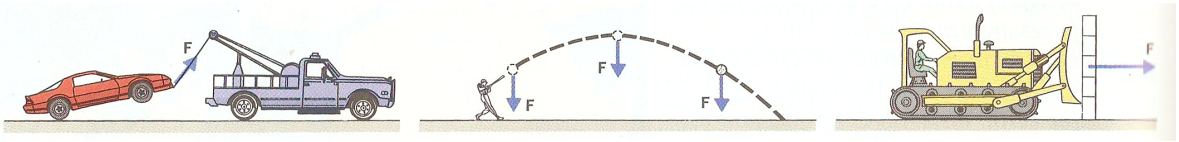
11th Physics 2 Force

2019-20

Force

Force is a common word and usually means a pull or a push. A tow truck pulls a stalled car by applying a force to the car. The force of gravity causes a fly ball in a baseball game to return to the earth by pulling downward on the ball, as it does on all objects. And a bulldozer pushes over the wall of a dilapidated building. The figure illustrates each of these examples and uses arrows to represent the forces. It is appropriate to use arrows, because a force is a vector quantity and has both a magnitude and a direction. The direction of the arrow gives the direction of the force, and the length is proportional to the strength, or magnitude, of the force.

(Cutnell/Johnson, "Physics" 1995)



1 . Indicating Forces

[Q1] Draw an arrow that represents the force (magnitude: F) acting on an object A with the point of action, magnitude and direction of the force.

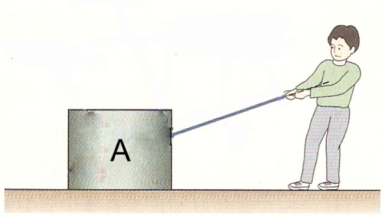


Fig.1

2 . Gravity on Earth

Gravity $W = mg$ (1)

$g = 9.80$ m/s^2

g : **Gravitational acceleration rate**

Fig. 2 shows two objects, A of mass m and B of mass 2m. Draw arrows representing gravity acting on the objects, and write their magnitude with symbols.

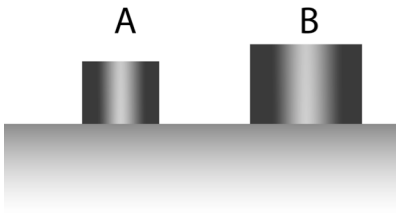


Fig.2

3 . Mass (W p16-17)(p.163)

[Q5] What is the magnitude of gravity exerted on an object of a mass of 4.0 kg?

[Q6] The magnitude of gravitational force exerted on an object is 98 N. What is the mass of the object?

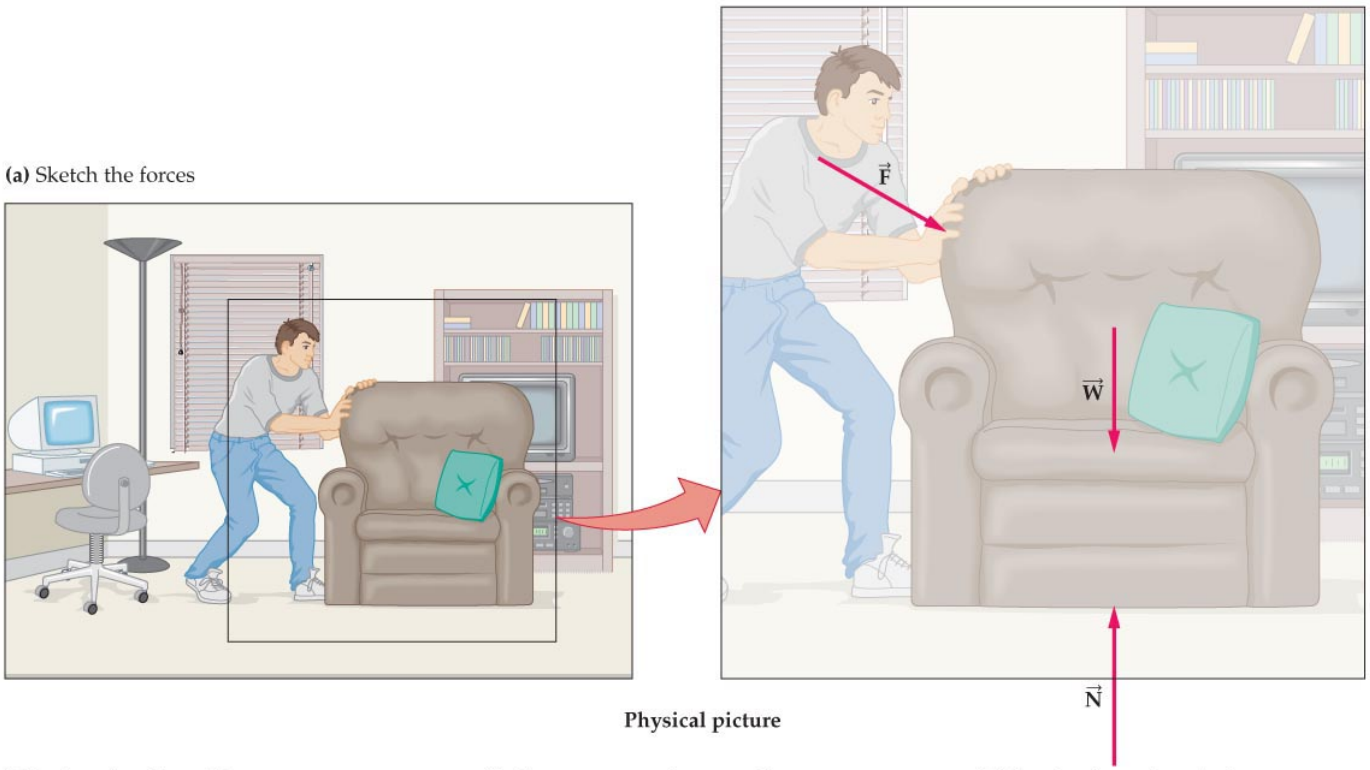
[Q7] Table 9 is a list of examples of masses.

[Q8] Explain the difference between mass and weight?

Table 9 Typical Masses (kg)

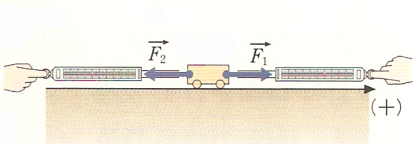
Sun	2×10^{30}
Earth	5.97×10^{24}
Space shuttle	2,000,000
Blue whale (Largest animal)	178,000
Whale shark (Largest fish)	18,000
Elephant (Largest land animal)	5,400
Automobile	1200
Human (adult)	70
Apple	0.3
Baseball	0.145
Honeybee	0.00015
Bacterium	10^{-15}
Proton	1.672×10^{-27}
Electron	9.109×10^{-31}

5. Diagramming Forces II - Free-Body Diagram (W p161)



6. Forces in Equilibrium

[Mini-Lab #23]



Equilibrium	Vector expression	$\vec{F}_1 + \vec{F}_2 = \mathbf{0}$	(4)
	Magnitude (always positive)	$F_1 = F_2$	

[Q16] In Fig. 15, two forces are exerted on a cart and it is at rest. (a) Tell what is the relation between the two forces. (b) Show an equation expressing the relation in terms of magnitude of the two forces. (c) Show an equation expressing the relation between the two vector forces. (d) What is the resultant force of the two forces?

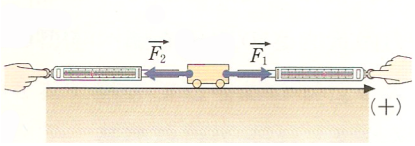


Fig. 16

[Q17] In Fig. 16, the mass of the weight is 1.0 kg and the system is at rest. (a) Find the magnitude and direction of the forces that exert on the weight. (b) Find the net force exerting on the weight.

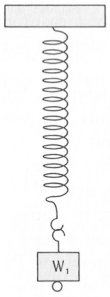


Fig. 17

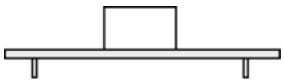
[Q18] In Fig. 18, a 1.5 kg book is at rest. (a) Find the magnitude and direction of the forces that exert on the book. (b) Find the net force exerting on the book.

Fid.18

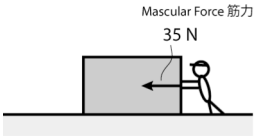
7. Various Forces (W p162~163)

[Mini-Lab #24]

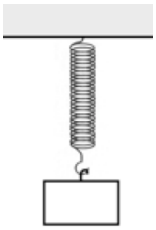
[Q17] In the following figures, a body shown by a rectangle is a mass of 10 kg, is at rest. Draw arrows to show all the forces exerted on this body and write their magnitude and names



a. Sitting on a table

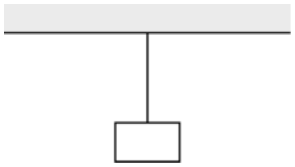


e. Pushed by a person

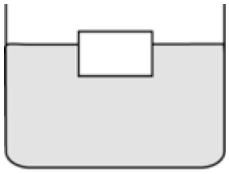


b. Suspended by a spring

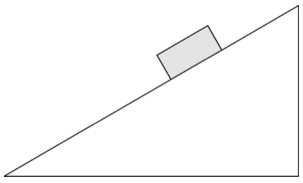
f. Pulled by a person



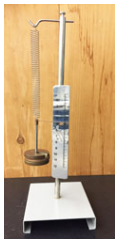
c. Suspended with a string

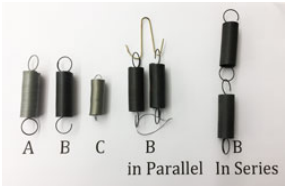


d. Floating on water



g. Sitting on a slope





8. Elastic Force

[Mini-Lab #25, Lab] Springs and the Hook's Law

Hooke's Law	$F = k\,x$	(3)

Fig. 12

[Q11] What kinds of tools do you use when you want to measure weight or force?

[Q12] A spring shows an elongation of 20 cm from its original length when a weight of 200 g is suspended. What is the force constant of this spring?

[Q13] A spring has an original length of 15.0 cm and force constant of 30.0 N/m. When you stretch it slowly as shown in Fig. 13, the total length becomes 20.0 cm. What is the magnitude of the elastic force that exerts on your hand?

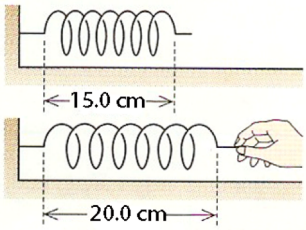
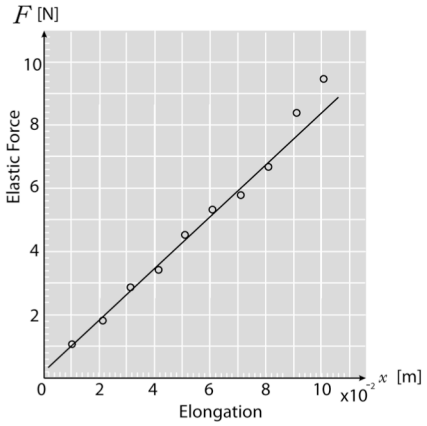
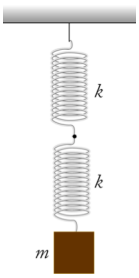


Fig. 13

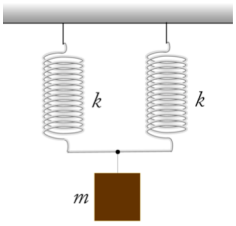
[Q14] The measured elongation of a spring produced by each of a series of forces is recorded in the figure at the right. (a) What is the value of the spring constant k? (b) Predict the elongation produced by a force of 4.70 N.



[Q15] Two light springs, whose spring force constants are both ***k*** [N/m], are connected in two ways, (a) in series or (b) in parallel, and then a weight of ***m*** [kg] is suspended. (1) How much does the level of the weight fall in (a) and (b)? (2) Find the equivalent spring constant of a system in (a) or (b).



(a)



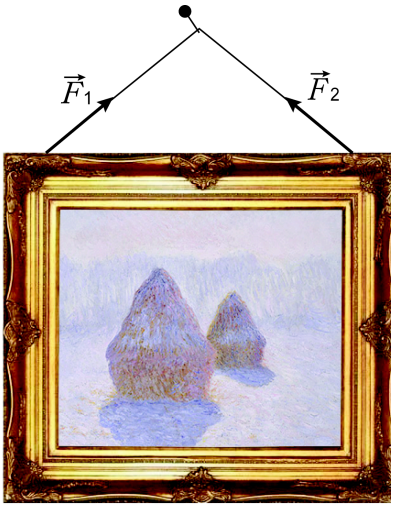
(b)

9. Addition of Forces

Combing Two Forces $\vec{F} = \vec{F}_1 + \vec{F}_2$ (8) $\vec{F}$: **Net Force**

- **Parallelogram Method**
- **Head-to-Tail Method**
- **Math Method**

[Q39] A painting is suspended with a piece of string at two places.
(a) Draw the net force of $\vec{F}_1$ and $\vec{F}_2$ by the addition of their vectors.
(b) What force is in equilibrium with the above forces?
(c) Draw the forces in equilibrium by the free-body diagram.

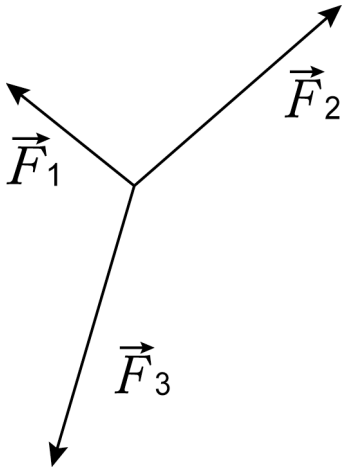


[Q40] The magnitude of the resultant of two forces is a minimum when the angle between them is
(1) 0° (2) 45° (3) 90° (4) 180°

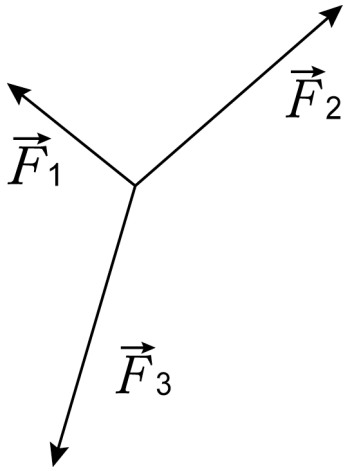
10. Three or More Forces in Equilibrium

Equilibrium of Three Forces	$\vec{F}_1 + \vec{F}_2 + \vec{F}_3 = \mathbf{0}$ (9)

[Q41] Find the net force vector to determine whether the following three forces are in equilibrium or not using two methods: (a) the parallelogram method and (b) the head-to-tail method.

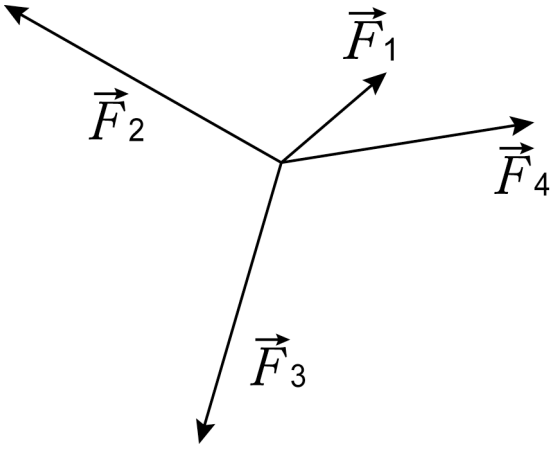


(a) parallelogram method

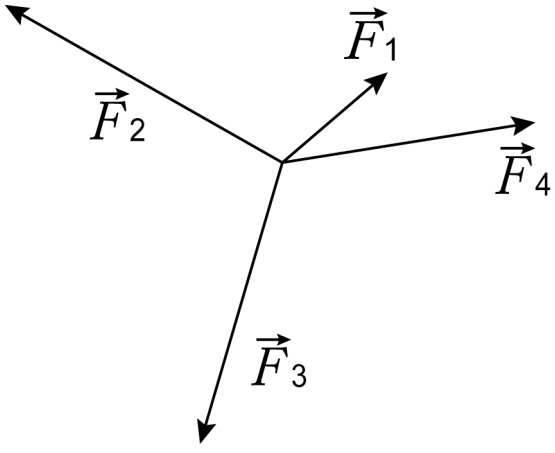


(b) head-to-tail method

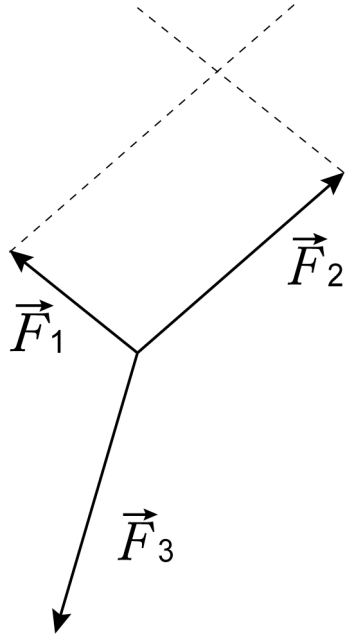
[Q42] Find the net force vector to determine whether the following four forces are in equilibrium or not using two methods: (a) the parallelogram method and (b) the head-to-tail method.



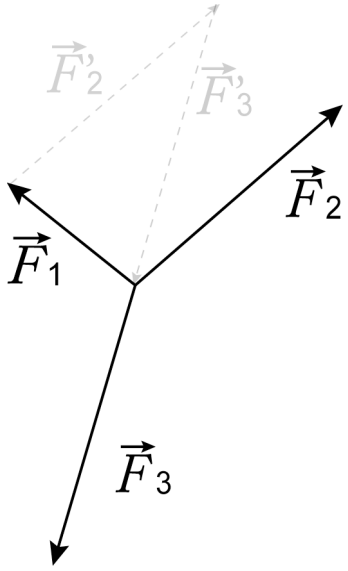
(a) parallelogram method



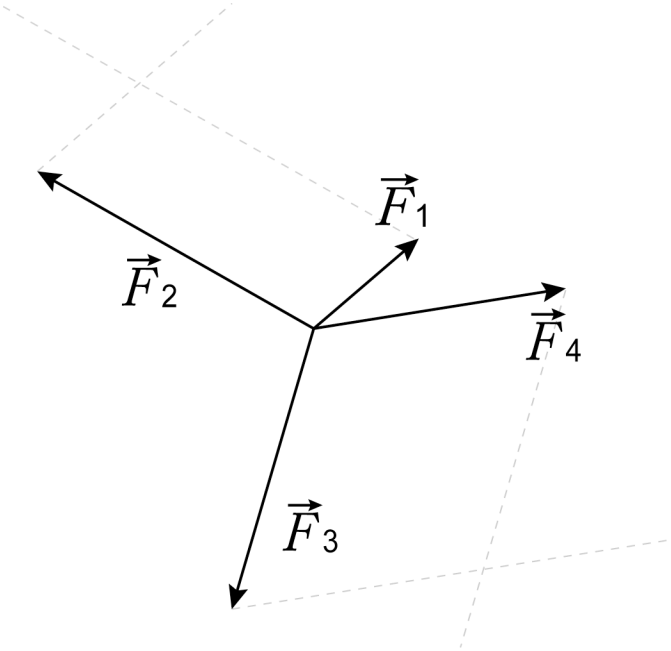
(b) head-to-tail method



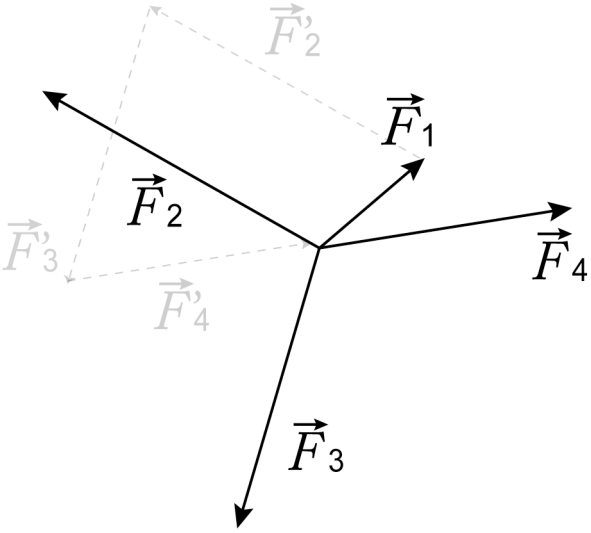
(a) parallelogram method



(b) head-to-tail method



(a) parallelogram method



(b) head-to-tail method

11. Components of Forces

Components of a Force	$F_x = F\cos\theta, \quad F_y = F\sin\theta$	(10)
Equilibrium of Three Forces	$\vec{F}_1 + \vec{F}_2 + \vec{F}_2 = \mathbf{0}$	
	$F_{1x} + F_{2x} + F_{3x} = 0$	(11)
	$F_{1y} + F_{2y} + F_{3y} = 0$	(12)

[Q46] A body with a mass of 3.00 kg is on a frictionless slope and is supported by a string as shown in the figure.

(a) Illustrate force vectors acting on this body with their names.

(b) Determine the magnitudes of the forces.

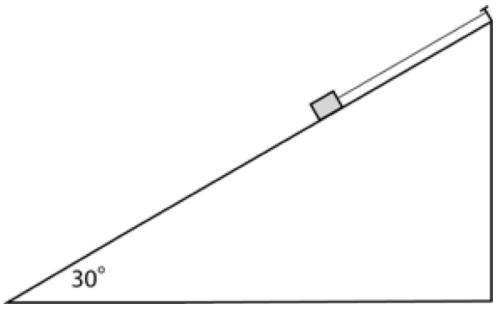
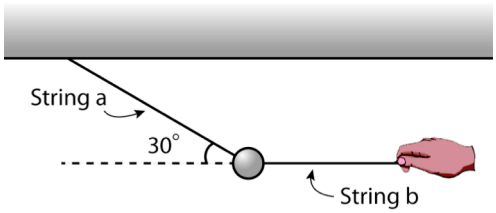
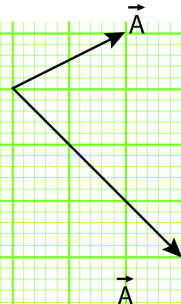


Fig. 46

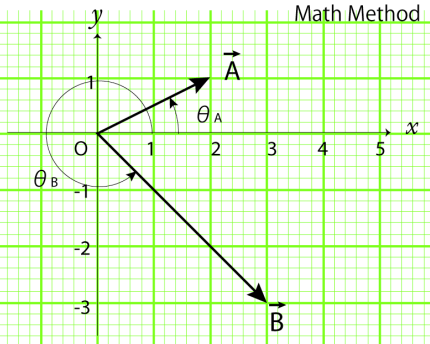
[Q47] A 1.0 kg object is supported with two strings, a and b. The string b is kept horizontally. Find the magnitudes of the tensional forces for the strings, a and b.



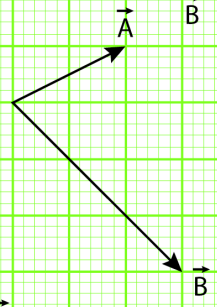
Paralleloram method



Math Method

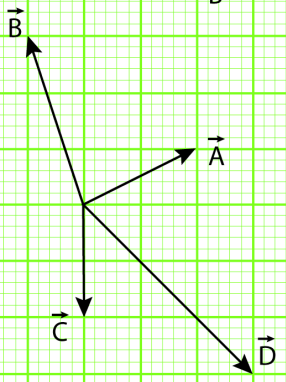


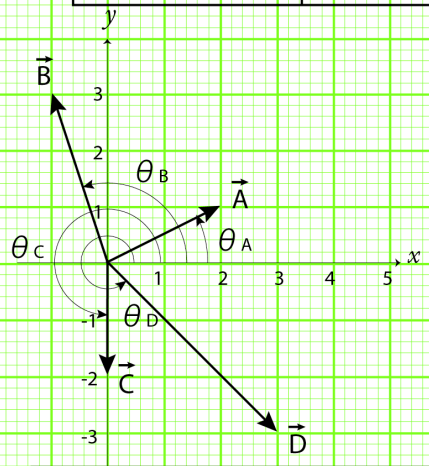
Head-to-Tail method



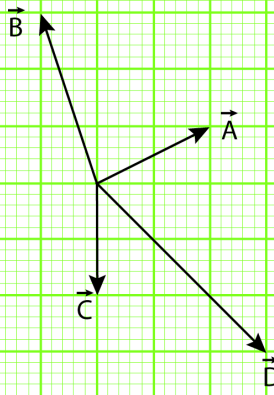
	θ	x	y
A=2.24	θA=26.6°		
B=4.24	θB=315.0°		
	Σ		

Parallelogram method





Head-to-Tail method

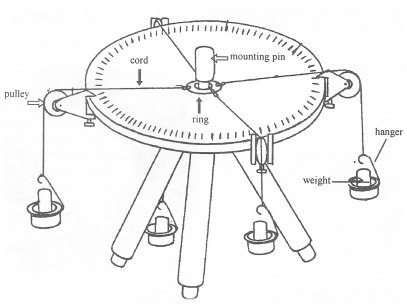


	θ	x	y
A=2.24	θA=26.6°		
B=3.16	θB=108.4°		
C=2.00	θC=270.0°		
D=4.24	θD=315.0°		
	Σ		

10. The Net Force of **Three or More Forces** (W p167)

The Net Force of Four Forces	$\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \vec{F}_4$ (9)

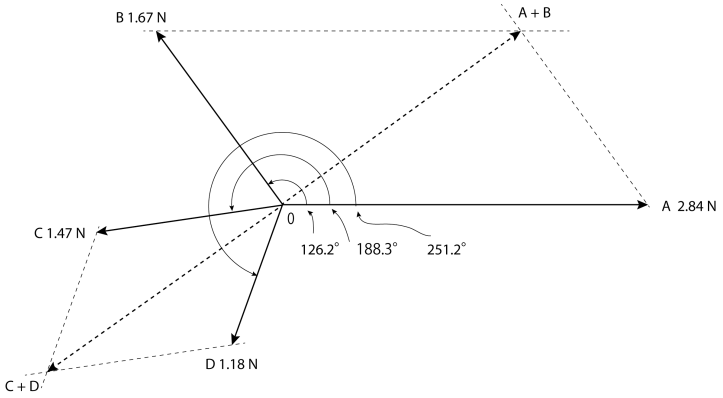
[Mini-Lab #26, Lab] Force Table



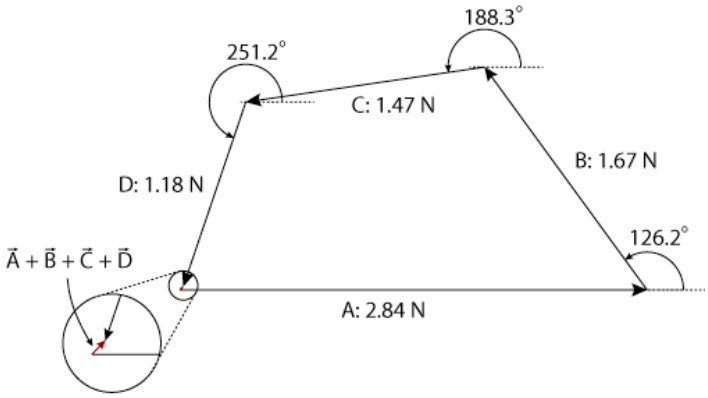
Example of Analysis

	N	Angle
A	2.84	0°
B	1.67	126.2°
C	1.47	188.3°
D	1.18	251.2°

1. Graph method - Parallelogram method



2. Graph method - Head-to-tail method



1. Math method

The Net Force of Four Forces $\vec{F} = \vec{F_1} + \vec{F_2} + \vec{F_3} + \vec{F_4}$ (9)

$$F_x = F_{1x} + F_{2x} + F_{3x} + F_{4x}$$

$$F_y = F_{1y} + F_{2y} + F_{3y} + F_{4y} \quad (10)$$

$$F = \sqrt{F_x^2 + F_y^2}, \qquad \theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) \quad (11)$$

Example

	N	Angle
A	2.84	0°
B	1.67	126.2°
C	1.47	188.3°
D	1.18	251.2°

	F	θ	$F_x = F\cos\theta$	$F_y = F\sin\theta$
	[N]	[°]	[N]	[N]
A	2.84	0	F_{Ax} = 2.84	F_{Ay} = 0
B	1.67	126.2	F_{Bx} = -0.986	F_{By} = 1.348
C	1.47	188.3	F_{Cx} = -1.455	F_{Cy} = -0.212
D	1.18	251.2	F_{Dx} = -0.380	F_{Dy} = -1.117
	$F_x = F_{Ax} + F_{Bx} + F_{Cx} + F_{Dx}$ $F_y = F_{Ay} + F_{By} + F_{Cy} + F_{Dy}$		F_x = 0.019	F_y =0.019

The magnitude and direction of the net force $F = \sqrt{F_x^2 + F_y^2} = 0.0026$

$$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = 45^\circ$$

12. Density (W p424)

Density	$\rho = \frac{m}{V}$	[kg/m^3]	(5)

[Q18] If a given sample of metal is found to have a mass of 210 g and a volume of 26.7 cm^3, what is the density of that metal in g/cm^3 and in kg/m^3?

[Q19] Find the magnitude of gravity exerted on the object having a volume V [m^3] and a density ρ [kg/m^3].

[Q20] Table is a list of examples of densities. Discuss how Archimedes found the method to determine whether some silver had been substituted by the dishonest goldsmith.

TABLE 15–1 Densities of Common Substances

Substance	Density (kg/m^3)
Gold	19,300
Mercury	13,600
Lead	11,300
Silver	10,500
Iron	7860
Aluminum	2700
Ebony (wood)	1220
Ethylene glycol (antifreeze)	1114
Whole blood (37 °C)	1060
Seawater	1025
Freshwater	1000
Olive oil	920
Ice	917
Ethyl alcohol	806
Cherry (wood)	800
Balsa (wood)	120
Styrofoam	100
Oxygen	1.43
Air	1.29
Helium	0.179

Fig. 20

[Q21] Overflow Can (Eureka Can)

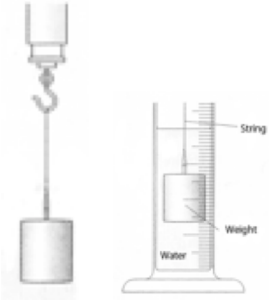
13. Buoyancy and Archimedes' Principle (W p431)

Archimedes' Principle

An object completely immersed in a fluid experiences an upward buoyant force equal in magnitude to the weight of fluid dispersed by the subject.

$$Buoyancy = \rho_f V g \qquad [N] \qquad (6)$$

[Q22] A weight is attached to a spring scale. When the weight is suspended in air, the scale reads 20.0 N; when it is completely immersed in water, the scale reads 17.7 N. What is the volume, mass and density of the weight?



[Q23] An air mattress is 3,45 m long, 0.995 m wide, and 25.6 cm deep. The mass of the air mattress is 2.50 kg.
What is the maximum mass the mattress can support in freshwater?


Fig. 23

[Q24] (a) What percentage of a floating of ice projects above the level of the water? Use the density values shown in the previous page. (b) An ice block floats on water in Fig. 24. Does the water level increase or decrease when the ice melts?

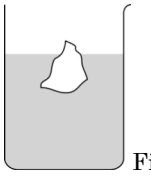
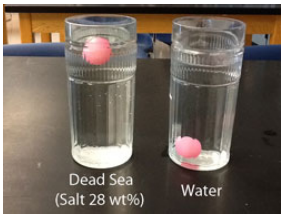
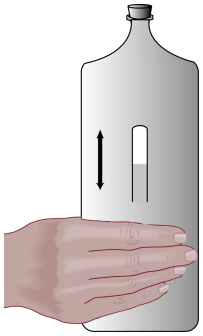


Fig. 24

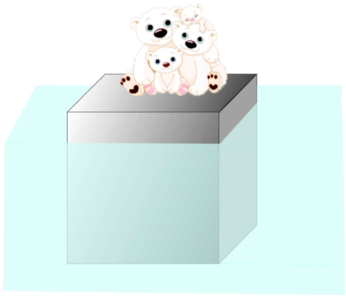
[Mini-Lab #27] Swimmer on Dead Sea,



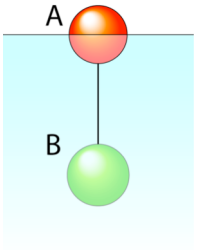
[Mini-Lab #28, Lab] Cartesian Diver.



[Q27] A floating ice is 3.0 m long, 3.0 m wide, and 3.0 m deep. What is the maximum mass the ice can support in freshwater?



*[Q] Two globes, A and B, having an identical volume is connected with a light and fine string and put into water. The globe A floats so as to raise just the upper half of the sphere out of the water without loosing the string. Assume the density of water and the globe A as ρ and $\rho/6$, respectively. (1) How many times is the magnitude of the buoyant force exerted on the globe A larger than the magnitude of gravity exerted on it? (2) Find the density of the globe B.

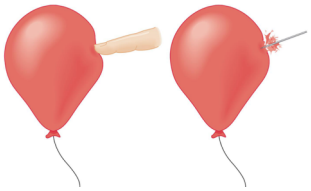


[Q29] What volume is necessary for a balloon to float a human with a mass of 60 kg using helium (The density of helium: $\rho_h = 0.179$ kg/m^3, The density of air: $\rho_{air} = 1.2$ kg/m^3).

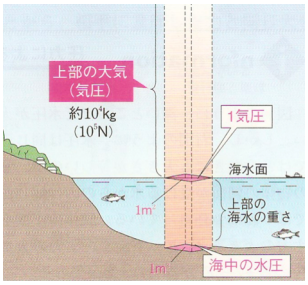
14. Pressure (W p367, p426-427)

Pressure	$p = \frac{F}{S}$		[Pa]	(7)

[Q30] A 79 kg person sits on 3.7 kg 4-leg chair. Each leg of the chair makes contact with the floor in a circle that has an area of 1.3 cm^2. Find the pressure exerted on the floor by each leg of the chair, assuming the weight is evenly distributed.



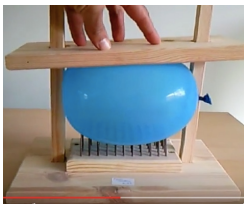
[Q31] Find the pressure exerted on the skin of a balloon if you press with a force of 3.6 N using a needle. The area of the needle tip is 2.0 x 10^{-7} m^2.

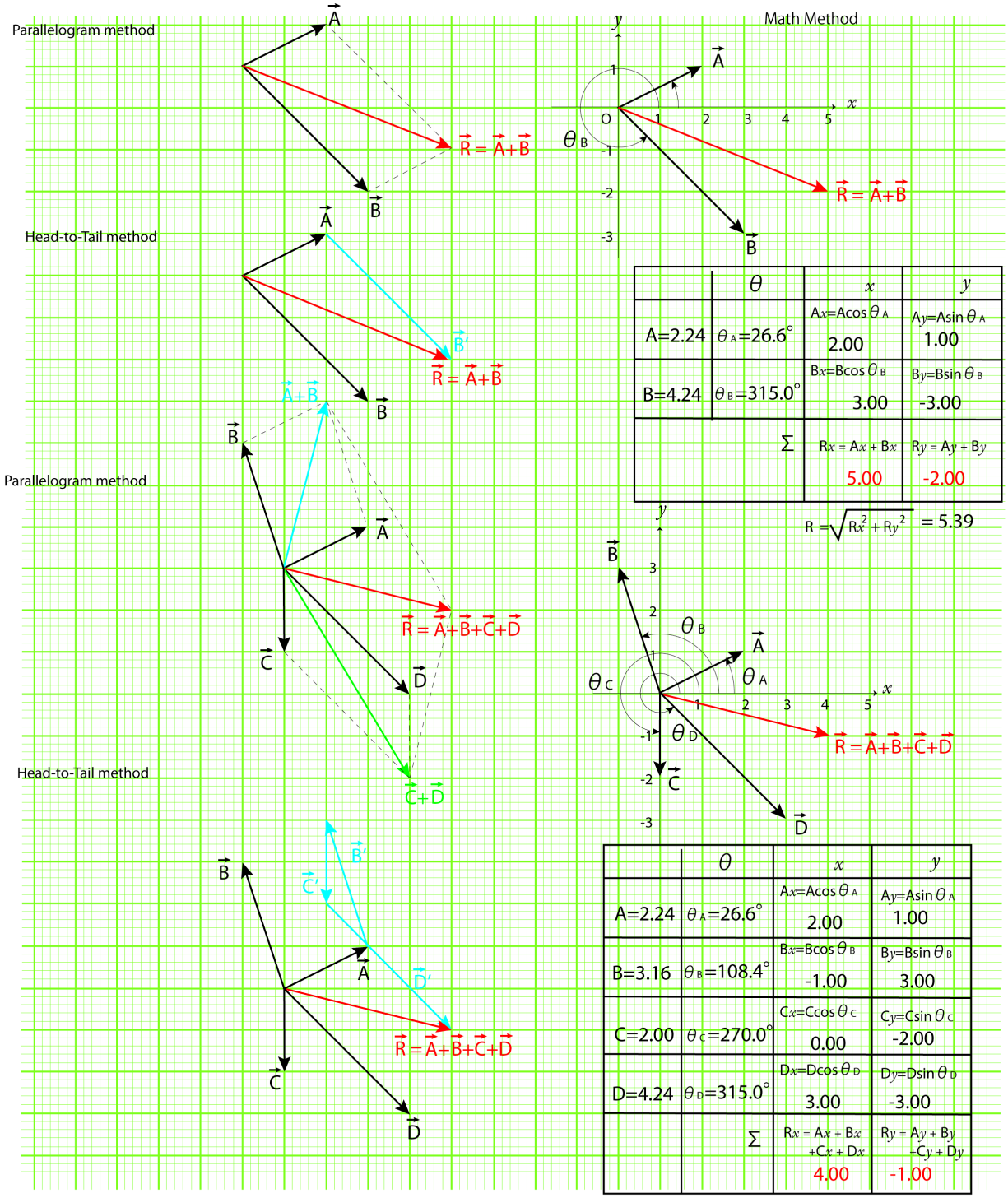


[Q32] Find the hydraulic pressure p [Pa] at the depth of d [m] in the sea, supposing atmospheric pressure as p_0 [Pa], the density of water as ρ [kg/m^3] and the gravitational acceleration rate as g [m/s^2].

[Q33] Find the water pressure by atm at a depth of 25 m in a lake.

[Mini-Lab #29] Pressure





	θ	x	y
A=2.24	θ_A=26.6°	A_x=Acos θ_A 2.00	A_y=Asin θ_A 1.00
B=4.24	θ_B=315.0°	B_x=Bcos θ_B 3.00	B_y=Bsin θ_B -3.00
	Σ	$R_x = A_x + B_x$ 5.00	$R_y = A_y + B_y$ -2.00

$R = \sqrt{R_x^2 + R_y^2} = 5.39$

	θ	x	y
A=2.24	θ_A=26.6°	A_x=Acos θ_A 2.00	A_y=Asin θ_A 1.00
B=3.16	θ_B=108.4°	B_x=Bcos θ_B -1.00	B_y=Bsin θ_B 3.00
C=2.00	θ_C=270.0°	C_x=Ccos θ_C 0.00	C_y=Csin θ_C -2.00
D=4.24	θ_D=315.0°	D_x=Dcos θ_D 3.00	D_y=Dsin θ_D -3.00
	Σ	$R_x = A_x + B_x + C_x + D_x$ 4.00	$R_y = A_y + B_y + C_y + D_y$ -1.00

$R = \sqrt{R_x^2 + R_y^2} = 4.12$