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2024-07-16

Physics, 4th Edition - David Halliday, Robert Resnick, Kenneth Krane

Contents

6 Momentum

6.1 Summary

- Forces that act for a time which is short relative to the time of observation of the system are called *impulsive forces.*
- The momentum of a body is defined as the product

6.2 Problems and Exercises

Exercise 6-14

Solution:

a. The momentum of each pellet is $p = mv = 1.03362\ \mathrm{kg \cdot m/s}$.
b. The average force exerted by the stream of pellets $F_{\text{av}} = 10p/t = 10.3362\ \mathrm{N}$.
c. The average force exerted by each pellet while in contact is $F_{\text{av}} = \frac{\Delta p}{\Delta t} = 689.08\ \mathrm{N}$.

Exercise 6-19

Let the mass of the module be m. We then have, by the rule of conservation of linear momentum,

$$\begin{aligned} 5mv_1 &= 4mv_2 + mv_3 \\ \Longleftrightarrow v_3 &= 5v_1 - 4v_2 \\ &= 4360\ \mathrm{km/h} \end{aligned}$$

Problem 6-20

Solution: The acceleration of the block is $a_1 = g \sin \alpha \Longrightarrow$
The velocity the block is $v = \sqrt{2da_1} = \sqrt{2gh}$.

Since the collision is inelastic, the two blocks stick together and at an initial speed of $v_2 = \frac{m_1 v_1}{m_2 + v_2}$. They slide a distance x before stopping; thus the average speed is $v_{av} = v_2/2$, so the stopping time is $t_2 = 2x/v_2$ and the acceleration is $a_2 = v_2/t_2 = \dfrac{v_2^2}{2x}$. The frictional force is $f = \mu(m_1 + m_2)g \Longrightarrow \mu = \dfrac{m_1^2}{(m_1+m_2)^2}\dfrac{h}{x} \approx 0.15$.

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8 Rotational Kinematics

8.1 Summary

- The *angular velocity* of anobject moving in a circular orbit ω is
$$\omega = \frac{\Delta\theta}{\Delta t}.$$
As $\Delta t \longrightarrow 0, \omega = \lim_{t\to 0}\dfrac{\Delta\theta}{\Delta t} = \frac{\mathrm{d}\theta}{\mathrm{d}t}$.
- The *angular acceleration α* is
$$\alpha = \frac{\Delta\omega}{\Delta t}.$$
As $\Delta \longrightarrow 0, \alpha = \dfrac{\mathrm{d}\omega}{\mathrm{d}t}$.
- For an object rotating with constant angular acceleration,
$$\omega = \omega_0 + \alpha t$$
and
$$\theta = \theta_0 + \omega_0 t + \frac{\alpha t^2}{2}.$$
- The relationship between and angular and linear variables:
$$\begin{aligned} v_t &= \omega r \\ a_T &= \alpha r \\ a_r &= \frac{v_T^2}{r} = \omega^2 r. \end{aligned}$$

8.2 Problems and Exercises

9. a. 4.8 m/s.
   b. It doesn't matter where one aims the arrow since the wheel is rigid.

32. a. $x^2 + y^2 = R^2$, meaning that the object moves in a circle.
   b. $v_x = x' = -\omega R \sin \omega t$; $v_y = \omega R \cos \omega t \Longrightarrow v = \omega R$. The direction is tangental to the circle.

c. $a_x = -\omega^2 R\cos\omega t, a_y = -\omega^2 R\sin\omega t \implies a = a_x^2 + a_y^2 = \omega^2 R$. The direction is centripetal.

24. The bar needs to make $12 \cdot 1.5 = 18$ turns. Thus the time taken for the bar to move 1.5 cm along the rod is $18 \cdot 60 : 237 \approx 4.56$ s.

29. a. $a_R = \frac{v_T^2}{r} = \frac{\omega^2 r^2}{r} = \omega^2 r = \alpha^2 t^2 r$.
    b. $a_t = \alpha r$.
    c. $a_R = a_T \tan 57°, t = \sqrt{\tan(57°)/\alpha}$. Then,

$$\theta = \frac{\alpha t^2}{2} = \frac{1}{2}\tan(57°) = 0.77 \text{ rad} \approx 44.1°.$$

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9.1 Summary

9.2 Problems and Exercises

Exercise 9-39

Solution: The acceleration is $a = 2st^2 = 0.059 \text{ m}/s^2 \implies \alpha = a/r = 1.204$ rad / s. On the other hand, since

$$m_1 g - T_1 = m_1 \tag{0}$$

and

$$-m_2 g + T_2 = m_2 a, \tag{1}$$

we get

$$T_1 = m_1(g - a); T_2 = m_2(g + a).$$

Since $T_1 > T_2$, $\tau = I\alpha = \frac{Ia}{r} = (T_1 - T_2)r \implies I = (T_1 - T_2)ar^2 = \left[\left(\frac{g}{a} - 1\right)m_1 - \left(\frac{g}{a} + 1\right)m_2\right]r^2 = 0.017 \text{ kg} \cdot \text{ m}^2$.

Exercise 9-41

Solution:

a. The angular velocity is $\omega = v_T/R = 56.49$ rad / s.
b. The angular acceleration is $\alpha = -\frac{\omega^2}{2\varphi} \approx 8.88$ rad / s.

c. The distance traveled is $x = \varphi r = 69.18$ m.

Exercise 9-40

Solution: The initial angular velocity is $\omega = 87.96$ rad / s; the angular acceleration is $\alpha = -\omega^2/2\varphi$. The rotational inertia is $I = \frac{1}{2}MR^2 \Longrightarrow \tau = I\alpha = Rf = \mu RN = \frac{M\omega^2 R^2}{4\varphi} \Longleftrightarrow \mu \approx 0.272$.

Problem 9-19

Solution:
a. Consider a differential of the disk. The frictional torque on said is

$$d\tau = r\,dF = r\frac{\mu_k Mg}{\pi R^2}2\pi r\,dr = \frac{\mu_k Mg 2r^2}{R^2}\,dr$$

$$\Longrightarrow \tau = \int_0^R \frac{\mu_k Mg 2r^2}{R^2}\,dr = \frac{\mu_k Mg 2R}{3}.$$

Problem 9-20

Problem 9-21

Problem 9-22

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23 The First Law of Thermodynamics

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2024-07-16

23.1 Summary

- Heat is energy that flows between between a system and its environment due to a temperature difference between them.
- Heat transfers via one of three mechanisms: conduction, convection and radiation.
- The first law of thermodynamics says that in any process between thermal states, the quantity $Q + W$ is constant irrspective of the path between them, where Q, W are the heat transffered and the work done on the system by forces that act through the system boundary, respectively. This quantity is equal to a change in value of a state function called the internal energy E_{int}:
$$Q + W = \Delta E_{\text{int}}.$$
- Heat capacity is define as the ratio of thermal energy transferred to a body in any process to the change of its change in temperature:
$$C = \frac{Q}{\Delta T}.$$
- Specific heat (capacity) is the heat capcity of the material of which the body is composed:
$$c = \frac{C}{m} = \frac{Q}{m\Delta T}.$$
- The heat energy needed to bring an object composed of a material with specific heat capcity from $T_1 \longrightarrow T_2$ is
$$Q = mc(T_2 - T_1).$$
- The work done by an ideal gas is $W = -\int p\,\mathrm{d}V = -\int_{V_1}^{V_2} p\,\mathrm{d}V$. From this we have the following special cases:
  - Isochoric: $W = 0$
  - Isobaric: $W = -pV_2 - V_1$
  - Isothermal: $W = -nRT\ln\left(\frac{V_2}{V_1}\right)$.
  - Adiabatic: $W = \frac{p_2V_2 - p_1V_1}{\gamma - 1}$, where γ is called the *ratio of specific heats.*
- The theorem of equipartition of energy: when the number of molecules is large, the average energy per molecule is $\frac{kT}{2}$ for each independent degree of freedom. This means that
  - for monoatomic gasses, $E_{\text{int}} = \frac{3}{2}NkT = \frac{3}{2}nRT$ (3 translational axes)

  - for diatomic gasses, $E_{\text{int}} = \frac{5}{2}NkT = \frac{3}{2}nRT$ (3 translational axes + 2 rotational axes)
  - for polyatomic gasses, $E_{\text{int}} = \frac{6}{2}NkT = 3nRT$ (3 translational axes + 3 roational axes)
- The internal energy of an ideal gas depends only on its temperature.
- Molar (isothermal) heat capcity C_v is defined by

$$C_v = \frac{Q}{n\Delta T} = \frac{\Delta E_{\text{int}}}{n\Delta T}.$$

- Molar (isobaric) heat capcity C_p is defined by

$$C_p = C_v + R.$$

23.2 Exercises

30 Capacitance

30.1 Summary

- Capacitance is defined as the ability to hold electric charges:

$$q = C\Delta V. \tag{30.1}$$

- For a parallel-plate capacitor,

$$C = \frac{\varepsilon_0 A}{d} \tag{30.2}$$

- For a spherical capacitor,

$$C = 4\pi\varepsilon_0 \frac{ba}{b - a} \tag{30.3}$$

- For a cylindrical capacitor,

$$C = 2\pi\varepsilon_0 \frac{L}{\ln(b/a)}. \tag{30.4}$$

- The energy stored in a capacitor is $U = \frac{q^2}{2C} = \frac{1}{2}C(\Delta V)^2$.

30.2 Problems and Exercises

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32 The Magnetic Field

32.1 Summary

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32.2 Problems and Exercises