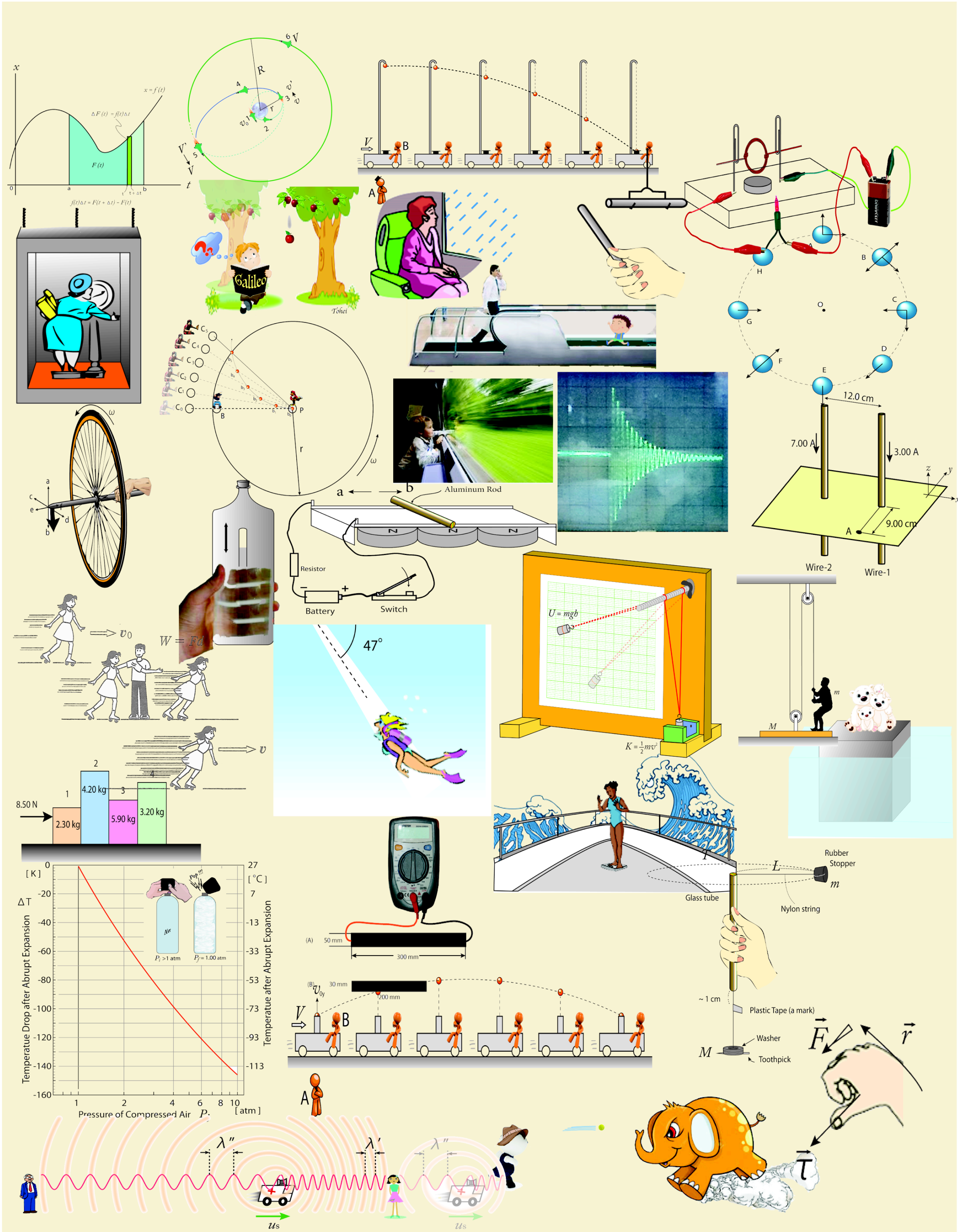
12^{th} Physics 1

Motion

2019-20



Keio Academy of New York

A Yearly Schedule

Chap	Walker "Physics		Test
(1,2)	(Introduction to Physics, 1-D Kinematics)		
3	Vectors in Physics	Packet-#1	1Q-#1
(4,5,6)	(2-D Kinematics, Newton's Laws of Motion, Applications)		
6-5	Circular Motion + Extra(Inertial Forces)	Packet-#1	1Q-#1
(7,8)	(Work and Kinetic Energy, Potential Energy)		
9	Linear Momentum and Collisions	Packet-#2	1Q-#2
10	Rotational Kinematics and Energy	Packet-#3	1Q-Ex
11	Rotational Dynamics and Static Equilibrium	Packet#3	2Q-#1
12	Gravity		2Q-#2
13	Oscillations about Equilibrium		2Q-#2
(14)	(Wave and Sound)		
14-3	Harmonic Wave Functions		2Q-#2
15	Fluids		2Q-Ex
(16)	(Temperature and Heat)		
17	Phases and Phase Changes		2Q-Ex
18	The Laws of Thermodynamics		3Q-#1
(19)	(Electric Charges, Forces, and Fields)		
19 5-7	Electric Field Lines, Gauss's Law		3Q-#2
20	Electric Potential and Electric Potential Energy		3Q-#2
(21)	Electric Current and Direct-Current Circuits)		
21 5-7	Kirchhoff's Rules, RC Circuits		3Q-Ex
22	Magnetism		4Q-#1
23	Magnetic Flux and Induction		4Q-#1
24	Alternating-Current Circuits		4Q-#1
25	Electromagnetic Waves		4Q-#1
(26,27)	(Geometrical Optics, Optical Instruments)		
28	Physical Optics: Interference and Diffraction		4Q-#1
29	Relativity		4Q-#2
30	Quantum Physics		4Q-#2
31	Nuclear Physics and Nuclear Radiation		4Q-Ex

Introduction to Physics

I-3 Dimensional Analysis

I-6 Order-of-Magnitude Calculation (Fermi Problems)

1. How many golf balls does it take fill a Boeing 747?

2. [#36] Give a ballpark estimate of the number of seats in a typical major league ballpark?

3. [#37] Milk is often sold by the gallon in plastic containers. (a) Estimate the number of gallons of milk that are purchased in the United States each year. (b) What approximate weight of plastic does this represent?

4. [#38] New York is roughly 3000 miles from Seattle. When it is 10:00 A.M. in Seattle, it is 1:00 O.M. in New York. Using this information, estimate (a) the rotational speed of the surface of Earth. (b) the circumference of Earth, and (c) the radius of Earth.

5. [#39] You've just won the $12 million cash lottery, and you go to pick up the prize. What is the approximate weight of the cash if you request payment on (a) quarters or (b) dollar bills?

6. How many piano tuners are there in Chicago?

7. How many electrons pass through a MacBook Air during the time it takes the lap top to consume a million joules?

Motion

III. Vectors in Physics

1. Vector - Diagram

2. A vector and its components $A_x = A\cos\theta, \quad A_y = A\sin\theta$

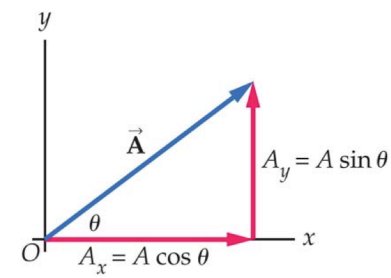
3. Adding and Subtracting Vectors

$$\vec{C} = \vec{A} + \vec{B} \quad \rightarrow \quad C_x = A_x + B_x, \quad C_y = A_y + B_y$$

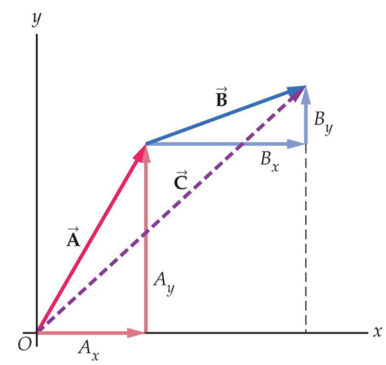
4. Components → Magnitude and Direction

$$C_x\,,\ C_y \quad \rightarrow \quad C = \sqrt{{C_x}^2 + {C_y}^2}, \quad \theta = \tan^{-1}\frac{C_y}{C_x}$$

1. Vector - diagram



2. Components



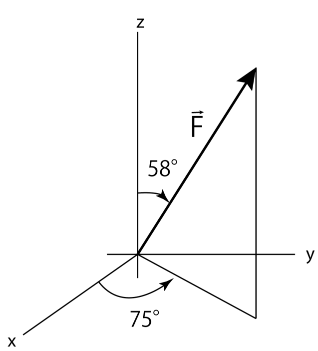
3. Addition

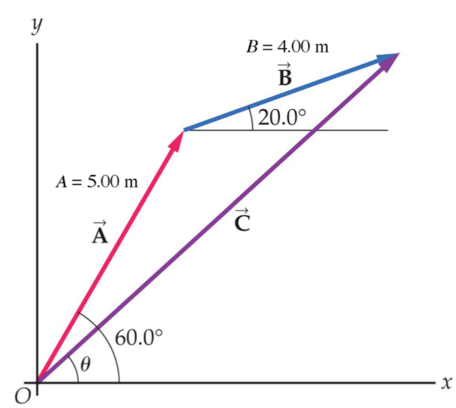
[Q1] Find A_x and A_y for the vector $\vec{A}$ with magnitude and direction given by $A = 3.5$ m and $\theta = 66^\circ$, respectively.

[Q2] Find B and θ for the vector $\vec{B}$ with components Bx $= 75.5$ m and By $= 6.20$ m.

[Q3] In Fig. Q3, find C and θ for the vector $\vec{C}$ where $\vec{C} = \vec{A} + \vec{B}$.

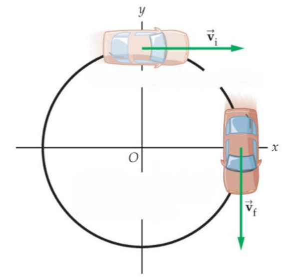
[Q4] In the figure below, the magnitude of $\vec{F}$ is $F = 65$ m. Find tits components.



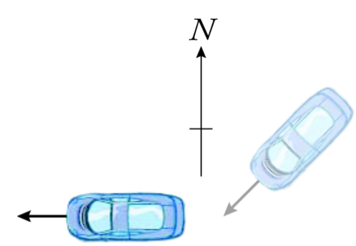


(Q10) A car is traveling to due east at 10.0 m/s. 15.0 seconds later it has rounded a corner and is now heading due south at 10.0 m/s. What are the magnitude and direction of its average acceleration during those 15.0 seconds?

(Equations



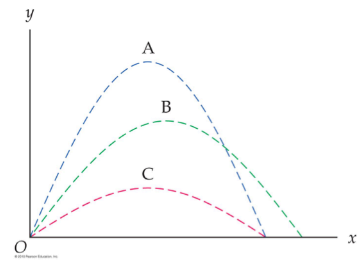
(Q11) A car is traveling to southwest at 11.0 m/s. 15.0 seconds later it has rounded a corner and is now heading west at 12.0 m/s. What are the magnitude and direction of its average acceleration during those 15.0 seconds?
(Equations)



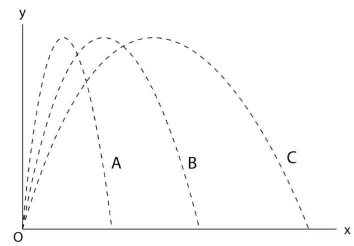
IV. Two-Dimensional Kinematics

4-5. Projectile Motion: Key Characteristics

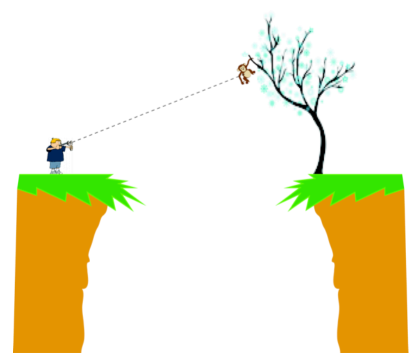
[Q5] Three projectiles (A, B and C) are launched with the same initial speed but with different launch angles, as shown. Rank the projectiles in order of increasing
(a) horizontal component of initial velocity and
(b) time of flight.



[Q6] Three projectiles (A, B and C) are launched with different initial speeds so that they reach the same maximum height, as shown. Rank the projectiles in order of increasing (a) initial speed and (b) time of flight.



[Q7] (Monkey and the Hunter) A hunter fires a dart gun with a harmless sedative at a monkey hanging from a vine a distance h vertically above the dart gun and a distance R horizontally away from the dart gun. The hunter aims directly at the monkey and fires, but just as the hunter fires, the monkey, using its incredible spider-monkey sense, realizes what's up and drops from the vine. Does the monkey avoid the dart?



IV. Newton's Laws of Motion
V. Applications

(Some Selected Problems)

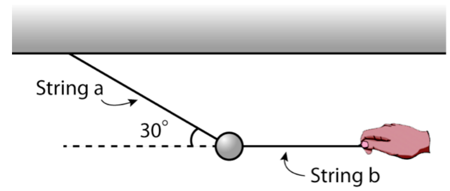


Fig. 29

[Q29] A 1.0 kg object is supported with two strings, a and b.　The string b is kept horizontally.　Find the magnitudes of the tensional forces for the strings, a and b.

[Q30] A light rope is passed over a light and frictionless pulley, and a 20.0 kg stand is connected to the one end of the rope, as shown in the figure.　A 70.0 kg person rides on the stand and pulls the other end of the rope.　(1) Draw the forces acting on the person.　(2) Find the magnitude of the force, exerted by the person, enough to lift off the ground.

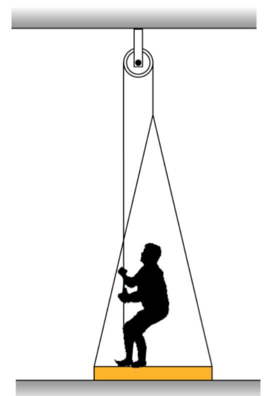


Fig. 30

[Q37] An object of a mass M [kg] on a level and rough surface is continued to pull with a force of T [N] to the right to cause a motion at a constant acceleration rate of a [m/s^2] to the right.　Find the acceleration rate supposing the gravitational acceleration rate as g [m/s^2] and the coefficient of kinetic friction between the board and the object as μ'.

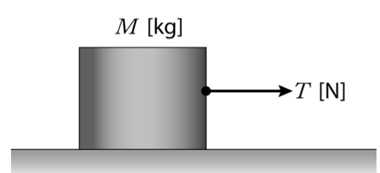


Fig. 37

[Q38] An object on a level and rough surface is slid with an initial speed of v_0. Assume that the coefficient of kinetic friction is μ' and the gravitational acceleration rate is g [m/s^2].

(a) What is the acceleration rate assuming the direction of the initial speed is positive.

(b) What distance does the object side to stop?

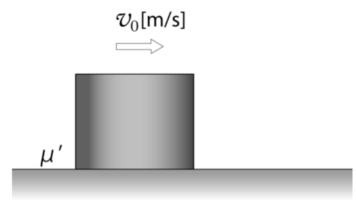


Fig. 38

[Q51] An object of mass m is placed on a board. A force is exerted on the object at an angle of α above the horizontal. When the magnitude of the force reaches F, the object begins to slide. Find the magnitude of F assuming the coefficient between the board and the object is μ.

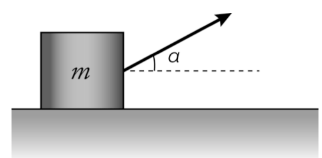


Fig. 51

[Q41] When an object is place on a inclined surface at an angle of θ, it slides down from rest at a constant acceleration rate a. Assume that the coefficient of kinetic friction between the object and the inclined surface is μ' and the gravitational acceleration rate is g.

a) Draw a free-body diagram.

b) Find the acceleration rate a.

c) Find the time the object slides in the distance L.

d) Find the velocity v when the object slides in a distance L.

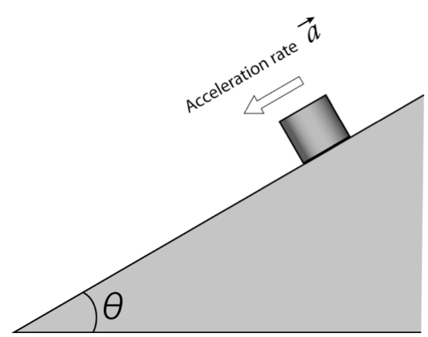


Fig. 41

[Q52] Two blocks, whose mass is M and m, are connected by a string, as shown in the figure. The smooth inclined surface makes an angle θ with the horizontal, and the block on the incline has a mass of M. Assume that the pulley is ideal.
a) Find the mass of hanging block that will cause the system to be in equilibrium.
b) When the block B moves downward, find the acceleration rate.

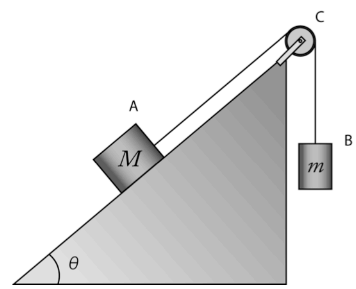


Fig. 52

[Q54] A level board of mass M is on the level and frictionless surface, and an object of mass m is on the board. Assume that the coefficient of static friction between the two is μ' and the gravitational acceleration rate is g.
The board is pulled with a string. Find the maximum acceleration rate on the condition that no slippage occurs between the object and the board.

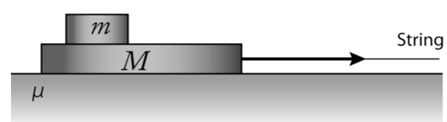
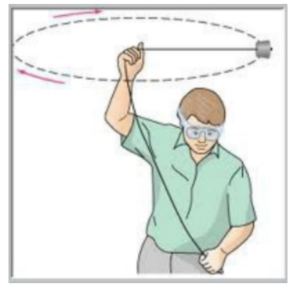


Fig. 54

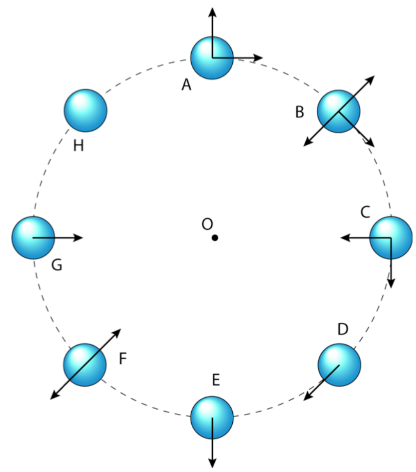
Circular Motion, Inertial Forces

[Mini-Lab #01] Circular Motion



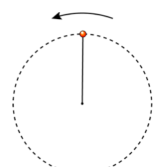
1. The direction of force in circular motion

[Q11] The figure shows a body undergoing circular motion with a constant speed on a table. Which combination of arrows represents the forces exerting the body?



[Q12] a) A ball on a string is swinging in a circle in uniform circular motion to the direction shown in the figure. (1) Draw arrow(s) representing force(s) exerting on the ball.

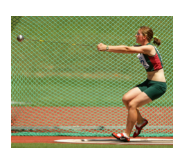
(2) If the string snaps, which direction is the ball flying to?


a

b) If you spin your wet unbrella, which direction are water drops flying to?


b

c) In the hammer throw, which direction is the hammer flying to?

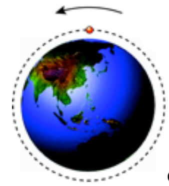

c

[Q13] Find what is working as the centripetal force in the following motion:

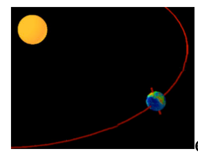
c) The hammer in the hammer throw


c

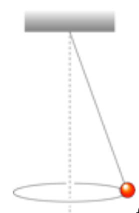
d) A satellite circulating around the Earth closely on its surface


d

e) The revolution of the earth


e

f) The circular motion of conical pendulum.

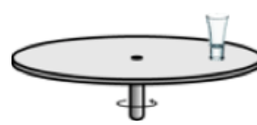

f

[Mini-Lab #02] Conical pendulum

g) A person riding a roller coaster


g

h) A cup circulating on a table inside a microwave oven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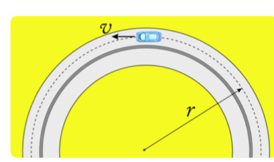
[Mini-Lab #03] An object on a rotating plate

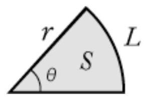
i) A car travelling on a horizontal circular track



i

1. Angular Position θ [rad] radian [rad]

$\theta = \frac{L}{r}$, $L = r\theta$



θ> 0 CCW, θ< 0 CW

360°= 2π[rad] $S = \frac{1}{2} r^2 \theta$

2. Average Angular Velocity $\omega_{av} \equiv \frac{\Delta\theta}{\Delta t}$ [rad/s]

3. (Instantaneous) Angular Velocity $\omega \equiv \lim_{\Delta t \to 0} \frac{\Delta\theta}{\Delta t}$ [rad/s]

4. Circular motion with a constant speed Period T [s] $T = \frac{2\pi}{\omega}$

Revolution n [revolution/s, Hz] $T = \frac{1}{n}$

$\omega = \frac{2\pi}{T} = 2\pi n$

5. Tangential Speed $v = \frac{2\pi r}{T} = 2\pi r n = r\omega$

2. Radian

[Q2-1] Convert 72°to rad.

[Q2-2] Find the area of an arc with a radius of 1.0 m and an angle of 72°.

[Q2-3] Find the area and the length of arc in an arc with a radius of 1.0 m and an angle of 3.0 rad.

3. Circular Motion

Angular displacement
Average angular velocity
Angular velocity
Angular acceleration

4 . Uniform circular motion

[Q4-1] Find the followings for an object moving at the rate of 10 times every 5.0 second on a circle with a radius of 0.40 m.

a) Number of revolution
b) Period
c) Angular velocity
d) Tangential speed

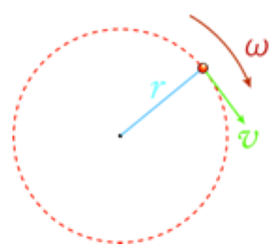


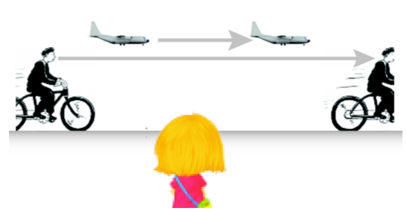
Fig. 4-1

[Q 4 -2] Find the followings:

a) The angular velocity or the revolution of the Earth.

b) The angular velocity or the rotation of the Earth.

[Q4-3] Which and how much is larger in angular velocity, a bike traveling at 20 km/hr and 2.0 m apart or an airplane flying at 1000 km/hr at a height of 10000 m.



[Q7-1] A 0.10 kg mass attached to a string undergoes uniform circular motion with a radius of 0.25 m on a horizontal frictionless surface.

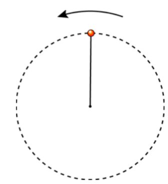


Fig. 7-1

a) What force is working as a centripetal force?

b) Find the magnitude of centripetal acceleration and centripetal force when the mass is moving at 2.0 m/s.

c) The string breaks when the tensile strength more than 19.6 N is exerted. (c-1) Find the number of revolution when the string breaks. (c-2) Find how fast and to which direction the mass flies at the moment the string breaks.

[Q7-2] Find the least velocity and period of a projectile to keep the orbit around the Earth and close to its surface. (The first cosmic velocity)

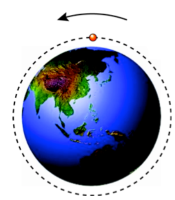


Fig. 7-2

[Q7-3] An object with a mass of 0.20 kg is placed at a position 0.60 m far from the center of a horizontal disk where the static frictional coefficient is 0.55 between the object and the disk. The disk is gradually increased in a rotation speed. Find the angular velocity when the object starts to move.

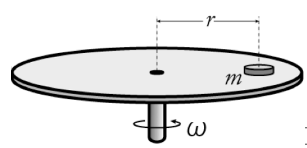


Fig. 7-3

([Mini-Lab #03] An object on a rotating plate)

[Q7-4] A car is travelling at a uniform speed along the curved highway. Draw arrows showing the direction and comparative magnitude of the force exerting on the car.

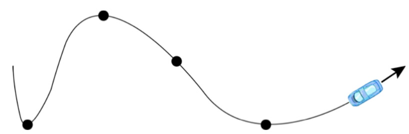


Fig. 7-4

[Q7-5] A 1200-kg car rounds a corner of radius $r = 45$ m. If the coefficient of static friction between the tires and the road is $\mu_s = 0.82$, what is the greatest speed the car can have in the corner without skidding?

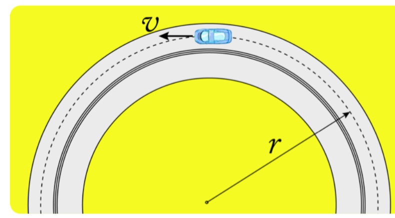


Fig. 7-5-A

Fig. 7-5-B

[Q7-6] If a roadway is banked at the proper angle, a car can round a corner without any assistance from friction between the tires and the road. Find the appropriate banking angle for a 900-kg car travelling at 20.5 m/s in a turn of radius 85.0 m.

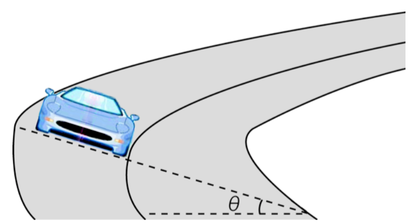


Fig. 7-6

**[Q7-7] Turns

a) b) c) d) e) f)

[Q7-8] A conical pendulum consists of a bob with a mass of m fixed on the end of a string with a length l. The bob moves at a constant speed in a circle with the string tracing out a cone where the angle of the string is θ relative to the vertical direction.

a) What force works as a centripetal force?
b) Express the following quantities using m、g、l and θ
   i) The tension of the string S
   ii) The magnitude of the centripetal force F
   iii) The speed of the bob v
   iv) The period of the bob T

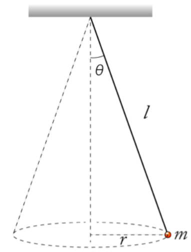


Fig. 7-8

([Mini-Lab #02] Conical pendulum)

[Q7-9] In a hollow cone where its vertex points downward vertically and the inner surface is frictionless, a small ball with a mass m [kg] undergoes a uniform circular motion at the height of l [m] from the vertex. Find the period T [s] of this motion.

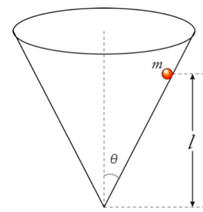
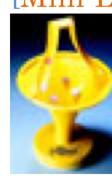


Fig. 7-9

[Mini-Lab #04] Vortex



[Mini-Lab #05] Rotating ring

[Q7-10] A 0.35 kg small ball has a hole, passes a wire ring with a radius of r = 0.45 m through the hole, and can move along a wire ring. When the wire ring rotates around the vertical axis passing through the center of the ring, the ball moves the wire. Assume that the friction between the ball and the wire is negligible.

a) Draw all the forces exerting the rotating ball.
b) Find the angular velocity ω when the angle θ between the vertical axis and the line connecting the center of the ring and the ball is 35°.

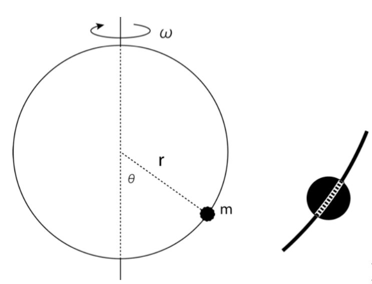


Fig. 7-10

[Mini-Lab #06, Lab] Uniform Circular Motion

Preparation

1. Washers, a rubber stopper with a hole, a glass tube, Nylon string, toothpicks, Scotch tape, a weight scale, a measure, a stopwatch
2. Measure the mass of a washer and a rubber stopper
3. Nylon string is passed through a glass tube. One end of the string is tied with the rubber stopper and the other end with a toothpick: four washers are placed on the toothpick. A piece of Scotch tape is fixed as a sign on the string approximately 1 cm under the bottom of the glass tube.
4. Hold the glass tube vertically and rotate the rubber glass so as to keep the location of the Scotch tape sign approximately 1 cm under the bottom of the glass tube: this enables to keep both of the radius of rotation r and the force acting the rubber stop. Practice this operation.

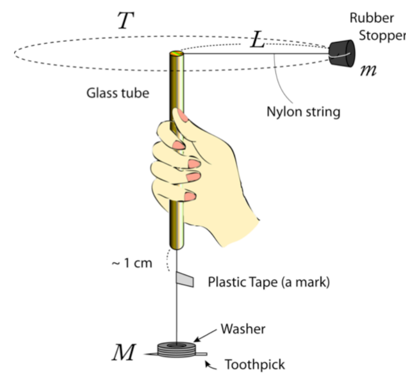


Fig. 8-a

Experiment-1: The relation between the rotation radius r and the period ω.
Keep the number of washers constant, such as 4. Rotate the rubber stopper with various rotation radius r, such as 20, 30, 40, 50 60 cm, and measure the time of 20 revolution, 20T, for each rotation radius. Find $\omega = 2\pi/T$.

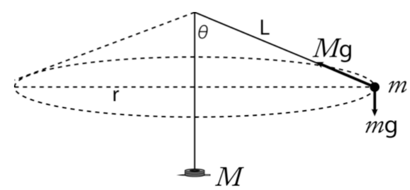


Fig. 8-b

Experiment-2: The relation between the centripetal force F and the period T.
Keep the rotation radius r constant, such as 30 cm. Rotate the rubber stopper with various number of washers, such as 3, 4, 5, 6, 7…, and measure the time of 20 revolution, 20T, for each rotation. Find T.

Analysis

1) Measurement: m, M, L, T
2) Relationships as a conical pendulum, shown in Fig. 8.

$$Mg\cos\theta = mg \qquad (1)$$

$$\theta = \cos^{-1}(m/M) \qquad (2)$$

3) Centripetal force $F = Mg\sin\theta$ (3)

Rotation radius $r = L\sin\theta$ (4)

Percent difference = $(L - r)/L \times 100$ (5)

The following analysis is performed under the assumption,
$\theta \approx 90°$, $r \approx L$, or centripetal force $F = Mg$ (6)

$$\omega = \frac{2\pi}{T} \qquad (7)$$

$$F = mr\omega^2 \qquad (8)$$

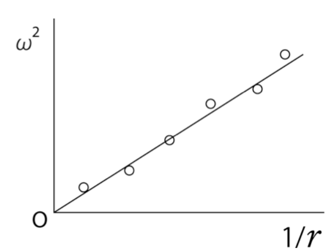


Table and graphs

9．Non-uniform Circular Motion

[Mini-Lab #07] Roller Coaster

[Q9-1] A small ball with a mass of m [kg], placed on the bottom A of the inner frictionless surface of a half cylinder with a radius of r [m], is given an initial velocity v_0 [m/s] in the direction perpendicular to the vertical axis of the half cylinder.

a) Find the normal force as a function of the angle θ during the ball is moving in contact with the inner surface.
b) Find the angle θ_0 when the ball goes off the inner surface.
c) Find the least initial velocity v_0 so that the ball can reach the top of the loop.

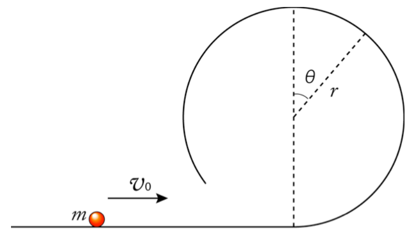


Fig. 9-1

[Q9-2] A track consists of a frictionless loop with a radius of r [m] placed on a vertical surface. The loop is connected with a slope, as shown the figure. A small ball is released from at rest on the slope at the height of h [m]. Find the least value of h so that the ball can reach the top of the loop C.

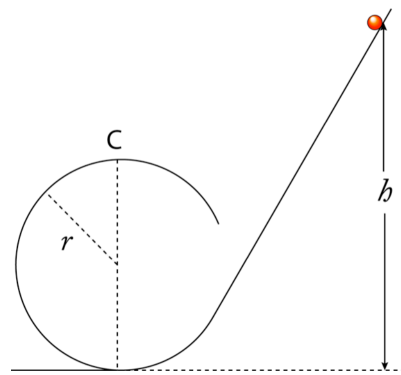


Fig. 9-2

[Q9-3] A frictionless hemisphere with a radius of r [m] is placed on horizontal surface. A small ball with a mass of m [kg], placed on the top of the hemisphere, moves down and goes off the surface at the point B and falls. Find the height B h [m] from the horizontal surface.

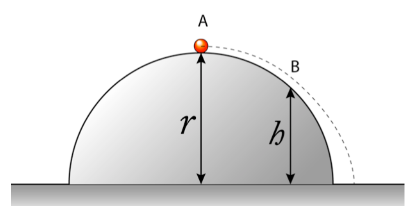
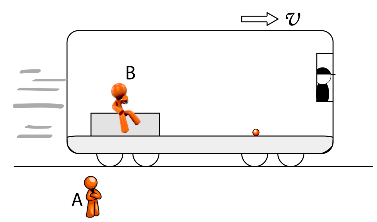


Fig. 9-3

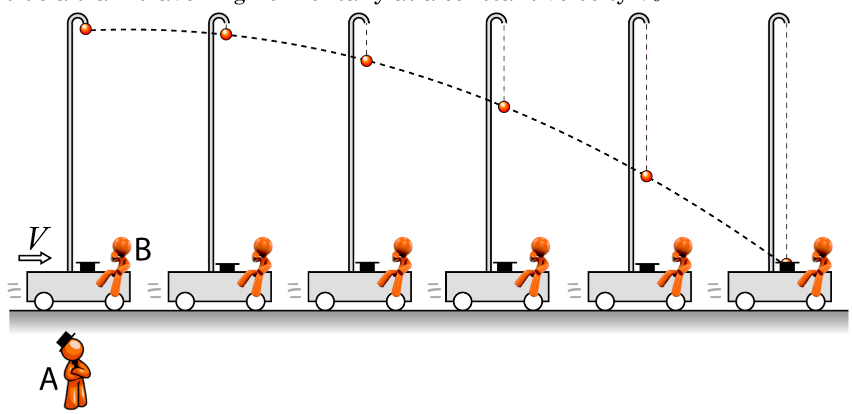
10. Inertial Frame and Non-Inertial Frame
[Q10-1] What is "inertial frame"? What is "non-inertial frame"?

11. Motion in an Inertial Frame
[1] A marble ball placed on the floor of a train travelling at a constant velocity v_0

Observer B inside Car:
Observer A on the Earth:

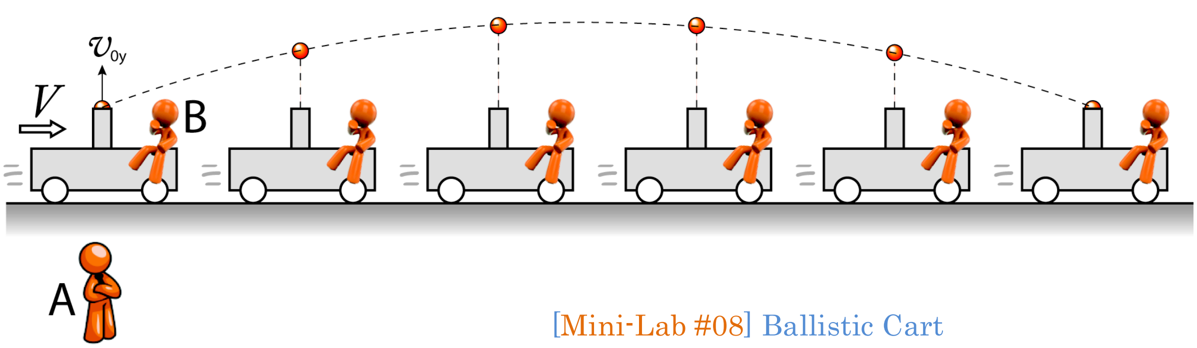


[2] Drop a ball inside a train travelling horizontally at a constant velocity v_0



Observer B inside Car:
Observer A on the Earth:

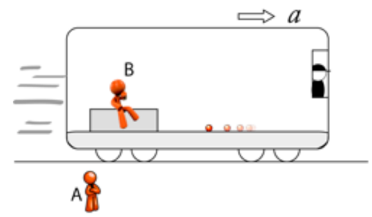
[3] Throw up a ball vertically inside a train travelling horizontally at a constant velocity v_0



Observer B inside Car:
Observer A on the Earth:

[Mini-Lab #08] Ballistic Cart

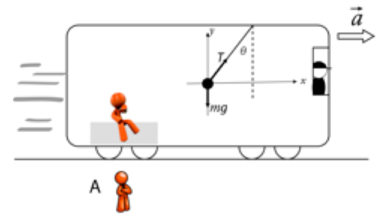
12. Inertial Force



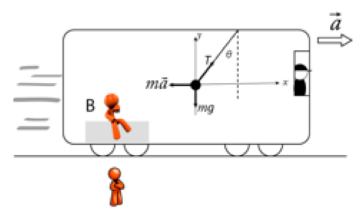
[5] A marble ball placed on the floor of a train travelling at a constant acceleration a

Observer B inside Car:
Observer A on the Earth:

[6] The ring of a hanging strap inside a train travelling horizontally at a constant acceleration a
Observer A on Ground:

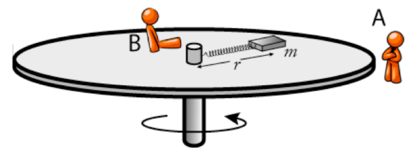


Observer B inside Car:



[7] Apparent weight inside an elevator moving vertically at a constant acceleration a

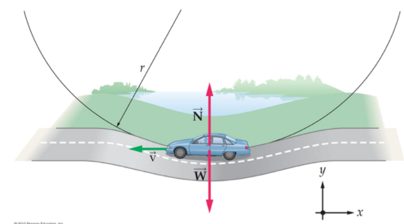
13. Centrifugal Force



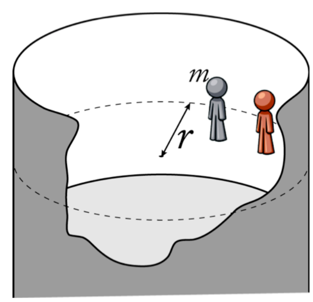
[Mini-Lab #09] A Spring on a Rotating Disk

[9] An object with a mass m [kg] connected with a spring of a spring constant k [N/m] on a turntable is rotating together with it around the central axis at a constant angular velocity ω [rad/s].
a) Find the length of spring r [m] from the observer A's point of view standing out of the turntable.

b) Find the length of spring r [m] from the observer B's point of view rotating together with the turntable.



[10] While driving along a country lane with a constant speed of 17.0 m/s, you encounter a dip in the road. The dip can be approximated as a circular arc, with a radius of 65.0 m. What is the normal force exerted by a car seat on an 80.0-kg passenger when the car is at the bottom of the dip?



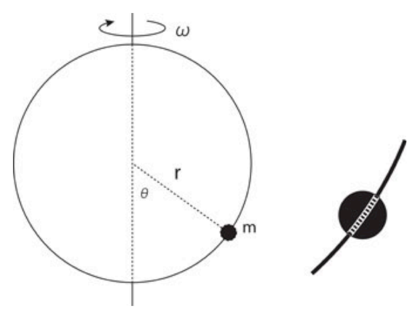
[12] The Rotor is an amusement park ride. It is a large upright barrel. Once the barrel has attained full speed rotation, the floor is retracted, leaving the riders stuck to the wall of the drum. Assume that the radius of a Rotor is 2.1 m, the mass of a human is 50 kg, and the static frictional coefficient between the Rotor and the human is 0.40.
a) Find the magnitude of centripetal force.
b) Find the magnitude of centrifugal force.
c) Find the least number of rotation to keep the human.

[Mini-Lab #10] Rotating a bucket of water

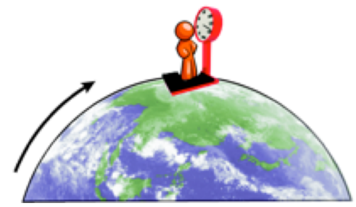
Why does the Water Stay in the Bucket?

[13] A student rotates a bucket of water around in a vertical circle with radius 1.2m. The mass of the water is 1.4 kg.
(13-a) What is the minimum speed that it can be rotated so the water remains in the bucket?
(13-b) Find the direction and magnitude of the centrifugal force at the top of the whirl in the case of (a).
(13-c) Why doesn't the water fall from the bucket?

([Mini-Lab #05] Rotating ring)



[15] Suppose you stand on a bathroom scale and get a reading 65 kg. In principle, would the scale read more, less, or the same if the earth did not rotate?



[16] Explain the previous problem using the concept of "centrifugal force."

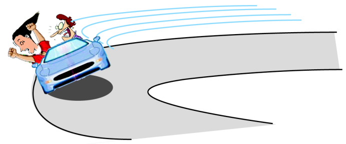
"Centrifugal Force," an inertial force or a fictitious force

(a)

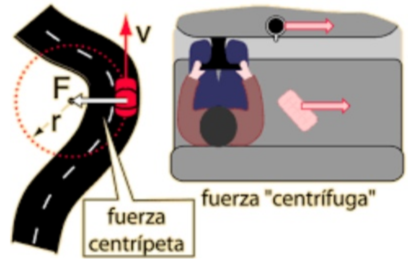
(b)

(c)

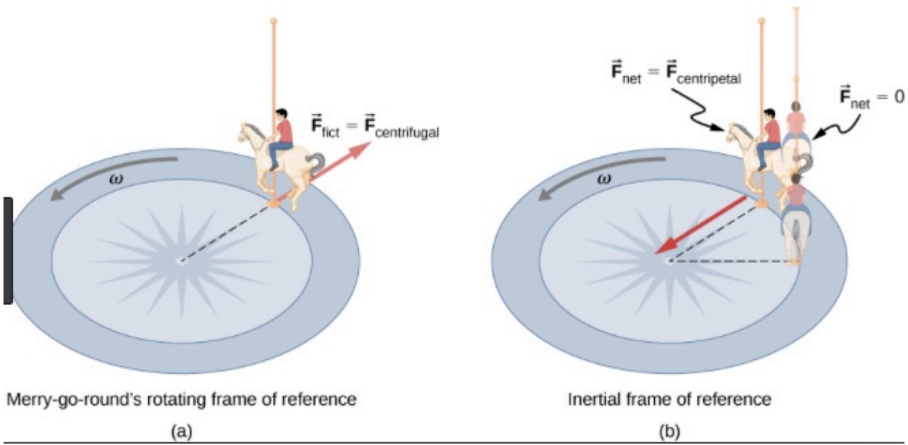
(d) Skidding car



(e) Driving at a hairpin curve



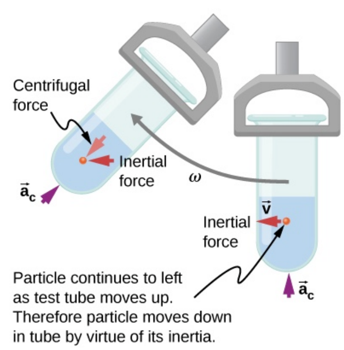
(f) Moving things inside a car



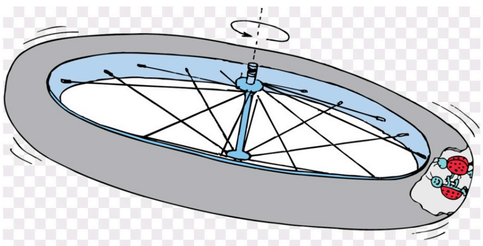
(g) Merry-go-round

(i) Running up in a bowl

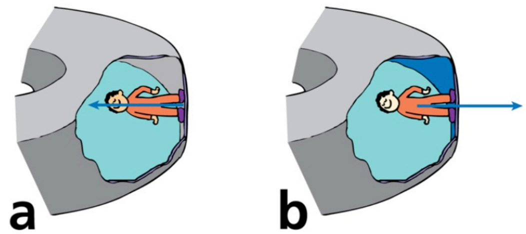
(j) Car acrobatics



(k) Centrifuge



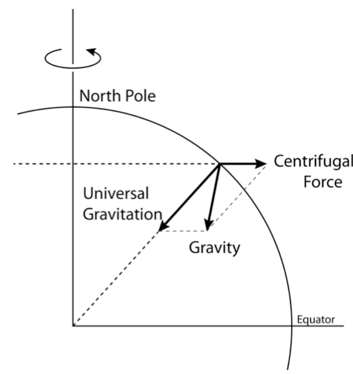
(l) Artificial gravity



(m) Artificial gravity

14. Gravity on Earth

[15] Any object on the Earth experiences the centrifugal force. Then, gravity is the net force of the universal gravitation and centrifugal force acting on an object.



Physical Characteristics of the Earth

Mean radius	6371.0 km
Equatorial radius	6378.1 km
Polar radius	6356.8 km
Volume	1.083×10^{12} km^3
Mass	5.972×10^{24} kg
Mean density	5514 kg/m^3
Equatorial rotation velocity	465.1 m/s
Angular velocity	7.272×10^{-5} rad/s

(a) Find the theoretical gravitational acceleration at the North pole.

(b) Find the theoretical value of universal gravitation exerted on an object with a mass of m [kg] on the Equator.

(c) Find the theoretical value of centrifugal acceleration exerted on an object with a mass of m [kg] on the Equator.

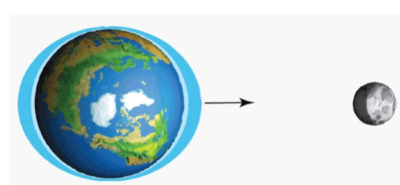
(d) Find the theoretical gravitational acceleration at the Equator.

(e) What is the percentage contribution of the centrifugal force to the gravity at the Equator.

(f) What is the percent change in gravitational acceleration at the Equator in comparison with that at the Pole.

15. The Tides

(Walker p404) E. Clancy, "The Tides," FN の高校物理（潮汐力）



* Why the ocean tides rise and fall twice a day? In the relation between Earth and Moon, the ocean water rises on the side closed to Moon and on the opposite side from Moon as well. In this deformation of water, Earth rotates once a day, then two high tides and two low tides occur daily. It is understandable that Moon pulls ocean water by the gravitational force. Why the opposite side also shows rising water?

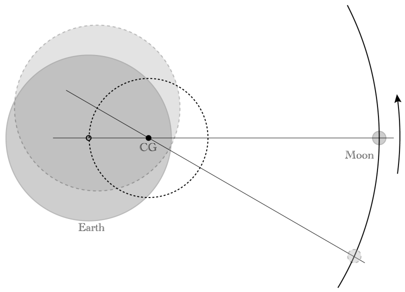


Fig.1 Path of earth's center (dashed circle) as it moves around the common center of gravity CG of the earth-moon system.

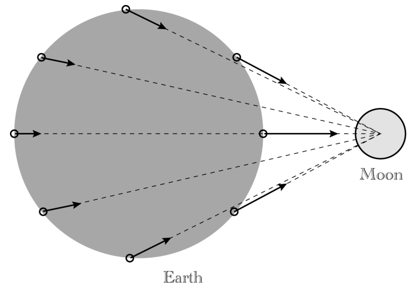


Fig. 5 Gravitational forces, due to the moon, on an object placed at various points on the earth's surface.

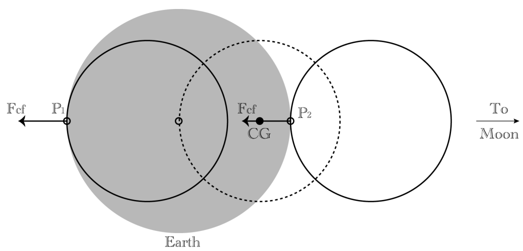


Fig. 2 The paths traced out by the points P1 and P2,

and the centrifugal force FCP.

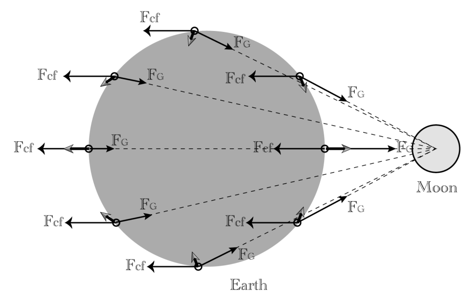


Fig. 6 The tidal generating forces.

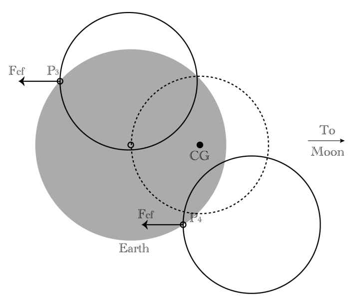


Fig. 3 Paths described by objects at points P3 and P4.

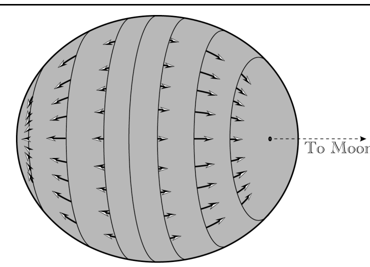


Fig. 7 The arrows represent the horizontal tide-generating forces.

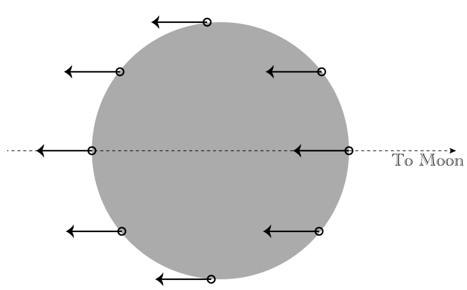


Fig. 4 Centrifugal forces, due to rotation of the earth-moon system about its common center of gravity.

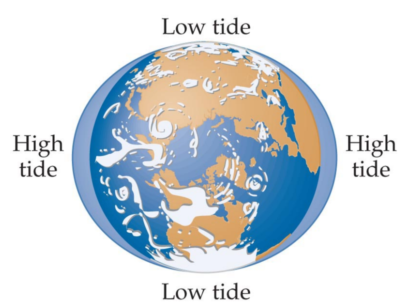
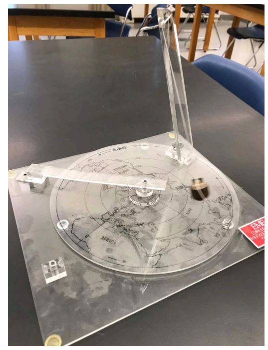


Fig. 8 Tidal deformation on Earth.

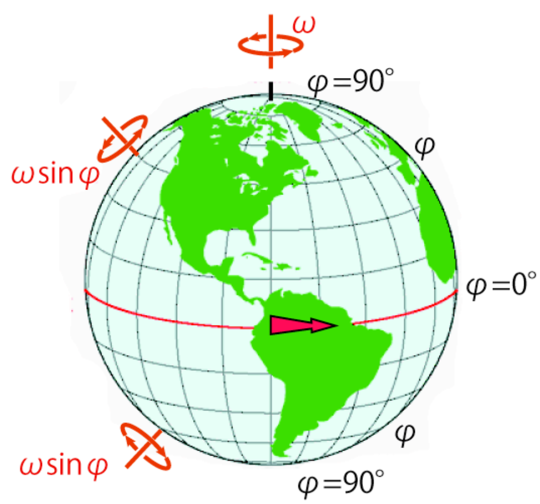
16. The Coriolis Force

[Mini-Lab #11~13]

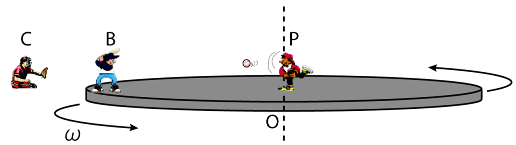
Foucault Pendulum			
	#11	#12	#13

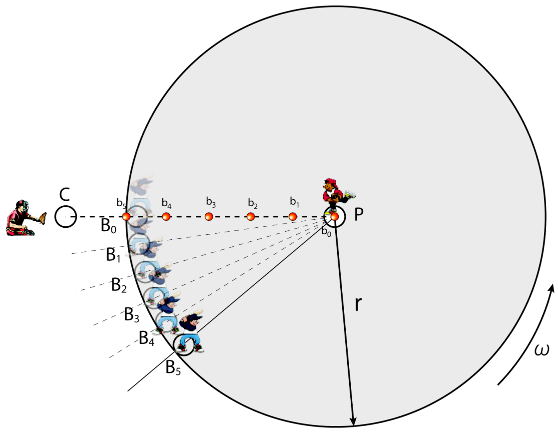
[Experiment #14~16]

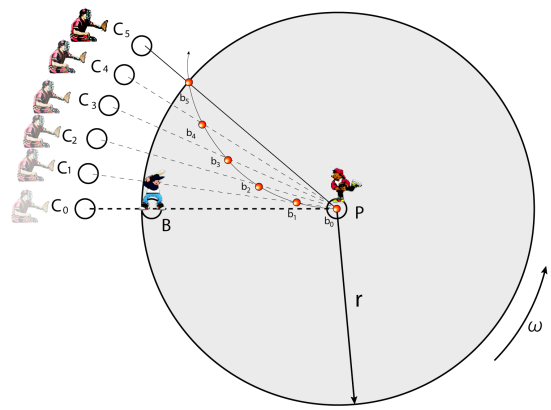
Coriolis Effect			
	#14	#15	#16 “Kenya Experiment”



1) Pitcher (P) throws a ball at the center of a turntable toward a batter (B) standing at the edge of the table.







I. Inertial Point of View
(The frame fixed to Catcher C)

II. Co-rotating Point of View
(The frame fixed to Pitcher P and Batter B)

2) Analysis of the Coriolis force –I (A projectile launched from the center of rotation)

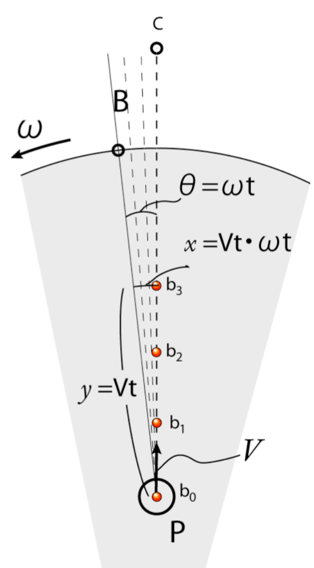
Angular velocity ω、The speed of a projectile: V
y : displacement
x : Deviation of the projectile (the Coriolis effect)

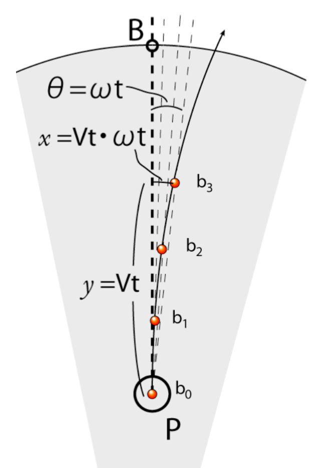
t (s) $y = V t$, $x = Vt \cdot \omega t = V\omega t^2$ (1)

The equation of motion at a constant acceleration :

$x = \frac{1}{2} a t^2$ (2)

(1) and (2) result in
Coriolis acceleration: $a = 2V\omega$
(3)
Coriolis force: $F_{co} = 2mV\omega$
(4)





A. Inertial Point of View B. Co-rotating Point of View

6) Analysis of the Coriolis force –II (General point on the Earth)

The rotational angular velocity of earth at a latitude φ°:

$\omega\sin\varphi$ (ω: the angular velocity of the rotation of the Earth)

Direction: CCW (in the Northern Hemisphere),
CW (in the Southern Hemisphere)

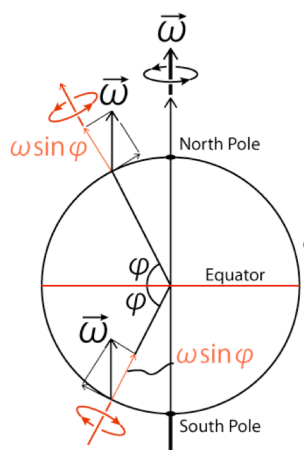
A projectile launched at a place with a latitude φ° at a speed V[m/s].

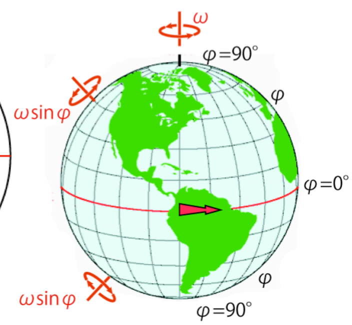
Displacement: Vt [m]

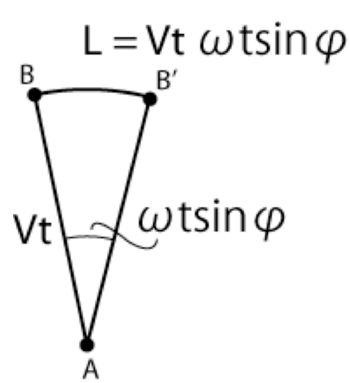
Deviation due to the Coriolis effect: $V\omega\sin\varphi \cdot t^2$ [m]

Direction of the deviation: Right (in the Northern Hemisphere),
Left (in the Southern Hemisphere)

[Q3] A projectile is launched at an initial horizontal and vertical speed of 500 m/s and 500 m/s, respectively. Find the deviation due to the Coriolis effect in the following two cases:
a) Launched at the North Pole.
b) Launched at 41° north latitude.

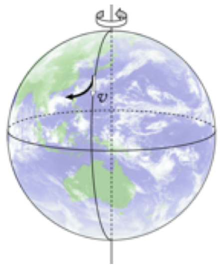


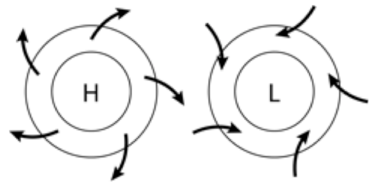




[Q4] Find the angle and direction that Foucault Pendulum shows a day at the following places:
a) The North Pole
b) New York (41° north latitude)
c) Tokyo (35° north latitude)
d) Singapore (1.2° north latitude)
e) Sydney (34° south latitude)

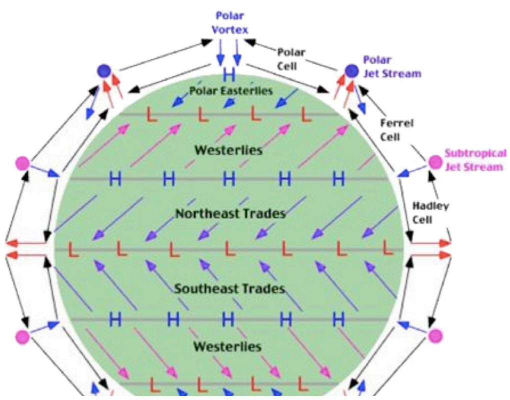
5) The Coriolis force in Meteorology and Oceanography

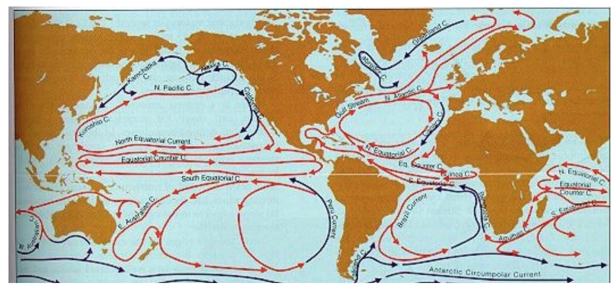




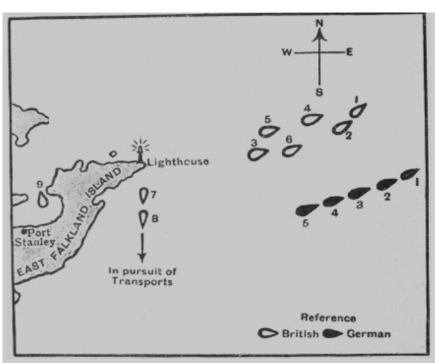
(a) (b)

(c)

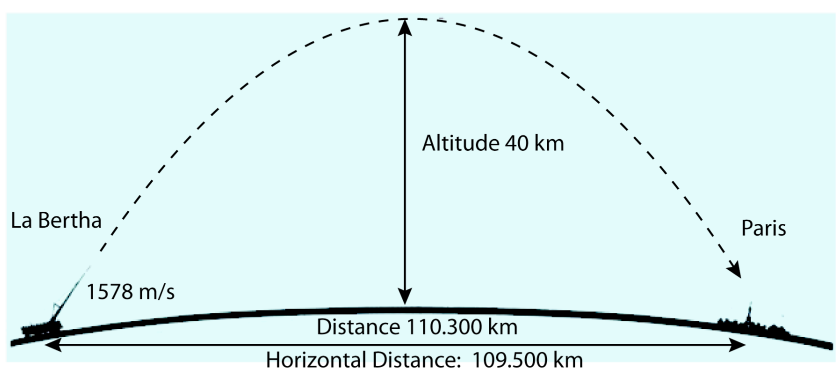




6) Long range gun



Battle off the Falkland Islands, December 8, 1914.



(f) The battle of Falkland Islands (1914) (g) The Paris gun (1918)