 and applied force till object accelerate (net force), i.e.

$$\begin{aligned} 79 \quad & \text{Applied Force} = \text{Applied force till object is stationary} + \text{Net force (ma)} \\ 80 \quad & \text{Applied force} = 98\text{N} + 30\text{N} \\ 81 \quad & \text{Applied Force} = 128\text{N} \end{aligned}$$

82 It means that if we apply 30N force to mass 10kg; then instead of going
83 upward, mass 10kg will fall down at the rate of $6.8m/s^2$ (i.e., to accelerate
84 the mass 10kg in upward direction on earth, it needed force more of 98N).

85 2.2. Applied Force (Horizontally)

86 Let two elephants pull a wooden log in opposite direction with equal but
opposite force of 200N as shown in figure 2, i.e.

Figure 2: Two elephants pull a wooden log with equal and opposite force

87 In above case, as we can observe that net force is zero but applied force
88 is 200N. Therefore, it shows that there is a difference between net force and
89 applied force. We can calculate net force (ma) but need to calculate applied
90 force (200N) till body stays stationary as shown in above case.
91

92 In another case, let a person applied force to a body of weight 50N held
 93 horizontally as shown in the figure 3.

Figure 3: Applied force to stationary body

94 In above case, the body stays stationary, i.e., net force is zero, which
 95 means that force by the push equals to static friction. We have the formula
 96 of static friction as, i.e.

$$97 \quad F_s = \mu_s \cdot F_n$$

98 Where F = static frictional force, μ_s = coefficient of static friction and
 99 F_n = normal force. Now, let the coefficient of static friction (μ_s) between
 100 the body and the floor is 0.3, then static friction will be equal to 15N, i.e.

$$\begin{aligned} 101 \quad F_s &= \mu_s \cdot F_n \\ 102 \quad F_s &= 0.3 \times 50N \\ 103 \quad F_s &= 15N \end{aligned}$$

104 As we know, static friction between two particular bodies remains con-
 105 stant; so, this simply means that we cannot calculate applied force less of a
 106 static friction (i.e., in above case, if the person applied force less of 15N, then
 107 it cannot be calculate with any equation). Hence, in this paper, an equation
 108 has been proposed that can calculate applied force on a body from zero to
 109 maximum.

110 3. Modification of Newton's Second Law of Motion.

111 When a body come into contact with another body to push or pull is force.
 112 It has been observed that in some cases force resulted in no acceleration.
 113 This happens due to various resistances, such as friction, air resistance, etc.

114 Therefore, an equation of applied force has been provided by adding the
115 concept of the resistances to the net force, i.e.,

$$F = r + ma \quad (5)$$

116 Where 'F' is applied force, 'r' is the effect of resistances, 'm' is mass and 'a'
117 is the acceleration. This equation explains that once the applied force exceeds
118 the amount of force need to budge the stationary body due to resistances,
119 then the applied force is converted into acceleration (ma). The more is the
120 applied force the more will be 'r' and 'ma'. Now, the thing is that we can
121 calculate 'ma' but not 'r'. To calculate 'r', applied force was studied during
122 such conditions when a stationary body does not budge due to air-resistance,
123 friction, etc. As we know that when we push/pull something, we apply force;
124 harder we push/pull, more will be the applied force. Practically, it is found
125 that a body holds some amount of applied force till it stays stationary due to
126 its weight or resistance if any, but when applied force exceeds that amount
127 then applied force passes out in the form of motion (acceleration).

128 To measure the amount of applied force holds by the body, a weighing
129 scale was hanged on a box and then applied some force on it. There, it was
130 found that when force was applied to the box with the hand; the box moved
131 when applied force exceeded 0.566N (i.e., box did not move by providing
132 applied force less of 0.566N). After that, more than double of this force
133 was applied. There, instead of getting doubled, the value of 'r' remained
134 between 0.540N – 0.590N (this variation was due to little variation in friction
135 of the road); whereas the acceleration increased directly proportional to the
136 applied force after it started from rest. It concludes that some part of the
137 applied force is required to overcome resistances (r) and when applied force
138 exceeds that amount, then 'r' becomes constant but acceleration increases
139 directly proportional to the applied force (ma). If there is no resistance, the
140 acceleration will increase independently w.r.t. applied force.

141 3.1. *Applied force when body moves with constant velocity*

142 In vacuum, a body moves in a straight line forever with a constant velocity
143 without supplying any force. But on Earth, constant force is needed to move
144 a body at constant velocity until it is disturbed by any resistance. If we hang
145 weighing scale on a body and apply constant force then the body will not be
146 considered moving at constant velocity till the 'r' is constant.

147 'r' constant = constant velocity

148 The value of 'r' will change only when either applied force or the effect of
 149 resistances change. Hence, it concludes that when force is applied to a body;
 150 then to keep a body move with a constant velocity, we will have to keep 'r'
 151 constant.

152 3.2. Applied force when acceleration is zero.

153 Let us assume that the acceleration produced by the body is zero, and
 154 when the acceleration is zero, the equation becomes

$$155 \quad F = r$$

156 To measure applied force on stationary body, the wall was considered as
 157 stationary body. A weighing scale is then placed on the wall and applied
 force on to it with the push as shown in figure 4.

Figure 4: Horizontal applied force on the wall

158 The wall is pushed three times (having variation in the amount of force)
 159 to check the variation of applied force on the wall. The calculation has been
 160 shown in the table 1.
 161

	Reading 1	Reading 2	Reading 3
Applied force	4.4N	13.1N	21.3N

Table 1: Calculation of applied force on the wall

162 As shown in figure 4, it is observed that when some force is applied with
 163 the hand by pushing the weighing scale on the wall, it applied horizontally
 164 force from the push equals to 4.4N, 13.1N and 21.3N. These practical obser-
 165 vations conclude that when the applied force is increased on to the weighing
 166 scale on the wall, weighing scale reading increased with the same rate.

167 4. Calculation of the Effect of Resistances (r)

168 During the application of applied force, resistances like frictional force,
169 air resistance, etc. tries to cease body's motion. To calculate the effect of
170 resistances, a weighing scale has been hanged to a box and then measured
171 the effect of resistances by applying force on it.

172 4.1. Frictional Force

173 To calculate friction, the box was placed on three different surfaces (in
174 terms of friction) as shown in the figure 5.

Figure 5: Frictional effect of the different surfaces on the box

175 We measured weight of the box along with weighing scale equals to
176 0.823N. Now, force was applied onto the given box and recorded readings
177 just before the box moved by using weighing scale. By doing this, effect of
178 friction was measured that ceased the body's motion as shown in the table
2.

	Reading 1	Reading 2	Reading 3
Box Weight	0.823N	0.823N	0.823N
Frictional Force	0.482N	0.601N	0.566N

Table 2: Calculation of the effect of Fictional force on the box

179

180 In the first case, the box was placed on surface 1 and started pushing it
181 horizontally as shown in the figure 5. It is observed that the given box started
182 moving when the applied force exceeded 0.482N as calculated by weighing
183 scale. Again, the same box was placed on the surface 2 and found to be that
184 box started moving when applied force exceeded 0.601N and in the last case,
185 same box was placed on the surface 3 and by similar procedure, applied force
186 was equal to 0.566N as calculated by weighing scale. Here, it is observed

187 that applied force increased with the increase in friction between the surface
 188 and the body. Hence, it concludes that equation is valid to calculate friction
 189 by using weighing scale.

190 4.2. Air resistance

191 To calculate air resistance, we placed the given box (weight=0.823N) on
 192 the floor and created the effect of air resistance by using air blower as shown
 193 in figure 6.

Figure 6: Effect of air-resistance on the box

194 In order to calculate air-resistance, air was blown straight onto the one
 195 side of the given box by keeping same distance but increasing speed of air
 196 flow in each case to measure the variation. After that force was applied on
 197 to the opposite side of the box and then readings were recorded just before
 198 the box moved. The calculation has been shown in the table 3.

	Reading 1	Reading 2	Reading 3
Speed of Air	Nil	Low	High
Air Resistance	0N	0.080N	0.123N
'r'	0.503N	0.583N	0.626N

Table 3: Calculation of the effect of air resistance on the box

199 As shown in figure 6, it is observed that when some force was applied
 200 on the box, it moved when applied force exceeded 0.503N as calculated by
 201 weighing scale in the absence of air resistance. In another case, when air-
 202 blower blew onto the given box at low speed, the box started moving when
 203 applied force exceeded 0.583N. Here, the applied force included both friction
 204 and air resistance. As the friction of the surface was 0.503N in the absence
 205 of air resistance. So, by subtracting frictional force to the applied force, we
 206 get the value of air resistance, i.e.,

$$\begin{aligned}
& \text{Air resistance} = \text{Applied Force} - \text{Frictional Force} \\
& \text{Air resistance} = 0.583 - 0.503\text{N} \\
& \text{Air resistance} = 0.080\text{N}
\end{aligned}$$

Again, when air-blower blew onto the given box at high speed, the applied force was equal to 0.626N as calculated by weighing scale.

$$\begin{aligned}
& \text{Air resistance} = \text{Applied Force} - \text{Frictional Force} \\
& \text{Air resistance} = 0.626 - 0.503\text{N} \\
& \text{Air resistance} = 0.123\text{N}
\end{aligned}$$

Here, it is observed that the calculated readings by using weighing scale measures exactly the same ratio of air resistance created by the air-blower. These practical observations conclude that equation is valid to calculate air resistance by using weighing scale.

5. Numerical Treatment

1. Let some force is applied to a stationary body of mass 100kg on the surface of Earth and Pluto. The weight on the Earth becomes 980N and on Pluto it becomes 62N. Now, calculate the applied force if body gets final velocity 20m/s after 10sec.

On Earth, weight = 980N (gravity = $9.8m/s^2$ and mass = 100kg),

$$\begin{aligned}
& F = ma + r \\
& F = 100\text{kg} \times [(20\text{m/s} - 0\text{m/s}) \div 10\text{s}] + r \\
& F = 100\text{kg} \times [20\text{m/s} \div 10\text{s}] + r \\
& F = 100\text{kg} \times 2m/s^2 + r \\
& F = 200\text{N} + r
\end{aligned}$$

On Pluto, weight = 62N (gravity = $0.62m/s^2$ and mass = 100kg),

$$\begin{aligned}
& F = ma + r \\
& F = 100\text{kg} \times [(20\text{m/s} - 0\text{m/s}) \div 10\text{s}] + r \\
& F = 100\text{kg} \times [20\text{m/s} \div 10\text{s}] + r \\
& F = 100\text{kg} \times 2m/s^2 + r \\
& F = 200\text{N} + r
\end{aligned}$$

Here, it has been found that the net force is same (200N) in both cases but the gravity act as resistance which directly increases friction; and when the effect of friction (r) increases, the applied force will have to increase with the same rate. Hence, to get same final physical quantities, we need to apply more applied force to mass 100kg on Earth as compared to same mass on Pluto.

6. Conclusions

The study explains that ' $F=ma$ ' is an equation of net force while applied force is the sum of net force and effect of resistances (r), whereas the effect of resistances is measured by weighing scale. Practically, applied force has been calculated in different cases by considering the effect of air resistance, which is generally not calculated, effect of friction. Hence, the results demand the modification of Newton's second law of motion.

7. Declaration

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7.2. Conflict of interest

The Author declares that he has no competing interest.

References

- [1] Shore, Steven N, (2008) "Forces in Physics" *Medieval Ideas of Force*, pp. 28-29 , ISBN: 978-0-313-33303-3.
- [2] Schmitt, Charles B, (1967) "Gianfrancesco Pico Della Mirandola (1469-1533) and His Critique of Aristotle" *The critique of Aristotle's physics*, pp. 146-147, ISBN 978-94-011-9681-9.
- [3] INTRLUDE 2, (2021, May 5) "Each Step Beyond" *Kansas State University, Department of Physics*, Retrieved From <https://web.phys.ksu.edu/fascination/Interlude2.pdf>.

- 266 [4] Castelli, Marco Raciti and Benini, Ernesto, (2013) “Advanced Materi-
267 als Research” *Philoponus Comments to Aristotle’s Physics as the First*
268 *Step to the Development of Modern Laws of Motion*, Vol. 748, pp 381-
269 385, ISSN: 1662-8985.
- 270 [5] Roeder, Mark (2011) “The Big Mo – Why Momentum Now Rules Our
271 World” *The Flow*, pp 19, ISBN: 978-0-75-353937-8.
- 272 [6] Opdenakker, Raymond and Cuypers, Carin (2019) “Effective Virtual
273 Project Teams” *Strategic Momentum*, pp 20, ISBN: 978-3-030-22227-7.
- 274 [7] Vogel, Hans Ulrich and Dux, Gunter (2010) “Concept of Nature” *In-*
275 *troductions – Mark Elvin*, pp 62, ISBN: 978-90-04-18526-5.
- 276 [8] Pedersen, Olaf (1993) “Early physics and astronomy: a historical in-
277 troduction” *Force and Motion in the Middle Ages*, pp 210, ISBN 0-521-
278 40340-5 (hbk), ISBN: 0-521-40899-7 (pbk).
- 279 [9] Wagner, Roger and Briggs, Andrew (2016) “The Penultimate Curios-
280 ity” *The Universal Law, The Age of Buridan*, pp -174, ISBN: 978-0-
281 19-107570-4.
- 282 [10] “IMPETUS THEORY” *Vanderbilt University*, Retrieved From
283 <https://www.vanderbilt.edu/AnS/physics/astrocourses/ast203/impetustheory.html>.
- 284 [11] Goodstein, David L and Goodstein, Judith R (1996) “Feynman’s Lost
285 Lectures” *From Copernicus to Newton*, pp 36-38, ISBN 9780099736219.
- 286 [12] Hewitt, Paul G (2007) “Conceptual Physics” *Newton’s First Law of*
287 *Motion – Inertia*, pp 25-26 and 64, ISBN: 978-81-317-1553-6.
- 288 [13] Hadzigeorgiou, Yannis (2016) “Imaginative Science Education” *Imag-*
289 *inative Thinking in Science and Science Education*, pp 12-13, ISBN:
290 978-3-319-29524-4.
- 291 [14] Ball, Philip (2013) “Curiosity” *Cosmic Disharmonies*, pp 202, ISBN-
292 13:978-0-226-04579-5.
- 293 [15] West, Bruce J and Griffin, Lori A (2003) “Biodynamics” *Introduction*
294 *to Science, Mechanics-A First Look*, pp.53-55, ISBN: 978-0-471-34619-
295 5.

- 296 [16] Doody, David (2003) “Deep Space Craft” *Navigating the Depths*, pp
297 54, ISBN: 978-3-540-89509-1.