化工系物理用書

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其他系開學後由任課老師指定

普物(上)最主要的課程內容爲力學與熱力學，和高中強調計算不同，大學強調的是定義、定律的了解、分析題目的能力與定律的應用。

所以學習上請多花時間去了解物理量的定義及物理定律的涵義，不要將思考侷限於某一特殊運動形式(如等加速度運動或自由落體)而要整體思考物理定律在任意運動模式下的應用。

Chapter1：Introduction and Vectors

- SI System：
  - Length is measured in meters (m)
  - Time is measured in seconds (s)
  - Mass is measured in kilograms (kg)
- Coordinate Systems
  - Cartesian Coordinate System (x,y)
  - Polar Coordinate System (r,θ)
- Vectors and Scalars

Example 1.1：Each of the displacement vectors $\vec{\mathbf{A}}$ and $\vec{\mathbf{B}}$ shown in Figure P1.1 has a magnitude of 3.00 m. Find graphically (a) $\vec{\mathbf{A}}+\vec{\mathbf{B}}$, (b) $\vec{\mathbf{A}}-\vec{\mathbf{B}}$, (c) $\vec{\mathbf{B}}-\vec{\mathbf{A}}$, and (d) $\vec{\mathbf{A}}-2\vec{\mathbf{B}}$. Report all angles counterclockwise from the positive x axis.

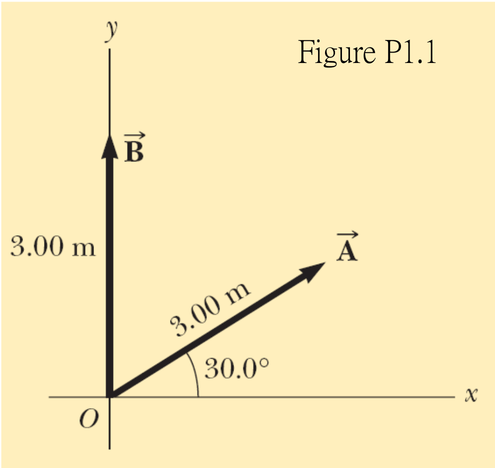


Figure P1.1

Example 1.2：An air-traffic controller observes two aircraft on his radar screen. The first is at altitude 800 m, horizontal distance 19.2 km, and 25.0° south of west. The second aircraft is at altitude 1 100 m, horizontal distance 17.6 km, and 20.0° south of west. What is the distance between the two aircraft? (Place the x axis west, the y axis south, and the z axis vertical.)

Chapter2：Motion in One Dimension

- Displacement $\Delta x = x_f - x_i$
- average velocity $v_{average} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{\Delta t}$
- Instantaneous Velocity $v_x = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$
- Average Acceleration $\bar{a}_{x,avg} = \frac{v_{xf} - v_{xi}}{t_f - t_i} = \frac{\Delta v_x}{\Delta t}$
- Instantaneous Acceleration $a_x = \lim_{\Delta t \to 0} \frac{\Delta v_x}{\Delta t} = \frac{dv_x}{dt} = \frac{d^2 x}{dt^2}$

Example 2.1：A position－time graph for a particle moving along the x axis is shown in Figure P2.1 (a) Find the average velocity in the time interval t = 1.50 s to t = 4.00 s. (b) Determine the instantaneous velocity at t = 2.00 s by measuring the slope of the tangent line shown in the graph. (c) At what value of t is the velocity zero?

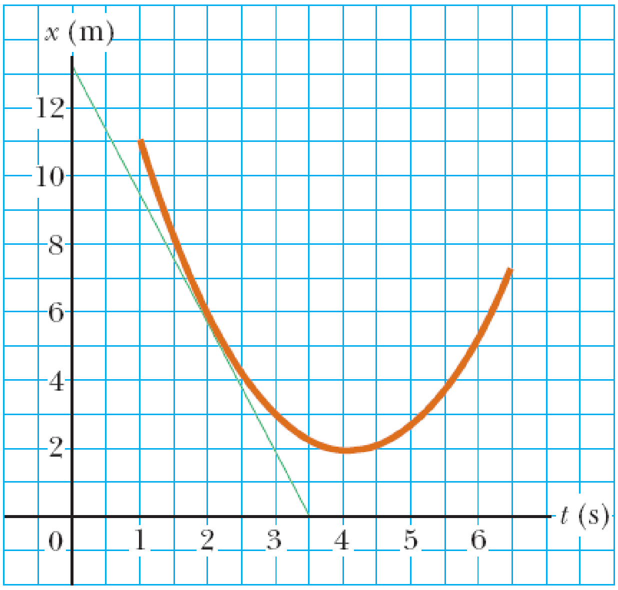


Figure P2.1

Example 2.2：A particle moves along the x axis according to the equation $x = 2.00 + 3.00t - 1.00t^2$, where x is in meters and t is in seconds. At t = 3.00 s, find (a) the position of the particle, (b) its velocity, and (c) its acceleration.

Chapter3：Motion in Two Dimensions

- Position vector $\vec{r}$
- The displacement of the object is defined as the change in its position $\Delta\vec{r} = \vec{r}_f - \vec{r}_i$
- Average Velocity $\vec{v}_{avg} = \frac{\Delta \vec{r}}{\Delta t}$
- Instantaneous Velocity $\vec{v} = \lim_{\Delta t \to 0} \frac{\Delta \vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$
- Average Acceleration $\vec{a}_{avg} = \frac{\vec{v}_f - \vec{v}_i}{t_f - t_i} = \frac{\Delta \vec{v}}{\Delta t}$

- Instantaneous Acceleration $\vec{a} = \lim_{\Delta t \to 0} \frac{\Delta \vec{v}}{\Delta t} = \frac{d\vec{v}}{dt} = \frac{d^2\vec{r}}{dt^2}$

- Position vector $\vec{r} = x\hat{i} + y\hat{j}$

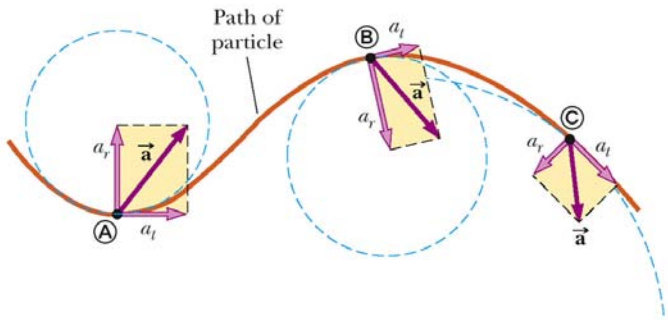
- Velocity $\vec{v} = \frac{d\vec{r}}{dt} = \frac{dx}{dt}\hat{i} + \frac{dy}{dt}\hat{j} = v_x\hat{i} + v_y\hat{j}$

- Uniform Circular Motion

  The tangential acceleration : $a_t = \frac{d|\vec{v}|}{dt}$

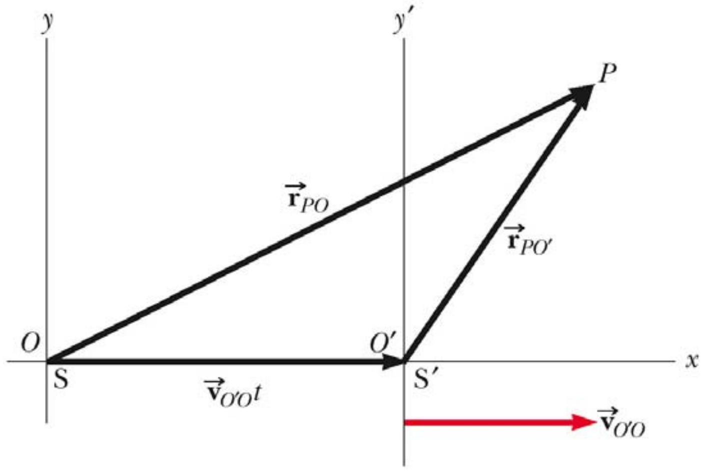
  The radial acceleration : $a_r = -a_c = -\frac{v^2}{r}$

  The total acceleration : $a = \sqrt{a_r^2 + a_t^2}$



- Relative Velocity

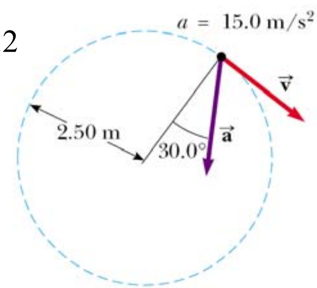
$$\vec{r}_{PO} = \vec{r}_{PO'} + \vec{v}_{O'O}t$$
$$\vec{v}_{PO} = \vec{v}_{PO'} + \vec{v}_{O'O}$$



Example 3.1：A fish swimming in a horizontal plane has velocity $\vec{\mathbf{v}}_i = (4.00\hat{\mathbf{i}} + 1.00\hat{\mathbf{j}})$ m/s at a point in the ocean where the position relative to a certain rock is $\vec{\mathbf{r}}_i = (10.00\hat{\mathbf{i}} - 4.00\hat{\mathbf{j}})$ m. After the fish swims with constant acceleration for 20.0 s, its velocity is $\vec{\mathbf{v}}_f = (20.00\hat{\mathbf{i}} - 5.00\hat{\mathbf{j}})$ m/s. (a) What are the components of the acceleration? (b) What is the direction of the acceleration with respect to unit vector $\hat{\mathbf{i}}$? (c) If the fish maintains constant acceleration, where is it at $t = 25.0$ s and in what direction is it moving?

Example 3.2：Figure P3.2 represents the total acceleration of a particle moving clockwise in a circle of radius 2.50 m at a certain instant of time. At this instant, find (a) the radial acceleration, (b) the speed of the particle, and (c) its tangential acceleration.

Figure P3.2



Chapter4：The Laws of Motion

- Newton's First Law：If an object does not interact with other objects, it is possible to identify a reference frame in which the object has zero acceleration
- Newton's Second Law：The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass

  $\Sigma F_x = m\, a_x$

  $\Sigma F_y = m\, a_y$

  $\Sigma F_z = m\, a_z$
- Newton's Third Law：If two objects interact, the force $\vec{F}_{12}$ exerted by object 1 on object 2 is equal in magnitude and opposite in direction to the force $\vec{F}_{21}$ exerted by object 2 on object 1
- Free Body Diagram
- Problem-Solving Hints

  Conceptualize the problem － draw a diagram

  Categorize the problem

  Equilibrium ($\Sigma F = 0$) or Newton's Second Law ($\Sigma F = m\, a$)

  Analyze

  Draw free-body diagrams for each object

  Include only forces acting on the object

  Establish coordinate system

  Be sure units are consistent

  Apply the appropriate equation(s) in component form

  Solve for the unknown(s)

  Finalize

  Check your results for consistency with your free- body diagram

  Check extreme values

Example 4.1：In Figure P4.1, the man and the platform together weigh 950 N. The pulley can be modeled as frictionless. Determine how hard the man has to pull on the rope to lift himself steadily upward above the ground. (Or is it impossible? If so, explain why.)

Example 4.2：What horizontal force must be applied to the cart shown in Figure P4.2 so that the blocks remain stationary relative to the cart? Assume that all surfaces, wheels, and pulley are frictionless. (*Suggestion:* Note that the force exerted by the string accelerates m_1.)

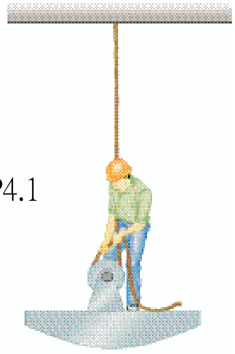
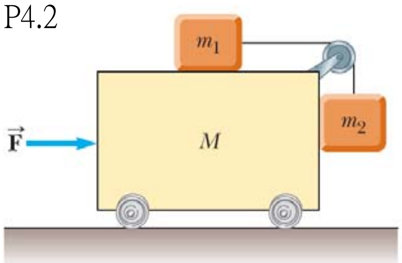


Figure P4.1

Figure P4.2



Example 4.3：Two objects are connected by a light string that passes over a frictionless pulley as shown in Figure P4.3. Draw free-body diagrams of both objects. The incline is frictionless, and m_1 = 2.00 kg, m_2 = 6.00 kg, and θ = 55.0°. Find (a) the accelerations of the objects, (b) the tension in the string, and (c) the speed of each of the objects 2.00 s after they are released simultaneously from rest.

Example4：An object of mass m_1 on a frictionless horizontal table is connected to an object of mass m_2 through a very light pulley P_1 and a light fixed pulley P_2 as shown in Figure P4.4. (a) If a_1 and a_2 are the accelerations of m_1 and m_2, respectively, what is the relation between these accelerations? Express (b) the tensions in the strings and (c) the accelerations a_1 and a_2 in terms of g and the masses m_1 and m_2.

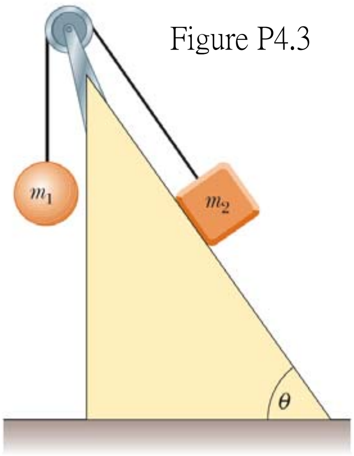


Figure P4.3

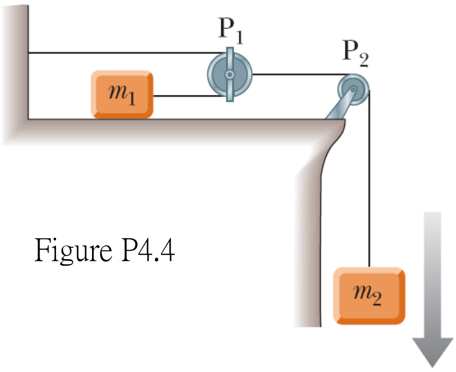
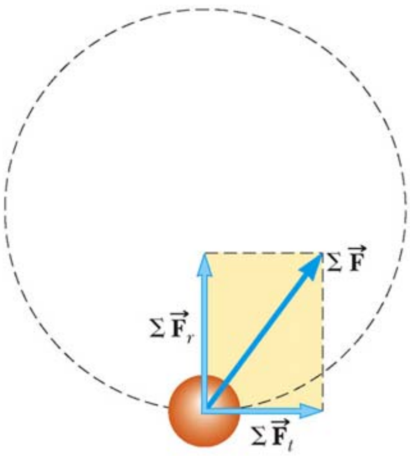


Figure P4.4

Chapter5：More Applications of Newton's Laws

- Static Friction and Kinetic Friction：Friction is proportional to the normal force

  $f_s \le \mu_s n$ and $f_k = \mu_k n$
- The direction of the frictional force is opposite the direction of motion and parallel to the surfaces in contact.
- The coefficients of friction are nearly independent of the area of contact.
- Centripetal Force
  - The force causing the centripetal acceleration is sometimes called the centripetal force.
  - This is not a new force, it is a new role for a force.
  - It is a force acting in the role of a force that causes a circular motion.
- Non-Uniform Circular Motion
  - The acceleration and force have tangential components.
  - $\vec{F}_r$ produces the centripetal acceleration.
  - $\vec{F}_t$ produces the tangential acceleration.
  - $\Sigma\vec{F} = \Sigma\vec{F}_r + \Sigma\vec{F}_t$



Example 5.1：Three objects are connected on the table as shown in Figure P5.1. The table is rough and has a coefficient of kinetic friction of 0.350. The objects have masses 4.00 kg, 1.00 kg, and 2.00 kg, as shown, and the pulleys are frictionless. Draw a free-body diagram for each object. (a) Determine the acceleration of each object and their directions. (b) Determine the tensions in the two cords.

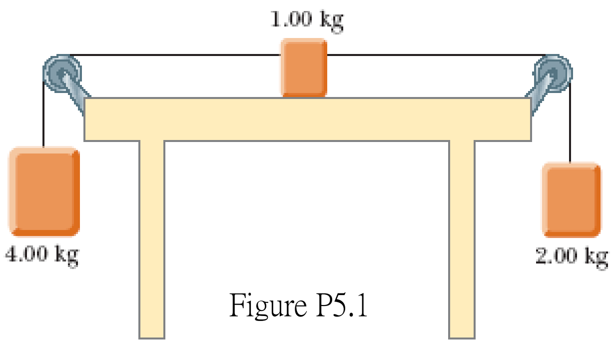


Figure P5.1

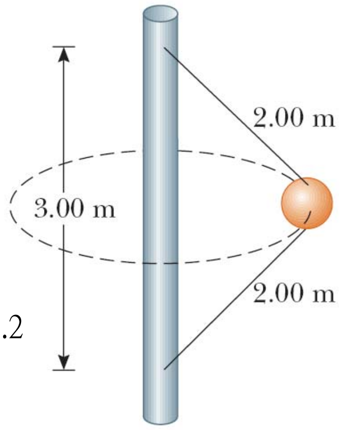
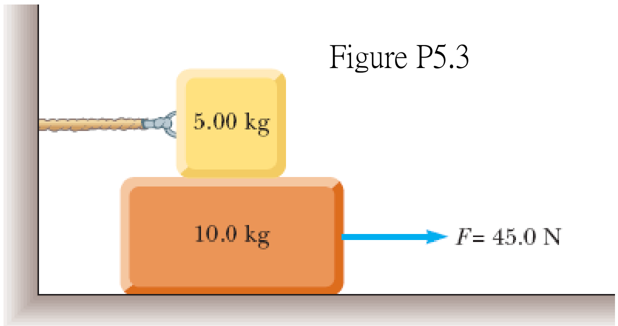


Figure P5.2

Example 5.2：A 4.00-kg object is attached to a vertical rod by two strings as shown in Figure P5.2. The object rotates in a horizontal circle at constant speed 6.00 m/s. Find the tension in (a) the upper string and (b) the lower string.

Example 5.3：A 5.00-kg block is placed on top of a 10.0-kg block (Fig. P5.4). A horizontal force of 45.0 N is applied to the 10-kg block, and the 5-kg block is tied to the wall. The coefficient of kinetic friction between all moving surfaces is 0.200. (a) Draw a free-body diagram for each block and identify the action-reaction forces between the blocks. (b) Determine the tension in the string and the magnitude of the acceleration of the 10-kg block.

Figure P5.3



Example 5.4：The following equations describe the motion of a system of two objects.

$$+n - (6.50\text{ kg})(9.80\text{ m/s}^2)\cos 13.0° = 0$$

$$f_k = 0.360n$$

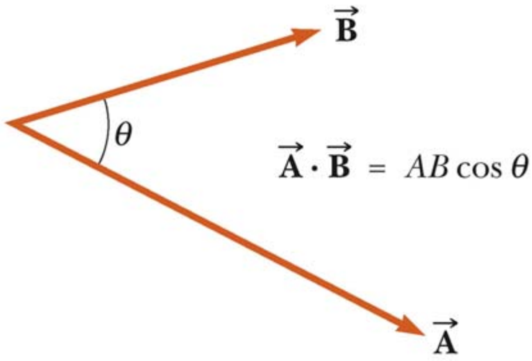
$$+T + (6.50\text{ kg})(9.80\text{ m/s}^2)\sin 13.0° - f_k = (6.50\text{ kg})a$$

$$-T + (3.80\text{ kg})(9.80\text{ m/s}^2) = (3.80\text{ kg})a$$

(a) Solve the equations for a and T. (b) Describe a situation to which these equations apply. Draw free-body diagrams for both objects.

Example 5.5：Consider an object on which the net force is a resistive force proportional to the square of its speed. For example, assume that the resistive force acting on a speed skater is $f = -kmv^2$, where k is a constant and m is the skater's mass. The skater crosses the finish line of a straight-line race with speed v_0 and then slows down by coasting on his skates. Show that the skater's speed at any time t after crossing the finish line is $v(t) = v_0/(1 + ktv_0)$.

Chapter 6：Energy and Energy Transfer



- Scalar Product of Two Vectors $\vec{A}\cdot\vec{B} = AB\cos\theta$

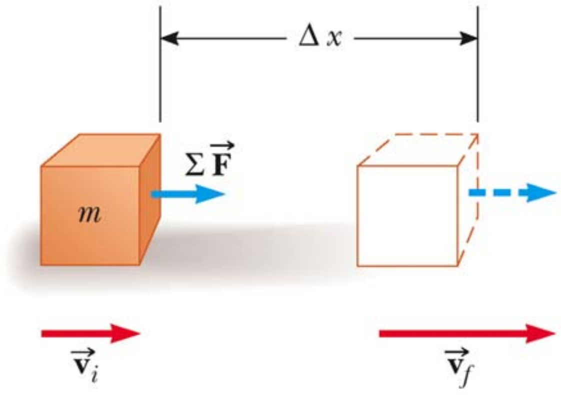
  Commutation：$\vec{A}\cdot\vec{B} = \vec{B}\cdot\vec{A}$

  Multiplication：$\vec{A}\cdot(\vec{B}+\vec{C}) = \vec{A}\cdot\vec{B} + \vec{A}\cdot\vec{C}$

  Component：$\vec{A}\cdot\vec{B} = A_xB_x + A_yB_y + A_zB_z$

- Work done on a system by a constant force $W = F\cdot\Delta r\cdot\cos\theta = \vec{F}\cdot\Delta\vec{r}$

- Work Done by a Varying Force $W = \int_{x_i}^{x_f} F_x dx$



$$W = \int_{x_i}^{x_f} \Sigma F dx = \int_{x_i}^{x_f} madx = \int_{v_i}^{v_f} mvdv$$

$$\Sigma W = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

- Kinetic Energy $K = \frac{1}{2}mv^2$
- Work-Kinetic Energy Theorem：$\Sigma W = K_f - K_i = \Delta K$
- Ways to Transfer Energy Into or Out of A System

  Work

  Mechanical Waves

  Heat

  Matter Transfer

  Electrical Transmission

  Electromagnetic Radiation

- Energy is conserved
  - This means that energy cannot be created or destroyed
  - If the total amount of energy in a system changes, it can only be due to the fact that energy has crossed the boundary of the system by some method of energy transfer
  - The Work-Kinetic Energy theorem is a special case of Conservation of Energy
- Power

Average Power $P_{avg} = \frac{W}{\Delta t}$

Instantaneous Power $P = \frac{dW}{dt} = \vec{F} \cdot \frac{d\vec{r}}{dt} = \vec{F} \cdot \vec{v}$

Example 6.1：For $\vec{\mathbf{A}} = 3\hat{\mathbf{i}} + \hat{\mathbf{j}} - \hat{\mathbf{k}}$, $\vec{\mathbf{B}} = -\hat{\mathbf{i}} + 2\hat{\mathbf{j}} + 5\hat{\mathbf{k}}$, and $\vec{\mathbf{C}} = 2\hat{\mathbf{j}} - 3\hat{\mathbf{k}}$, find $\vec{\mathbf{C}} \cdot (\vec{\mathbf{A}} - \vec{\mathbf{B}})$.

Example 6.2：A force $\vec{\mathbf{F}} = (4x\hat{\mathbf{i}} + 3y\hat{\mathbf{j}})$ N acts on an object as the object moves in the x direction from the origin to $x = 5.00$ m. Find the work done on the object by the force.

Example 6.3：A 650-kg elevator starts from rest. It moves upward for 3.00 s with constant acceleration until it reaches its cruising speed of 1.75 m/s. (a) What is the average power of the elevator motor during this time interval? (b) How does this power compare with the motor power when the elevator moves at its cruising speed?

Example 6.4：A small particle of mass m moves at constant speed as it is pulled to the top of a frictionless half-cylinder (of radius R) by a cord that passes over the top of the cylinder as illustrated in Figure P6.3. (a) Show that $F = mg \cos \theta$. (*Note:* If the particle moves at constant speed, the component of its acceleration tangent to the cylinder must be zero at all times.) (b) By directly integrating $W = \int \vec{F} \cdot d\vec{r}$, find the work done by the force in moving the particle at constant speed from the bottom to the top of the half-cylinder.

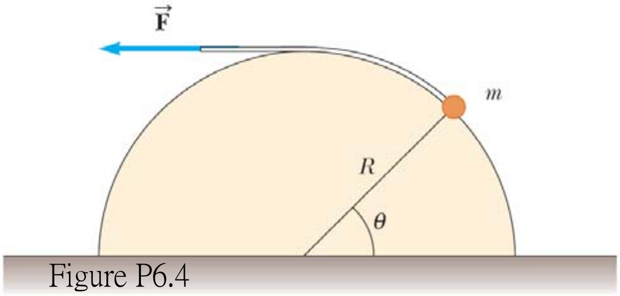


Figure P6.4

Figure P6.5

Example 6.5：The ball launcher in a classic pinball machine has a spring that has a force constant of 1.20 N/cm (Figure P6.5). The surface on which the ball moves is inclined 10.0° with respect to the horizontal. The spring is initially compressed 5.00 cm. Find the launching speed of a 100-g ball when the plunger is released. Friction and the mass of the plunger are negligible.

Chapter 7：Potential Energy

- Conservative Forces
  - A conservative force is a force between members of a system that causes no transformation of mechanical energy within the system
  - The work done by a conservative force on a particle moving between any two points is

independent of the path taken by the particle

- The work done by a conservative force on a particle moving through any closed path is zero

■ Potential Energy Difference $\Delta U = U_f - U_i = -\int_{\vec{r}_i}^{\vec{r}_f} \vec{F} \cdot d\vec{r}$

■ Elastic Potential Energy $U_s = \frac{1}{2}kx^2$

■ Conservation of Energy：

$\Delta K + \Delta U + \Delta E_{int} = \Delta E_{system} = 0$ or $K + U + E_{int} = \text{constant}$

■ Conservative Forces and Potential Energy $F_x = -\frac{dU}{dx}$

■ Work-Kinetic Energy Theorem：$\Sigma W = W_{non} + W_c = K_f - K_i = \Delta K$

$= W_{non} - \Delta U$

$W_{non} = \Delta K + \Delta U$

Example 7.1：The force $\vec{\mathbf{F}} = (3\hat{\mathbf{i}} + 4\hat{\mathbf{j}})$ N acts on a particle that moves from *O* to *C* in Figure P7.1. Calculate the work the force $\vec{\mathbf{F}}$ does on the particle as it moves along each one of the three paths *OAC*, *OBC*, and *OC*. (Your three answers should be identical.)

Example 7.2：A force acting on a particle moving in the *xy* plane is given by $\vec{\mathbf{F}} = (2y\hat{\mathbf{i}} + x^2\hat{\mathbf{j}})$ N, where x and y are in meters. The particle moves from the origin to a final position having coordinates $x = 5.00$ m and $y = 5.00$ m as shown in Figure P7.1. Calculate the work done by $\vec{\mathbf{F}}$ on the particle as it moves along (a) *OAC*, (b) *OBC*, and (c) *OC*. (d) Is $\vec{\mathbf{F}}$ conservative or nonconservative? Explain.

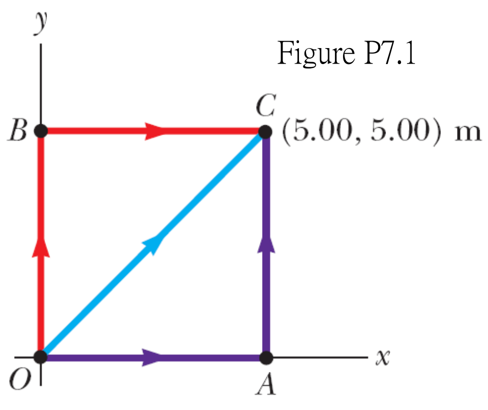


Figure P7.1

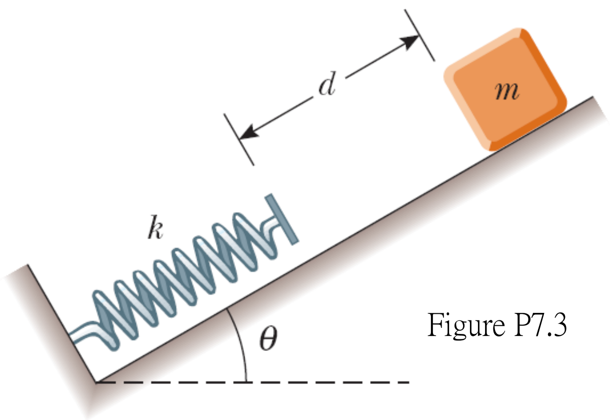


Figure P7.3

Example 7.3：An object of mass m starts from rest and slides a distance d down a frictionless incline of angle θ. While sliding, it contacts an unstressed spring of negligible mass as shown in Figure P7.3. The object slides an additional distance x as it is brought momentarily to rest by compression of the spring (of force constant k). Find the initial separation d between the object and the spring.

Example 7.4：A single conservative force acting on a particle varies as $\vec{\mathbf{F}} = (-Ax + Bx^2)\,\hat{\mathbf{i}}$ N, where A and B are constants and x is in meters. (a) Calculate the potential energy function $U(x)$ associated with this force, taking $U = 0$ at $x = 0$. (b) Find the change in potential energy of the system and the change in kinetic energy of the particle as it moves from $x = 2.00$ m to $x = 3.00$ m.

Example 7.5：A potential energy function for a two-dimensional force is of the form $U = 3x^3y - 7x$. Find the force that acts at the point (x, y).

Example 7.6：A block of mass 0.500 kg is pushed against a horizontal spring of negligible mass until the spring is compressed a distance x (Fig. P7.6). The force constant of the spring is 450 N/m. When it is released, the block travels along a frictionless, horizontal surface to point B, the bottom of a vertical circular track of radius $R = 1.00$ m, and continues to move up the track. The speed of the block at the bottom of the track is $v_B = 12.0$ m/s, and the block experiences an average friction force of 7.00 N while sliding up the track. (a) What is x ? (b) What speed do you predict for the block at the top of the track? (c) Does the block actually reach the top of the track, or does it fall off before reaching the top?

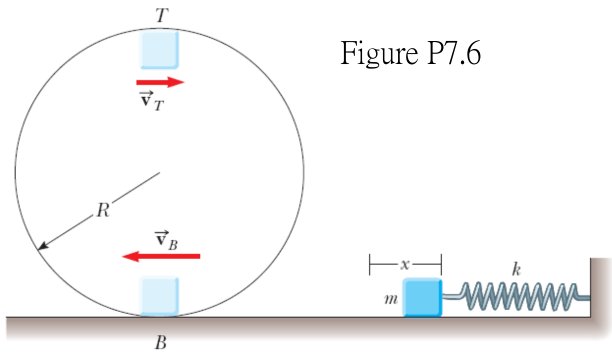


Figure P7.6

解釋名詞 (以下 20 題解釋名詞，任選五題作答)

1. 何謂慣性座標系？
2. 伽利略時空轉換式？舉例說明”空間是絕對的”這句話？
3. 功能原理
4. 何謂保守力？保守力場內質點運動為何需有位能的定義？位能如何定義？
5. 克普勒行星運動三定律
6. 楊氏係數的定義
7. 駐波的物理特性
8. 拍頻的定義為何？發生的原因為何？
9. 如何以等速率圓周運動模擬簡諧運動
10. 伯努利方程式與其物理意義
11. 理想氣體動力論與能量均分原理
12. 惠根斯原理與費馬原理
13. 克希霍夫支點與迴路定律

14. 電阻與電流的定義？一個電子元件的電功率的定義爲何？
15. 質譜儀與霍耳效應的工作原理
16. 安培定律與法拉第定律
17. 彩虹發生的原因？下過雨的黃昏，天空呈現紅色的原因？
18. 愛因斯坦的光子論與如何解釋光電效應實驗？
19. 波耳的類氫原子模型的基本假設
20. 德布羅意的物質波假說爲何？何謂波粒二元性？舉例說明之

計算題 (全做)

1. A ball is thrown at 21 m/s at 30° above the horizontal from the top of a roof 16 m high. Find: (a) the time of flight; (b) the horizontal range; (c) the maximum height; (d) the angle at which the ball hits the ground; (e) the velocity when it is 2 m above the roof.

2. Block A of mass $m_A = 2.0kg$ is on the front face of cart B of mass $m_B = 3.0kg$. A force of 60 N acts on B. What is the minimum coefficient of friction needed for A not to slid down?

3. A car travels in a horizontal circle around a curve of radius *r* banked at an angle θ to the horizontal. If μ is the coefficient of static friction. Show that the maximum speed possible without sliding sideways is $V_{\max} = \sqrt{\dfrac{rg(\mu + \tan\theta)}{1 - \mu\tan\theta}}$.

4. A ball of mass m moves in a vertical circle at the end of a string. Show that the tension at the bottom is greater than at the top by 6 *mg*.

5. Two particle with masses m_1 and m_2 travel toward each other with speeds u_1 and u_2. They collide and stick together. Show that the loss in kinetic energy is $m_1 m_2 (u_1 + u_2)^2 / 2(m_1 + m_2)$.