Transcend the Conservation law —— Correction the falsehood in Rotation dynamics

GuangSan Yu
Harbin • Macro • Dynamics Institute 150066, P. R. China

E-mail: yuguagsan@sohu.com

Abstract. In Rotation dynamics of the classical mechanics, there is a serious error, namely the notion of the force moment. Via the arm of force that vary the force moment, can vary the dimension of the force, this is wrong. But Rotation dynamics and whole theory system, is to regard the notion of this kind of force moment as the foundation, moreover establish create. Thereupon, the hitherto of thereinto the Rotation dynamics, abound the multifarious mistake. In complete of the Rotation dynamics of the inertia locomotion, the notion of the force moment is meaningless. The and force moment extraordinary resemble react, that is other concept Inertia-torque. Inertia-torque is mass and arm of force product at object or particle. Similar in this way through correction after, the Rotation dynamics will have the grand change. And thereupon we can also achieve, versus physics several celebrated conservation law of the exceed. The world science will have a grand advancement.

Key Words：conservation law; Rotation dynamics; Inertia-torque; force moment; arm of force

PACS：45.50.àj, 45.20.-d, 45.40.àf, 45.50.Dd

1. Introduction:

Concerning idea of save labour of lever, initially engender in B.c. Third century and B.c. Four centuries. Since then until now, rotation dynamics namely is in, on the foundation of this kind of moment of force concept of the force multiply force arm, establish of engender. The concept of that new Inertia-torque, nope is force multiply force arm, is but the mass multiply force arm. Such as if wee of change, shall in physics create the miracle. Actualize momentum is not conservation and energy is not conservation ….

For the sake of the textual treatise, author searched that and physics history, and turn dynam, and momentum principle, correlative monograph and literature.

2. Inertia-torque notion

Inertia-torque is inertial mass of matter and the arm of force the product. As the figure 1, that a stem g, with above it that one dot that O, as dot of origin moreover the immobility for at a axes. Thereupon at both sides in O, forming force arm is 1 and 2 that two forces moment. In a side of that 1 d of force arm, fixedly that an object W, its mass is m.

So, that 1d of the arm of force, in here, that Inertia-torque is: $G_1 = m \times 1d$ (2.0.1)

When the stem g turn angle θ , in figure 1. Both sides of g, because turn the radian length of the lineation, and both sides the arm of force the length, of the ratio is geometric proportion.

The arm of force that 2d section the Inertia-torque is: $G_2 = xm \times 2d$ (2.0.2)

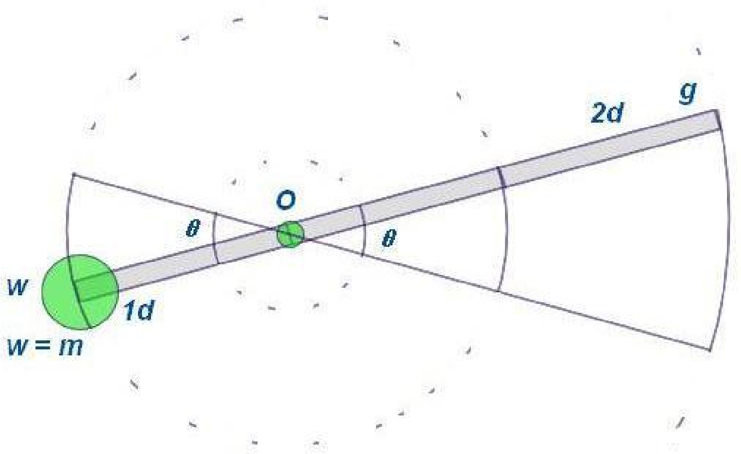

Figure 1. Lever and Inertia-torque

The Inertia-torque is resemble with force moment relation. So should have: $G_1 = G_2$.

∴ $m \times 1d = xm \times 2d$ ∴ $x = 1/2$.

By the expressions (2.0.1) can gained: $G_1 = Qm \times \frac{1}{Q} 1d$ therefore at the mass m and force arm d, separate multiply one numeral and this numeral of reciprocal, its Inertia-torque G is immovability. Namely when Inertia-torque immovability at that time, the mass is more big, the force arm the more small, vice versa. This with the plight of the force moment, resembles very much.

2.1. The force moment still has the plight of the meaning

In statics equilibriumly or is non-inertia process system, the force moment action the continue exist.

For example figure 2, balancing pole g is in the fulcrum Z and O the both sides, placed that two object, mass respectively is 1 m and 2 m. At this time the bar is the gravity equilibrium the state, the stillness of motionless. The both sides the force of the force moment is dissimilar, (Because at this time of force namely gravity, namely the object mass), accord the force moment change the concept of bulk of force.

Mankind at the earliest the discover the lever save labour, and subsequently the Rotation dynamics, the force moment varies the notion of the dimension of the force, namely in such statics equilibriumly phenomenon engender.

In non-inertia process of system, for instance in axletree in rotation rigid body, or the arm of force location of the certain dimension, have the time of friction force action. For overcoming the friction force, but plus the force moment in the force, also accord the force moment alter the force bulk principle. At this time at arm of force the more big the time, namely the thrust needful more small, namely more labor-saving.

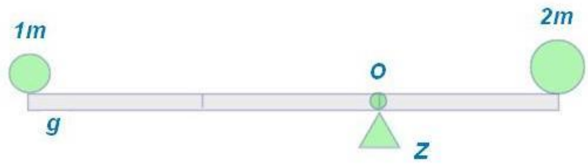

Figure 2. Statics equilibriumly the force moment

2.2. Dynamics the Inertia-torque in the meaning

When a turn system inside, nonentity analogy friction force such non-inertia force action the time, this system namely be unfit for in the force moment principle. This time and force moment have some alike, that is another parameter Inertia-torque: $G = md$ (2.2.1)

In an Inertia-torque system, force action is on the arm of force, be called the Inertia-torque force.

Inertia-torque force: $$F_{md} = md\frac{d\omega}{dt} = m\frac{du}{dt} \qquad (2.2.2)$$

By this expression espy, Inertia-torque force F_{md}, the action is m in the mass, force arm is the Inertia-torque of that d, generate that $\frac{d\omega}{dt}$ angular acceleration. F_{md} that two the subscript letter, namely denote the mass m respectively and force arm d.

By expression (1.2.2) can espy, if the value hold of the Inertia-torque is constant, that simply m and d these two values is oppositely to transformation the time, then at same angular acceleration $\frac{d\omega}{dt}$ the time, the value of the Inertia-torque force F_{md} also is immovability. It just varies, its subscript m and d opposite value.

This is very interesting, this explain when the force the Inertia-torque of action the time, regardless the point of action of the force is at how big the arm of force, the want to in creation same magnitude angular acceleration the time, the require force is alike magnitude. So differs of, nobbut the force arm big the time, the burthen the mass namely small. Moreover arm of force small the time, the burthen the mass namely big. Such plight, via in subscript md of F_{md}, namely can mark and display.

Therefore, for long time, rotation dynamics inside, concerning force moment change the concept of the magnitude of the force, is a mistake.(Unless the burthen of the force is a similar friction force like this of non-inertial force). Under mostly the circumstance, so-called changes the circumstance of the size of the force, the likelihood simply changed the mass of burthen of the force. Burthen the mass is big, namely think the force is big. Burthen the mass is small, namely think the force is small. But this is force so as to, a certain extent mass of object, the acceleration of the certain size in acquisition, namely: $F = ma$. of the definition is also irrelevant.

The expression(2.2.2) is applicably in, neglecting friction force and so on influence, the system of any rotation rigid body. Namely in the ordinary rotation rigid body system, the want to engender its an angular acceleration, a force for needing infliction F_{md}, regardless is to act in how big forces arm, the size of its force is all equally.

2.3. Lnertia-torque the mass and the burthen mass

Mass in the Inertia-torque, have verity subsistent, actual physics mass. As the figure 1, Inertia-torque: $G_1 = m \times 1d$, that m of the inside. As well as in the force arm, actually nought the actual physics mass. As $G_2 = xm \times 2d$, that xm of the inside. Namely is nonexistent. It fact is G_1 mass m, passing the force arm inverse ratio transform arrives that G_2 of, the mass of the mapping. It is in force action, in that G_2 the time, G_2 force arm versus force display is, the burthen mass of the equivalence.

Therefore in Inertia-torque, have actual mass, namely mass. For instance we shall its sign m. Also hadorwould via the mapped of force arm, equivalent the burthen mass, namely burthen mass. We can shall its sign m''.

Because of this reason, such as figure 1 the Inertia- torque, also should be been divided into two kind. For example, there is that G_1 of the true mass, and burthen mass of that G_2. We can sign G_1 as that G, sign G_2 as that G''. With show have or nought true mass.

When a rotation rigid body be constituted by a lot of particals, then among them of the Inertia-torque has that G, also there is G''. Also be likely to two kind, all have.

But, whichever G or G'', or m or m'', their dynamics attribute, namely they in turn tangent orientation inertia or force attribute, entirety is the same. In the computing of force, true the mass m , and burthen mass m'', is complete equivalence (Burthen mass m'', and true mass m , merely a little differ, namely it in turn normal orientation, nought inertial centrifugal force).

2.4. Total Inertia-torque of rigid body

The rigid body of the fixed-axis rotation, have the Inertia-torque decided. Namely: $G = md$.

If a rigid body of fixed-axis rotation, it be constituted by some particals. It of per a particle, have each of the mass m, and to the force arm d of the shaft. So the total Inertia-torque of this rigid body is:

$$G_z = m_1 d_1 + m_2 d_2 + \cdots\cdots + m_n d_n = \sum m_i d_i \tag{2.4.1}$$

In classical the dynamics of the Rotation, have concerning the definition of the moment of inertia: $I = \sum m_i r_i^2$.

This a definition, because it is from initial, concerning the error of the force moment, the deduce come out, therefore it also is wrong. Use it come to indicate the inertia of rotor, meaning that is comparatively ambiguous.

2.5. The centroid-moment of the rotation rigid body

The total Inertia-torque of the rotation rigid body is:

$$G_z = \sum m_i d_i \tag{2.5.1}$$

But the centroid-moment of the rotation rigid body, is the rigid body the mass of total that m_z, and the product of the force arm d_x, is equal to the total Inertia-torque G_z.

Namely:

$$G_{zx} = m_z d_x = \sum m_i d_i \tag{2.5.2}$$

In expression inside that G_{zx} namely representative the centroid-moment. G that two subscript z and x, representative the overall mass m_z and the force arm d_x.

We have obviously: $$d_x = \frac{(\sum m_i d_i)}{m_z} \qquad (2.5.3)$$

Namely overall Inertia-torque G_z by overall mass m_z divide, gained force arm d_x, namely is rigid body centroid-moment G_{zx}, the only of compare of force arm. Because that d_x is only, so to it the definition centroid-arm. By endpoint of centroid-arm, line out the lineation of round or arc, namely commissary the centroid of rotation of the rigid body.

The total Inertia-torque of the rigid body, is a constant. thereby toward centroid-arm d_x excluding, any other force arm d_i.

Should have: $$G_z = m_{zf}'' d_t = \sum m_i d_i \qquad (2.5.4)$$

∴ $$m_{zf}'' = \frac{(\sum m_i d_i)}{d_t} \qquad (2.5.5)$$

In expression inside, d_t is dx outside, the certain a force arm, m_{zf} " is toward total Inertia-torque G_z and force arm d_t, the overall burthen mass of the equivalence of the force.

By expression (2.5.5) know, on the rotation rigid body, in while taking the dissimilarity force arm, in the overall burthen mass of the force arm endpoint, according to the inverse proportion change of the force arm change. Namely force arm if change Q multiple, overall burthen mass namely change $1/Q$ multiple. The arm of force if augment, overall burthen mass namely minish. Vice versa.

Therefore, be that d_t at that > d_x, or< d_x in while of both sides change. When d_t> d_x and tends while infinite, m_z" tend nigh null. Contrarily in d_t<d_x and to infinitesimal, m_z" tend in infinity. In back a sort of circumstances, is force arm while tend nigh is 0, the equal the force through the rotation axis, thereupon regardless how big the force, the axis that also can't screw.

The expression (2.5.5) also indicate, in random rotation rigid body, adopt random force arm, in its the arm of force the endpoint, all have a assured rotation burthen mass. For the rotation of the rigid body, this burthen mass and the reality mass of the object, completeness is the equivalence. And is to can pass the mechanics measurement, the mensuration come out.

2.6. The rotation rigid body the linearity momentum and angular momentum

From expression (2.5.4) then: $$m_{zf}'' d_t = \sum m_i d_i \qquad (2.6.1)$$

If the angular velocity of the rotation rigid body is aω. so its rotation linearity momentum is:

$$P_x = m_{zf}'' \ d_t \omega = (\sum m_i d_i)\omega \qquad (2.6.2)$$

We awareness, m_{zf}" • d_t is equal to the total Inertia-torque G_z, is a constant. So for a rotation rigid body, at it of the angular momenta ω ascertains, then it of the rotation linear momentum is a P_x, is also a certainty quantity. Namely as if the above expression (2.6.2) shows.

Among them regardless with random force arm d_t value (as long as do not take 0 or infinity), the rotation linear momentum P_x is all immovability. Simply corresponding in d_t change, m_{zf} " pursuant inverse proportion change.

Within text, the total angular momenta of the concerning rotation system, is and within classical rotation dynamics of calculate methods of alike.

namely: $$P_x d_x = m_1 d_1^2 \omega + m_2 d_2^2 + \cdots\cdots = \sum m_i d_i^2 \omega \quad (2.6.3)$$

Hereinbefore is anent rotation of rigid body of, the Inertia-torque the show of concept. And it versus rotation dynamics the meaning in, and corresponding such as, the burthen mass of the Inertia-torque; the total Inertia-torque of the rigid body; the centroid-moment of the rigid body; the linear momentum of the rotation rigid body the angular momentum etc. A series of and new notion and the establishment of the principle. With the classical rotation dynamics theory, have the essential the differ. And point out, within classical rotation dynamics theory, the serious the error.

The textual point out, classical rotation dynamics, the principle of the concerning force moment, within the statics equilibriumly the still useable. When the rotation resistance is a not inertial force in quasi friction force, also still useable. But in the inertia interaction in matter, in occur while angular displacement and rotation, that not useable.

The notion of the Inertia-torque that textual adduce, chiefly compliant rigid body and the rotation of the rigid body. In partical dynamics, if the assistance member between none similarity lever and its principle, this notion also is meaningless. Thereupon textual of discuss, chiefly compliant rigid body and the rotation of the rigid body.

3. Transcend the Conservation law

The Conservation law is that can outdo of, look the hereinafter of the treatise.

3.1. Transcend the Law of Conservation of energy

According to the Inertia-torque the principle, and front 1.6 stanza adduce, the momentum of linear of rotation of that a rotation rigid body, is a constant quantity.

For example: $$P_x = m_{zf}" \ d_t \omega = (\sum m_i d_i)\omega \quad (2.6.2)$$

Regardless the force arm d_t takes any value (d_t and rotation radius R, theoretically at > 0 and < ∞ all can), its rotation linear momentum P_x nor change. Simply so as to burthen mass $m_{zf}"$, change with the reverse proportion that.

Now a miracle namely appear. The above instance indicate, a rotation rigid body, it along with the change of the force arm, will have the dissimilar rotation kinetic energy. In classical Rotation dynamics, the computing expression of the Rotation kinetic energy is:

$$W_x = \frac{\Delta m_1 u_1^2}{2} + \frac{\Delta m_2 u_2^2}{2} + \cdots = \frac{\Delta m_1 r_1^2 \omega^2}{2} + \frac{\Delta m_2 r_2^2 \omega^2}{2} + \cdots = \sum \frac{\Delta m_i r_i^2 \omega^2}{2} = (\sum \Delta m_i r_i^2 \omega^2)\frac{\omega^2}{2} \quad (3.1.1)$$

Thereupon by expression (2.6.2) got: $$W_x = \frac{m_{zf}" \ d_t^2 \omega^2}{2} = (\sum m_i d_i^2)\frac{\omega^2}{2} \quad (3.1.2)$$

Namely is with Inertia-torque the principle, the rotation kinetic energy of the rotation rigid body. By this expression can know, while Inertia-torque fixedness, along with the change of the force arm d, the rigid body will present the dissimilarity the rotation kinetic energy.

For instance, if force arm change Q double, this mass $m"$ to change $1/Q$ double.

Namely: $$W_x = \frac{m_{zf}{}'' \; d_t^2 \omega^2}{2} g \frac{Q^2}{Q} = \frac{m_{zf}{}'' \; d_t^2 \omega^2}{2} gQ \qquad (3.1.3)$$

So the rotation kinetic energy changed that Q double.

A rotation rigid body, in its different force arm, present the dissimilarity rotation kinetic energy. Thereupon a rotation rigid body, its the kinetic energy, not is single. It in fact along with the change of the force arm, but have multiple the kinetic energy of every kind of level. Moreover its value is what the dimension that is dissimilarity. When a system, energy that it have, is to have multi-distinctness values, you think that does it may be the Conservation of energy?

For example in parallelism move of a object, and collision of d t of force arm in a rigid body. Rigid body begin rotation, its rotation kinetic energy is: $W_x = \frac{m_{zf}{}'' \; d_t^2 \omega^2}{2}$ this is also this collision input that kinetic energy.

After this time. In here the force arm Q d t of the rigid body, make its collide with outer another object again. To here rotation kinetic energy: $W_q = \frac{m_{zf}{}'' \; d_t^2 \omega^2}{2} Q$, convey to by collide object.

In above course, the rotation rigid body the first the kinetic energy that input is: $W_x = \frac{m_{zf}{}'' \; d_t^2 \omega^2}{2}$, but after that, the kinetic energy of output is: $W_q = \frac{m_{zf}{}'' \; d_t^2 \omega^2}{2} Q$. Namely output's energy, that than input of the energy is big Q double. Thereupon, at this time of this rotation rigid body, namely not is energy conservation of, this also was beyond all doubt.

A rotation rigid body, it of near come the direction of the shaft, rotation kinetic energy that namely small. But the direction of its away from shaft, rotation kinetic energy that namely big. Thereupon, the rotation of any rigid body, all is that is rotation kinetic energy is not conservation of, thereupon is also is energy is not conservation.

3.2. Momentum is not conservation principle

The momentum is also would is not conservation. As the figure 3:

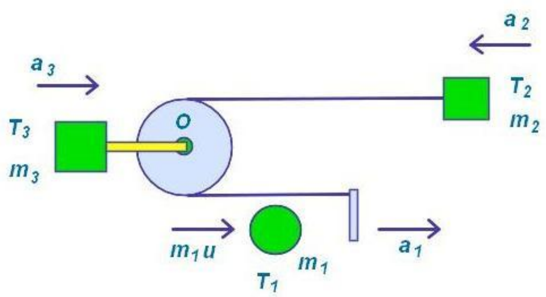

Figure 3. The system of the momentum is not conservation

There is T_1, T_2, T_3 three objects, the mass is m_1, m_2, m_3 respectively. Suppose figure interior, move pulley and pulley rope and other parts, the mass is null and none friction force.

While begin that, that T_1 from roundish left side with u velocity fly come. Hit the rope pulley the parts, namely fixedly on it. And pull the pulley rope, and pulley and T_2, T_3 all move arise.

The collision force of the for example above collision, in T_1, T_2, T_3 respectively is:

$$F_1 = m_1 a_1 , F_2 = m_2 a_2 , F_3 = m_3 a_3 .$$

According to the principle of Inertia-torque, the Inertia-torque force of the rotation rigid body, is not because force arm of change the change. Thereupon, hereinbefore each collision force the equivalency. Namely: $F_1 = F_2 = F_3$, and: $m_1 a_1 = m_2 a_2 = m_3 a_3$ (3.2.1)

Impulse the computing expression is:

$$I = \int_{t0}^{t1} F dt \qquad (3.2.2)$$

Because above three collisions the force the equivalency, the time of the collision also alike, so the force of three collisions the impulse also equivalency.

Namely: $I_1 = \int_{t0}^{t1} F_1 dt$, $I_2 = \int_{t0}^{t1} F_2 dt$, $I_3 = \int_{t0}^{t1} F_3 dt$. and: $I_1 = I_2 = I_3$ (3.2.3)

The impulse the sum of that for this collision course:

$$P_i = -I_1 - I_2 + I_3 = -I_1 = -\int_{t0}^{t1} F_1 dt \qquad (3.2.4)$$

Then the momenta change of the impact course:

$$P_i = -\int_{t0}^{t1} F_1 dt = -P_1 \qquad (3.2.5)$$

So hereinbefore concussion course, the system the total momenta occur that $-P_1$ change. But this course, the only systematic inside object acts mutually, but none external force from the outside of system of the action.

So this system, and this course, befallen the momentum is not conservation.

Textual author, concerning similarity figure 3 the system that show, proceed through the test of the physical experiment device. And collate the experiment data of the proceeded the measurement, testify the experiment is achieved the momentum is not conservation. But the experiment the hadorwould a question, namely the measurement data indicate, the experiment forming, of the momentum is not conservation, of that degree, that smaller above computing. Because experiment is at with the device of the equal mass, make its interaction moreover measure its operation consequential of method accomplish. So trow, experiment inside of that friction force affect, is be capable of by standoff. But the result of the experiment, yet bewildering.

By analysis of the depth, we detect. Friction force for toward the ordinary linearity move object, and similarity figure 3 the action of such move pulley device, is inconsistent. In back a situation, the friction force makes classical Rotation dynamics inside, the force moment varies the phenomemon of the dimension of the force, from the new presence. Thereupon it conduce, the result of the experiment is clearly smaller computing value.

So while experimenting slewing power system, need advert contain the friction force or other of non-inertial force of affect, but make it is on the certain degree, still having the force moment of the classical Rotation dynamics the principle speciality. This is to requires to take into the analysis and eliminate.

3.3. Realization the angular momentum is not conservation the method

Angular momentum is not conservation, is also can achieve.

Because the momentum is not conservation that of object is possible, the linear momentum of so a rotation body, too can is not conservation. As long as a rotation body the line momentum is not conservation, then it of angular momentum too can is not conservation.

To do that *R* of the rotation body constant, but make its rotation line momentum changed, so actualize angular momentum is not conservation.

Above dispart the three section, discussed the energy is not conservation, the momentum is not conservation, the angular momentum is not conservation of to the principle and method. The Conservation law of the physics, if we prove is can exceed. Also not is by entirety denial these law. Because in a lot of circumstances, or is yet under the plurality circumstance, these law is still the useable. Use that pass the law, can still make we, use the simple method, accomplish a lot of sciences operation accurately.

Certainly, seek and achieve, exceed the principle and method of conservation law. Is that a process that creates the miracle of science, will bring the science and physics the important progress.

4. Summing-up

Textual the proven, classical rotation dynamics inside, concerning moment of force the concept, only compliant statics equipoise, or the course of not inertial action force. But not compliant the inertial dynamics course. Compliant inertial dynamics course, is and moment concept similar Inertia-torque concept. Classical rotation dynamics, because primal moment concept error, after this, whole system info all come under influence. Make this system info in inside, that a lot of notions and cognition to is all wrong.

Promulgate of the principle of the new Inertia-torque, make rotation dynamics occur prodigiouss change. Moreover generates that some new phenomemon, that past none detect. For instance energy is not conservation, and actualize the momentum is not conservation the method, and actualize the angular momentum is not conservation the method, etc. Therefore, this is one grand science advancement, and scientific fruit.

References:

[1]《natural science important event year gnomon》 compile team. 1975.7 natural science important event year gnomon. *Shanghai: Shanghai People's publishing organization* (in Chinese) [《自然科学大事年表》编写组. 1975.7. 自然科学大事年表. 上海：上海人民出版社]

[2] Guo Yiling, Sen Huijun. 2005.8 Physics history. *Beijing: Chinhua university publishing organization* (in Chinese)[郭奕玲，沈慧君. 2005.8 物理学史. 北京：清华大学出版社]

[3] [US] F·Calorie. 2010.4 Physics history. Dai Nianzu. *Beijing: Chinese People's university publishing organization* (in Chinese)[[美]弗・卡约里. 2010.4 物理学史. 戴念祖译. 北京：中国人民大学出版社]

[4] [D]Horst Stocker. 2004.1 Physics handbook. Wu Xizen, Li Zuxia, Cen Siping. Beijing: *Beijing university publishing organization* (in Chinese)[[德]Horst Stocker. 2004.1 物理手册. 吴锡真，李祝霞，陈师平 译. 北京：北京大学出版社]

[5] Xu Longdao. 2004.5 Physics lexicon. *Beijing: science publishing organization* (in Chinese) [徐龙道编著. 2004.5 物理学词典. 北京：科学出版社]

[6] D.Halliday, R.Resnick. 1979.5 Physics foundation. Zeng Yongling. *Beijing: Higher education publishing organization* (in Chinese)[D. 哈里德，R. 瑞斯尼克. 1979.5 物理学基础(上册). 郑永令译. 北京：高等教育出版社]

[7] Cheng Souzu, Jiang Ziyong.1961.8 Common physics. *Beijing: People's education publishing organization* (in Chinese)[程守洙，江之永.1961.8 普通物理学(第一册). 北京：人民教育出版社]
[8] Qin Jiahua.1993.1 Classical mechanics. *Hefei: Chinese science technology university publishing organization* (in Chinese)[秦家桦.1993.1 经典力学. 安徽合肥：中国科学技术大学出版社]
[9] Yu Quanxun, Lin Mingxi, Xue Cengsan.2000.1 Mechanics conspectus. *Beijing: science publishing organization* (in Chinese)[于全训，林明喜，薛成山.2000.1 力学概论. 北京：科学出版社]
[10] Cheng Jiafu.2000.1 mechanics. *Beijing: science publishing, Anhui: Chinese science technology university publishing organization* (in Chinese)[程稼夫.2000.1 力学. 北京：科学出版社，安徽：中国科学技术大学出版社]
[11] Zang Sanhui, Wang Huzu.1990.8 mechanics. *Beijing: Chinhua university publishing organization* (in Chinese)[张三慧，王虎珠.1990.8 力学. 北京：清华大学出版社]
[12] Zeng Yongling, Jia Qimin.1989.10 mechanics. *Shanghai: Fudan university publishing organization* (in Chinese)[郑永令，贾起民.1989.10 力学（上册）. 上海：复旦大学出版社]
[13] [US] J.B.Marion.1985.12 Classical dynamics of particle and system. Li Seng. *Beijing: Higher education publishing organization* (in Chinese)[[美] J.B.Marion .1985.12 质点与系统的经典动力学. 李笙译. 北京：高等教育出版社]
[14] W. Hausi.1987.2 Mechanics principle introduction. Ling Zenfang, Guo ru. *Tianjin: Nankai university publishing organization* (in Chinese)[W.豪瑟.1987.2 力学原理导论. 凌振芳，郭儒 译. 天津：南开大学出版社]
[15] Li Qingbo, Kang Cong.2002.3 university physics experiment. *Harbin: Heilongjiang science technology publishing organization* (in Chinese) [李庆波，康崇.2002.3 大学物理实验. 哈尔滨：黑龙江科学技术出版社]
[16] Jiang ying, An Wenyu, Wang Guorong.2002.3 Common physics experiment. *Harbin: Harbin industry university publishing organization* (in Chinese)[江影，安文玉，王国荣.2002.3 普通物理实验. 哈尔滨：哈尔滨工业大学出版社]
[17] Duan Jihui, Xu Conglan, Meng Zaomin.1987.5 physics demo experiment handbook. *Jinan: Sandong education publishing organization* (in Chinese)[段吉辉，徐从兰，孟昭敏.1987.5 物理学演示实验手册. 济南：山东教育出版社]
[18] Wikipedia. Momentum . http://en.wikipedia.org/wiki/Momentum#Conservation_of_momentum [2012-5-20]
[19] 万云芳，冯祝. 求解坐标-动量耦合体系的方法[J]. 山东师大学报(自然科学版)，1997，12(1)：98-101.
[20] 胡先权，丁朝远. 空间平移不变性与动量守恒的严格证明[J]. 重庆师范学院学报(自然科学版)，2001，18(3)：5-8.
[21] 谢国亚. 在气垫导轨上验证动量守恒定律的误差分析[J]. 重庆邮电学院学报，1998，10(3)：87-88.
[22] 张操. 关于相对论中的质量和动量[J]. 中国传媒大学学报自然科学版，2009，16(3)：24-26.
[23] 邵国建，苏静波. 带转动自由度的内参型非协调元研究[J]. 计算力学学报，2005，22(1)：59-63.
[24] 唐军杰，王爱军，赵昆，张鹏. 变转动惯量刚体定轴转动的数值研究[J]. 内蒙古师范大学学报(自然科学汉文版)，2012，41(2)：187-190.
[25] 于全训. 定轴转动基本方程[J]. 山东师大学报(自然科学版)，1998，13(4)：456-457.
[26] 姜玉明，蔡敏. 刚体定点转动的两种解题方法[J]. 沈阳师范学院学报(自然科学版)，1999，(2)：20-22.
[27] 高坚，佟明安，贺昌政. 刚体转动渐进跟踪控制的逆系统方法[J]. 电子科技大学学报，2002，31(2)：141-144.
[28] 宋洪训. 关于定轴转动刚体的动量矩[J]. 山东师大学报(自然科学版)，1998，13(3)：329-330.