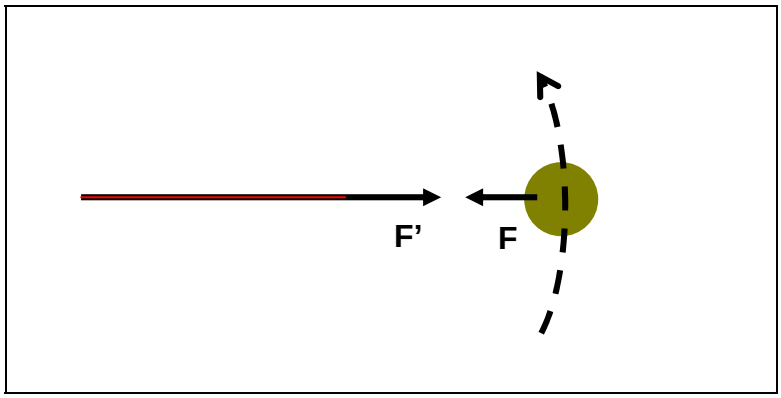
離心力是向心力的反作用力嗎？

把小球繫在繩端，然後把它旋轉作圓周運動。 若忽略重量，繩的張力是作用於小球，提供它作圓周運動用的向心力。繩拉小球，小球拉繩。所謂『離心力是向心力的反作用力』即是圖中的 F' (F 的反作用力) 就是離心力。



<u>這說法的根據</u>

1. 顧名思義，『離心力』是一個方向指離中心的力。

2. 上圖顯示的向心力的反作用力 (F') 的方向是指離中心的。所以，F'就是離心力。

<u>物理學普遍對此的觀點</u>

1. 國內、外不少學者<u>均沒有認同</u>以上看法。

1.1 網站 A Glossary of Frequently Misused or Misunderstood Physics Terms and Concepts. By Donald E. Simanek, Lock Haven University.
http://www.lhup.edu/~dsimanek/glossary.htm
"Centrifugal force. When a non-inertial rotating coordinate system is used to analyze motion, Newton's law F = ma is not correct unless one adds to the real forces a fictitious force called the centrifugal force. The centrifugal force required in the non-inertial system is equal and opposite to the centripetal force calculated in the inertial system. Since the centrifugal and centripetal forces are concepts used in two different

formulations of the problem, they cannot in any sense be considered a pair of reaction forces. Also, they act on the same body, not different bodies."

1.2 Fermi Laboratory 的網站

http://www.fnal.gov/pub/inquiring/questions/centripetal.html

" Now we understand, that the centripetal force acting on B causes its circular motion. But where is the centrifugal force??? What is it? The third Newton's law says: If A acts on B by a force, B acts on A by another force, called the reaction force, which has the same magnitude but opposite direction. Many people confuse the centrifugal force with this reaction force acting ON A BY B. (As an illustration of the reaction force, just remember, that if you rotate a ball (B) on the end of a rope, your hand (A) FEELS a force, which is the reaction force to the centripetal force.) Please remember, this reaction force is not the centrifugal force introduced by physicist. ……."

1.3 Physics, Volume 1, Fourth Edition (Author: Resnick, Halliday, Krane, Publisher: Wiley 1992, Page 118)

"Riding on a merry-go-round, you are again in a accelerated and therefore noninertial frame in which objects will apparently move outward from the axis of rotation under the influence of the centrifugal force. If you hold a ball in your hand, it seems to you to be in equilibrium, the outward centrifugal force being balanced by the inward force exerted on the ball by your hand. To a ground observer, who is in an inertial reference frame, the ball is moving in a circle, accelerating toward the center under the influence of the centripetal force you exert on it with your hand. To a ground observer, there is no centrifugal force because the ball is not in equilibrium: it is accelerating radially inward."

1.4 The Feynman Lectures on Physics, Volume 1 (Author: Feynman, Leighton, Sands, Publisher: Addison-Wesley, 1963, Page 12-11)

"Another example of pseudo force is what is often called "centrifugal force." An observer in a rotating coordinate system, e.g. in a rotating box, will find mysterious forces, not accounted for by any known origin of force, throwing things outward toward the walls. These forces are due merely to the fact that the observer does not have Newton's coordinate system, which is the simplest coordinate system."

1.5 Mechanics,Third Edition(Author:Symon, Publisher: Addison-Wesley 1977, Page 279)

"A great deal of confusion has arisen regarding the term "centrifugal force." This force is not a real force, at least in classical mechanics, and is not present if we refer to a fixed coordinate system in space."

1.6 The Encyclopedia of Physics, Third Edition (Edited by Robert M.Besancon, Publisher: Van Nostrand Reinhold, 1984, Page 1080)

"It should be noted here that the concept of centripetal force is much preferred by physicists to that of centrifugal force. In fact, the latter term is denied and labeled as fictitious in some treatments of the subject. However, this negative attitude may be justified only when the observer of the motion is in an inertial frame of reference. Centrifugal forces have a proper place in noninertial reference frames."

2. 偶見在一些物理教育書刊出現的見解：

2.1 在圓周運動者為參考座標，所看到的假力 (pseudo-force, fictitious force, apparent force) 是離心力。但更貼切的應稱它為「慣性離心力 (inertial centrifugal force)」。

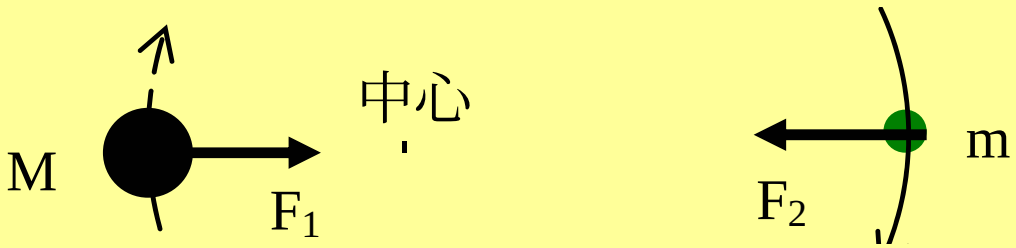
2.2 向心力的反作用力也是離心力。為了與慣性離心力區分，這個力應簡單稱為 「離心力 (centrifugal force)」。

這是「兩種離心力」說法，有問題嗎？

稱向心力的反作用力為「離心力」是說不通的，因為此力的方向根本就不一定是離心 ！

考慮下例，看看向心力的反作用力有否資格被稱為離心力？

兩個物體 M 和 m，利用它們相互之間的萬有引力，令大家一齊繞著系統的質心轉。



M 受到的向心力是 F_1；m 受到的向心力是 F_2。 F_1 是向心力，它的反作用力是 F_2。但 F_2 也是指向中心，而不是指離中心。這例中，向心力的反作用力不是離心的！

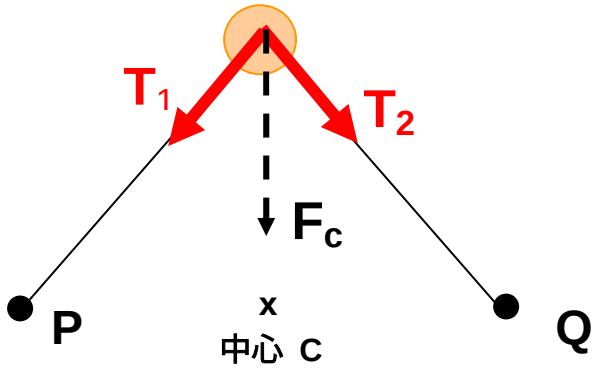
連「離心」這個起碼的資格也不一定有，硬要說它是「離心力」，是否有點牽強？

一個科學概念必須具普遍性。「向心力的反作用力是離心力」似乎不合這標準。

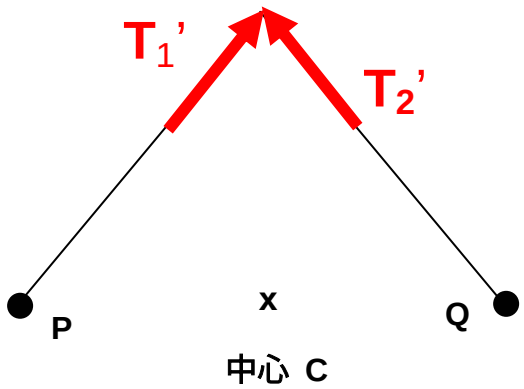
再者，向心力不一定有一個實在的反作用力！

向心力作用在進行圓周運動的物體上，但可以是沒有一個別物體是受其反作用力作用的。

例：如圖所示，物體受兩繩拉着，每條繩給予物體的張力（T_1 和 T_2）的矢量和是 F_C 。物體繞 C 旋轉；F_C 就是此圓周運動所需的向心



T_1 和 T_2 的反作用力（T_1' 和 T_2'）分別作用在那裡？



P 受的力是 T_1' ；Q 受的力是 T_2' 。 T_1' 和 T_2' 均不是離心力。

T_1' 和 T_2' 的矢量和才是「向心力的反作用力」。但這個力根本毫無物理意義(研究甚麼物體會用上此力？)， 硬說這是「離心力」，合理嗎？

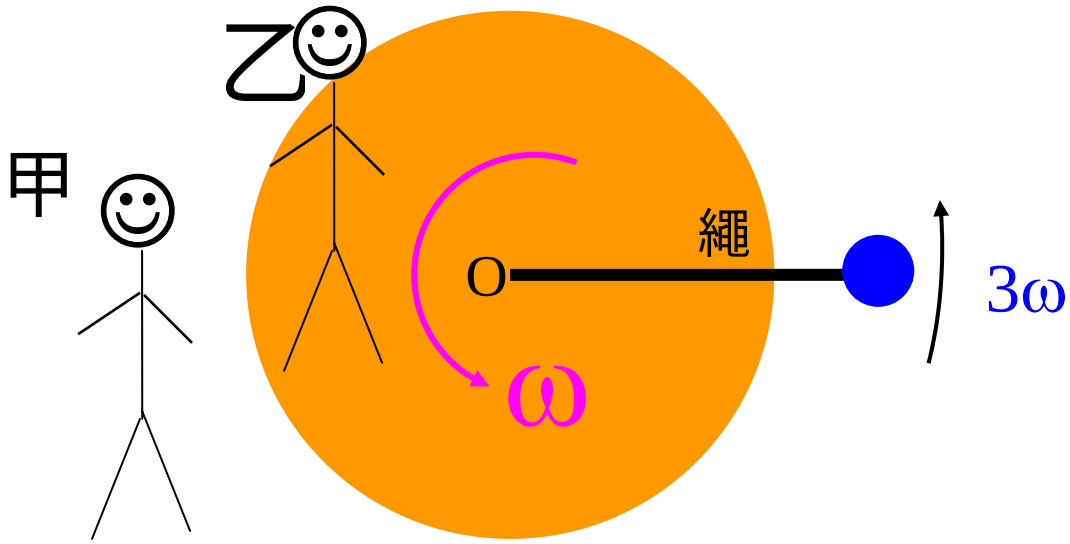
總括，「向心力的反作用力」可以是

1. 不離心；
2. 不具物理意義。

有甚麼道理稱此力為離心力呢？

(以下只適合高程度讀者)

最後，我再把提供另一例，給大家思考。



圖中，一個以 O 為中心、並以 3ω 逆時針轉動的小球(藍色)。另外，一個以 O 為中心以 ω 逆時針轉動的圓盤(橙色)。圓盤的轉動與小球

的轉動無關。

甲是站在地面的觀察者，他看見小球以 3ω 轉動。所以小球受到的向心力是 $m(3\omega)^2r = 9m\omega^2r$。此力來自繩的張力，所以小球作用於繩的力也是 $9m\omega^2r$ (向外)。

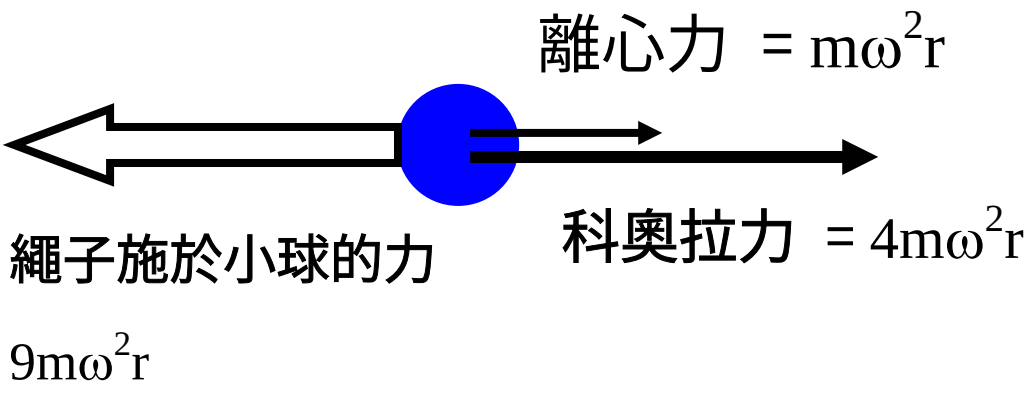
乙是站在圓盤的觀察者，因此乙並不是一位慣性觀察者；他是一名非慣性觀察者 (non-inertial observer) 。乙看見小球的運動不符合牛頓定律。若要符合，就要引入假力 (pseudo-force) 。假力中除了大家認識的離心力 (centrifugal force)， 還有一個是高中同學少認識的科奧拉力 (Coriolis force) (學習颱風的形成，必涉及此力)。

在一個以 ω 轉動的加速參考系統中觀看，所有東西都多受

- 離心力 (centrifugal force) 作用： $m\omega^2r$ (m 是該物件的質量， ω不是該物件的角速，而是觀察者的角速)

- 科奧拉力 (Coriolis force) 作用： $-2m\vec{\omega} \times \vec{v_r}$ (m 是該物件的質量， ω是觀察者的角速，v_r 是非慣性觀察者看見小球 m 的速度)。在上圖，乙看見小球是以 $2\omega r$ 的速度向上行走。所以小球受到的科奧拉力是 $4m\omega^2r$ (向外) 。

乙看見小球受的力：



所以乙看見小球受到的淨力是 $9m\omega^2r - m\omega^2r - 4m\omega^2r = 4m\omega^2r$ (指向圓心)。合理嗎？合理！因為乙是看見小球以 $3\omega - \omega = 2\omega$ 轉動。所以乙看見小球受的淨力就是乙轉動所需的向心力 $m(2\omega)^2r = 4m\omega^2r$。

以乙觀看，小球的離心力是 $m\omega^2r$，但小球的向心力是 $4m\omega^2r$。

離心力是向心力的反作用力嗎？

(1) 此處，離心力是 $m\omega^2r$，向心力是 $4m\omega^2r$。連數值也不相同，它們可以是作用力與反作用力的關係嗎？

(2) 這裡的向心力部份來自假力。眾所周知，假力是沒有反作用力的。即是，此處的向心力就是沒有反作用力！

硬要說：『向心力的反作用力是離心力』只會造成概念矛盾、誤導學生、觀念大混亂。

相關文章：甚麼是向心力？甚麼是離心力？

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