Lecture 18

Agenda:
- Review for exam
- Assignment: For Monday, read chapter 14 (not 13)

Newton’s Laws and the Atwood’s Machine

Two blocks are connected using a massless rope as shown. The 2.00 kg pulley has a moment of inertia about its pivot of 2.00 kg m$^2$. The masses are $m_1 = 3.00$ kg, $m_2 = 1.00$ kg. Initially they are at rest.

a) What is the acceleration of the 1\textsuperscript{st} mass?

b) What is the difference in the tensions?

c) How fast is the 1\textsuperscript{st} mass going after it falls 2.00 m?

1: \[ \Sigma F_y = m_1 \ a_1 = -m_1 \ g + T_1 \]

2: \[ \Sigma F_y = m_2 \ a_2 = -m_2 \ g + T_2 \]

Notice \( a = a_1 = -a_2 \)

\[ I = m_{\text{Pulley}} \ R^2 \quad (R=1.00 \text{ m}) \]

3: \[ \Sigma \tau_{\text{Pulley}} = I \ \alpha = I \ (-a/R) = R \ T_1 - R \ T_2 \quad \text{(if} \ a > 0, \ \text{up, then} \ \alpha < 0) \]

\[ m_{\text{Pulley}} \ R^2 \ (-a/R) = R \ T_1 - R \ T_2 \]

\[ - m_{\text{Pulley}} \ a = T_1 - T_2 \]

1-2 gives \[ m_1 a_1 - m_2 a_2 = (m_1 + m_2) \ a = (m_2 - m_1) \ g + (T_1 - T_2) \]
Continued….

1-2+3 gives \( m_1a_1 - m_2a_2 = (m_1 + m_2) a = (m_2 - m_1) g - m_{\text{Pulley}} a \)

or \( (m_1 + m_2 + m_{\text{Pulley}}) a = (m_2 - m_1) g \)

\[ a = \frac{(m_2 - m_1) g}{(m_1 + m_2 + m_{\text{Pulley}})} \]

\[ a = \frac{(1.00 - 3.00) 10.0}{(3.00+1.00+2.00)} = \frac{-10.0}{3.00} \text{ m/s}^2 \]

b) \(-m_{\text{Pulley}} a = T_1 - T_2 = -2.00 (-10.0/3.00) N = 20.0/3.00 N \)

c) Use conservation of energy! \( K_i = 0 \) (at rest) \( U_i = 0 \) (by design)

\[ E_{\text{Mech}} = K_i + U_i = 0 = K_f + U_i = \frac{1}{2} m_1 v^2 + \frac{1}{2} m_2 v^2 + \frac{1}{2} I\omega^2 - m_1 gh + m_2 gh \]

\[ \frac{1}{2} (m_1+m_2) v^2 + \frac{1}{2} m_{\text{Pulley}} v^2 = m_1 gh - m_2 gh \]

\[ v^2 = 2(m_1 - m_2)gh/(m_1+m_2 + m_{\text{Pulley}}) = 4.00 \times 10.0 \times 2.0/(6.00) \text{ m}^2/\text{s}^2 \]

\[ v^2 = (80.0/6.00) \text{ m}^2/\text{s}^2 \]

Exercise

Work/Energy for Non-Conservative Forces

• An air track is at an angle of 30° with respect to horizontal. The cart (with mass 1.0 kg) is released 1.0 meter from the bottom and hits the bumper at a speed, \( v_1 \). This time the vacuum/air generator breaks half-way through and the air stops. The cart only bounces up half as high as where it started.

• How much work did friction do on the cart? (\( g=10 \text{ m/s}^2 \))

Notice the cart only bounces to a height of 0.25 m

A. 2.5 J
B. 5.0 J
C. 10. J
D. -2.5 J
E. -5.0 J
F. -10. J
Exercise
Work/Energy for Non-Conservative Forces

• How much work did friction do on the cart? \( g=10 \text{ m/s}^2 \)
  \[ W = F \Delta x = \mu mg \cos \theta \Delta x \text{ is not easy to do, esp. if } \mu \text{ not given} \]

• Work done \( (W) \) is equal to the change in the mech. energy of the “system” \( (U+K) \).
  \[ E_{\text{final}} - E_{\text{initial}} \text{ and is } < 0. \ (E = U+K) \]

• Here \( U_{\text{gravity}} \) is “in” the system and \( K_{\text{final}} = K_{\text{initial}} = 0 \)

Use \( W = U_{\text{final}} - U_{\text{initial}} = mg (h_f - h_i) = -mg \sin 30^\circ 0.5 \text{ m} \)

\[ W = -2.5 \text{ N m} = -2.5 \text{ J or (D)} \]

(A) 2.5 J  (B) 5 J  (C) 10 J  (D) –2.5 J  (E) –5 J  (F) –10 J

Exercise
Work/Energy for Non-Conservative Forces

• Alternatively we could look at \( W_{\text{net}} = \Delta K \)

• Again \( K_{\text{final}} = K_{\text{initial}} = 0 \)

• \( W_{\text{net}} = \Delta K = 0 = W_{\text{gravity}} + W_{\text{friction}} \)

  \[ = (mg \sin \theta) (0.5 \text{ meter}) + W_{\text{friction}} \]

\[ W_{\text{friction}} = -2.5 \text{ N m} = -2.5 \text{ J or (D)} \]

And the result is the same

(A) 2.5 J  (B) 5 J  (C) 10 J  (D) –2.5 J  (E) –5 J  (F) –10 J
Springs

- A Hooke’s Law spring with a spring constant of 200 N/m is first stretched 3.0 m past its equilibrium distance and then is stretched 9.0 m.
- How much work must be done to go from 3.0 m to 9.0 m?
- \[ W = U_{\text{final}} - U_{\text{initial}} = \frac{1}{2} k (x-x_{\text{eq}})_{\text{final}}^2 - \frac{1}{2} k (x-x_{\text{eq}})_{\text{init}}^2 \]
  \[ = 100 \left[ (9)^2 - (3)^2 \right] J = 100(72) J = 7200 \text{ J} \]

Chapter 7 (Newton’s 3rd Law) & Chapter 8

**Newton’s Second Law**

Expressed in \(x\)- and \(y\)-component form:

\[
(F_{\text{net}})_x = \sum F_x = ma_x \\
(F_{\text{net}})_y = \sum F_y = ma_y
\]

**Newton’s Third Law**

Every force occurs as one member of an action/reaction pair of forces. The two members of an action/reaction pair:

- Act on two different objects.
- Are equal in magnitude but opposite in direction:
  \[ \vec{F}_{A \text{ on } B} = - \vec{F}_{B \text{ on } A} \]
Chapter 8

Angular velocity
\[ \omega = \frac{d\theta}{dt} \]
\[ \nu_c = \omega r \]

Angular acceleration
\[ \alpha = \frac{d\omega}{dt} \]
\[ \alpha_r = \alpha r \]

Orbits
A circular orbit has radius \( r \) if
\[ \nu = \sqrt{rg} \]

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Chapter 8

Uniform Circular Motion
- \( \nu \) is constant.
- \( \vec{F}_{net} \) points toward the center of the circle.
- The centripetal acceleration \( \vec{a} \) points toward the center of the circle. It changes the particle’s direction but not its speed.

Nonuniform Circular Motion
- \( \nu \) changes.
- \( \vec{a} \) is parallel to \( \vec{F}_{net} \).
- The radial component \( a_r \) changes the particle’s direction.
- The tangential component \( a_t \) changes the particle’s speed.
**Chapter 9**

**Law of Conservation of Momentum**

The total momentum \( \vec{P} = \vec{p}_1 + \vec{p}_2 + \cdots \) of an isolated system is a constant. Thus

\[
\vec{P}_i = \vec{P}_f
\]

**Newton’s Second Law**

In terms of momentum, Newton’s second law is

\[
\vec{F} = \frac{d\vec{p}}{dt}
\]

Momentum \( \vec{p} = m\vec{v} \)

Impulse \( J = \int_{t_i}^{t_f} \vec{F}(t) \, dt = \text{area under force curve} \)

Impulse and momentum are related by the impulse-momentum theorem

\[
\Delta \vec{p}_x = J_x
\]

This is an alternative statement of Newton’s second law.

**Chapter 9**

**System** A group of interacting particles.

**Isolated system** A system on which there are no external forces or the net external force is zero.

Before-and-after pictorial representation

- Define the system.
- Use two drawings to show the system before and after the interaction.
- List known information and identify what you are trying to find.

**Law of conservation of momentum** The total momentum \( \vec{P} \) of an isolated system is a constant. Interactions within the system do not change the system’s total momentum.
Chapter 10

Law of Conservation of Mechanical Energy

If there are no friction or other energy-loss processes (to be explored more thoroughly in Chapter 11), then the mechanical energy \( E_{\text{mech}} = K + U \) of a system is conserved. Thus

\[
K_f + U_f = K_i + U_i
\]

- \( K \) is the sum of the kinetic energies of all particles.
- \( U \) is the sum of all potential energies.

**Kinetic energy** is an energy of motion:

\[
K = \frac{1}{2}mv^2
\]

**Potential energy** is an energy of position

- **Gravitational:** \( U_g = mgy \)
- **Elastic:** \( U_s = \frac{1}{2}k(\Delta s)^2 \)

**Basic Energy Model**

Energy diagrams

These diagrams show the potential-energy curve PE and the total mechanical energy line TE.

- The distance from the axis to the curve is PE.
- The distance from the curve to the TE line is KE.
- A point where the TE line crosses the PE curve is a turning point.
- Minima in the PE curve are points of stable equilibrium.
- Maxima are points of unstable equilibrium.

**Hooke’s law**

The restoring force of an ideal spring is

\[
(F_{\text{eq}})_s = -k\Delta s
\]

where \( k \) is the spring constant and \( \Delta s = s - s_i \) is the displacement from equilibrium.

**Basic Energy Model**

- Energy is transferred to or from the system by work.
- Energy is transformed within the system.

Two versions of the energy equation are

\[
\Delta E_{\text{sys}} = \Delta K + \Delta U + \Delta E_{\text{th}} = W_{\text{ext}}
\]

\[
K_f + U_f + \Delta E_{\text{th}} = K_i + U_i + W_{\text{ext}}
\]
**Chapter 10**

**Law of Conservation of Energy**

- **Isolated system:** \( W_{\text{ext}} = 0 \). The total energy \( E_{\text{sys}} = E_{\text{mech}} + E_{\text{th}} \) is conserved. \( \Delta E_{\text{sys}} = 0 \).
- **Isolated, nondissipative system:** \( W_{\text{ext}} = 0 \) and \( W_{\text{diss}} = 0 \). The mechanical energy \( E_{\text{mech}} \) is conserved. \( \Delta E_{\text{mech}} = 0 \) or \( K_i + U_i = K_f + U_f \).

The work-kinetic energy theorem is

\[
\Delta K = W_{\text{net}} = W_c + W_{\text{diss}} + W_{\text{ext}}
\]

With \( W_c = -\Delta U \) for conservative forces and \( W_{\text{diss}} = -\Delta E_{\text{th}} \) for dissipative forces, this becomes the energy equation.

**Chapter 11**

The work done by a force on a particle as it moves from \( s_i \) to \( s_f \) is

\[
W = \int_{s_i}^{s_f} F_i \, ds = \text{area under the force curve}
\]

\[
= \vec{F} \cdot \Delta \vec{s} \quad \text{if} \quad \vec{F} \text{ is a constant force}
\]

Conservative forces are forces for which the work is independent of the path followed. The work done by a conservative force can be represented as a **potential energy:**

\[
\Delta U = U_f - U_i = -W_c(i \rightarrow f)
\]

A conservative force is found from the potential energy by

\[
F_s = -dU/ds = \text{negative of the slope of the PE curve}
\]

Dissipative forces transform **macroscopic energy** into thermal energy, which is the **microscopic energy** of the atoms and molecules. For friction:

\[
\Delta E_{\text{th}} = f_s \Delta s
\]
Chapter 11

Power is the rate at which energy is transferred or transformed:

\[ P = \frac{dE_{\text{sys}}}{dt} \]

For a particle moving with velocity \( \vec{v} \), the power delivered to the particle by force \( \vec{F} \) is \( P = \vec{F} \cdot \vec{v} = F_v \cos \theta \).

Dot product

\[ \vec{A} \cdot \vec{B} = AB \cos \alpha = A_xB_x + A_yB_y \]

Chapter 12

The moment of inertia and Center of Mass

\[ I = \sum m_i r_i^2 = \int r^2 \, dm \]

is the rotational equivalent of mass. The moment of inertia depends on how the mass is distributed around the axis. If \( I_{\text{cm}} \) is known, the \( I \) about a parallel axis distance \( d \) away is given by the parallel-axis theorem: \( I = I_{\text{cm}} + Md^2 \).

Rotational Dynamics

Every point on a rigid body rotating about a fixed axis has the same angular velocity \( \omega \) and angular acceleration \( \alpha \).

Newton’s second law for rotational motion is

\[ \alpha = \frac{\tau_{\text{net}}}{I} \]

Use rotational kinematics to find angles and angular velocities.
Chapter 12

**Conservation Laws**

**Energy** is conserved for an isolated system.

- Pure rotation $E = K_{rot} + U_g = \frac{1}{2}I\omega^2 + Mg_y$cm
- Rolling $E = K_{rot} + K_{cm} + U_g = \frac{1}{2}I\omega^2 + \frac{1}{2}Mv_{cm}^2 + Mg_y$cm

**Angular momentum** is conserved if $\vec{\tau}_{net} = 0$.

- Particle $\vec{L} = \vec{r} \times \vec{p}$
- Rigid body rotating about axis of symmetry $\vec{L} = I\vec{\omega}$

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**Important Concepts**

Torque is the rotational equivalent of force:

$$\tau = rF \sin \phi = rF \hat{r} = dF$$

The vector description of torque is

$$\vec{\tau} = \vec{r} \times \vec{F}$$
Example problem: Going in circles

- A 2.0 kg disk tied to a 0.50 m string undergoes circular motion on a rough but horizontal table top. The kinetic coefficient of friction is 0.25. If the disk starts out at 5.0 rev/sec how many revolutions does it make before it comes to rest?

- Work-energy theorem
- \( W = F \cdot d = 0 - \frac{1}{2}mv^2 \)
- \( F = -\mu mg \cdot d = -\frac{1}{2}mv^2 \)
- \( d = \frac{v^2}{2\mu g} = (5.0 \times 2\pi \times 0.50)^2 / (0.50 \times 10) \ m = 5 \pi^2 \ m \)
- Rev = \( d / 2\pi = 16 \) revolutions
- What if the disk were tilted by 60°?
You like to drive home fast, slam on your brakes at the start of the driveway, and screech to a stop “laying rubber” all the way. It’s particularly fun when your mother is in the car with you. You practice this trick driving at 20 mph and with some groceries in your car with the same mass as your mother. You find that you only travel half way up the driveway. Thus when your mom joins you in the car, you try it driving twice as fast. How far will you go this time?

A. The same distance. Not so exciting.
B. \( \sqrt{2} \) times as far (only \( \sim 7/10 \) of the way up the driveway)
C. Twice as far, right to the door. Whoopee!
D. Four times as far crashing into the house. (Oops.)

\[ W = F \, d = - \mu \, N \, d = - \mu \, mg \, d = \Delta K = 0 - \frac{1}{2} \, mv^2 \]

\[ W_1 = - \mu \, mg \, d_1 = \Delta K_1 = 0 - \frac{1}{2} \, mv_1^2 \]

\[ W_2 = - \mu \, mg \, d_2 = \Delta K_2 = 0 - \frac{1}{2} \, m(2v_1)^2 = -4 \, (\frac{1}{2} \, mv_1^2) \]

- \( \mu \, mg \, d_2 = -4 \, (\mu \, mg \, d_1) \rightarrow d_2 = -4 \, d_1 \)

A. The same distance. Not so exciting.
B. \( \sqrt{2} \) times as far (only \( \sim 7/10 \) of the way up the driveway)
C. Twice as far, right to the door. Whoopee!
D. **Four times as far crashing into the house. (Oops.)**
Kinetic Energy

• To practice your pitching you use two baseballs. The first time you throw a slow curve and clock the speed at 50 mph (~25 m/s). The second time you go with high heat and the radar gun clocks the pitch at 100 mph. What is the ratio of the kinetic energy of the fast ball versus the curve ball?

A. ¼
B. ½
C. 1
D. 2
E. 4

\[
\frac{KE_2}{KE_1} = \frac{1}{2} mv_2^2 / \frac{1}{2} mv_1^2 = \frac{100^2}{50^2} = 4
\]

(A) 1/4  (B) 1/2  (C) 1  (D) 2  (E) 4
Work and Energy

- A block of mass $m$ is connected by a spring to the ceiling. The block is held at a position where the spring is unstretched and then released. When released, the block
  (a) remains at rest.

  (b) oscillates about the unstretched position

  (c) oscillates about a position that is lower than the unstretched position

  (d) oscillates about a position that is higher than the unstretched position
Momentum & Impulse

A rubber ball collides head on (i.e., velocities are opposite) with a clay ball of the same mass. The balls have the same speed, v, before the collision, and stick together after the collision. What is their speed immediately after the collision?

A. 0
B. $\frac{1}{2} v$
C. 2 v
D. 4 v

Momentum & Impulse

A rubber ball collides head on with a clay ball of the same mass. The balls have the same speed, v, before the collision, and stick together after the collision. What is their speed after the collision?

(a) 0

(b) $\frac{1}{2} v$

(c) 2 v

(d) 4 v
Momentum, Work and Energy

- A 0.40 kg block is pushed up against a spring (with spring constant 270 N/m) on a frictionless surface so that the spring is compressed 0.20 m. When the block is released, it slides across the surface and collides with the 0.60 kg bob of a pendulum. The bob is made of clay and the block sticks to it. The length of the pendulum is 0.80 m. (See the diagram.)

- To what maximum height above the surface will the ball/block assembly rise after the collision? \( g=9.8 \text{ m/s}^2 \)

A. 2.2 cm  
B. 4.4 cm  
C. 11. cm  
D. 22 cm  
E. 44 cm  
F. 55 cm

Momentum, Work and Energy

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- To what maximum height above the surface will the ball/block assembly rise after the collision?

A. 2.2 cm  
B. 4.4 cm  
C. 11. cm  
D. 22 cm  
E. 44 cm  
F. 55 cm
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Momentum, Work and Energy (Now with friction)

- A 0.40 kg block is pushed up against a spring (with spring constant 270 N/m) on a surface.
- If \( m_{\text{static}} = 0.54 \), how far can the spring be compressed and the block remain stationary (i.e., maximum static friction)?
  \[
  \Sigma F = 0 = k u - f = k u - \mu N \\
  u = \mu \frac{mg}{k} = 0.54 \left( \frac{0.40 \times 10 \text{ N}}{270 \text{ N/m}} \right) = 0.0080 \text{ m}
  \]

Momentum, Work and Energy (Now with friction)

- A 0.40 kg block is pushed up against a spring (with spring constant 270 N/m) on a surface. The spring is now compressed 2.0 m.
- If \( m_{\text{kinetic}} = 0.50 \) and the block is 8.0 m away from the unstretched spring, how high will the clay/block pair rise?
  \[
  E_{\text{mech}} (at collision) = U_{\text{spring}} + W_{\text{friction}} = \frac{1}{2} k u^2 - \mu mg d \\
  1/2 m v^2 = 135(4.0) - 0.50(0.40 \times 10) \times 10 = (540 - 20) \text{ J} = 520 \text{ J} \\
  v^2 = 1040/0.40 \text{ m}^2/\text{s}^2 \\
  \text{Now the collision (cons. of momentum) and the swing.}
  \]
Work and Energy

A mass is attached to a Hooke's law spring on a horizontal surface as shown in the diagram below. When the spring is at its natural length, the block is at position Y.

When released from position X, how will the spring potential energy vary as the block moves from X to Y to Z?

(a) It will steadily increase from X to Z.
(b) It will steadily decrease from X to Z.
(c) It will increase from X to Y and decrease from Y to Z.
(d) It will decrease from X to Y and increase from Y to Z.
Work and Energy

- An object moves along a line under the influence of a single force. The area under the force vs. position graph represents

(a) the impulse delivered to the object

(b) the work done on the object.

(c) the change in the velocity of the object.

(d) the momentum of the object.
**Momentum and Impulse**

- Henri Lamothe holds the world record for the highest shallow dive. He belly-flopped from a platform 12.0 m high into a tank of water just 30.0 cm deep! Assuming that he had a mass of 50.0 kg and that he stopped just as he reached the bottom of the tank, what is the magnitude of the impulse imparted to him while in the tank of water (in units of kg m/s)?

(a) 121  
(b) 286  
(c) 490  
(d) 623  
(e) 767

\[ \Delta p = \sqrt{2 \times 9.8 \times 12.3} \times 50 \]
Two particles, one positively charged and one negatively charged, are held apart. Since oppositely charged objects attract one another, the particles will accelerate towards each other when released. Let $W_+$ be the work done on the positive charge by the negative charge. Let $W_-$ be the work done on the negative charge by the positive charge. While the charges are moving towards each other, which of the following statements is correct?

(a) $W_+$ is positive and $W_-$ is negative.
(b) $W_+$ is negative and $W_-$ is positive.
(c) Both $W_+$ and $W_-$ are positive.
(d) Both $W_+$ and $W_-$ are negative.
(e) Without knowing the coordinate system, the sign of the work can not be determined.
Momentum & Impulse

Suppose that in the previous problem, the positively charged particle is a proton and the negatively charged particle, an electron. (The mass of a proton is approximately 1,840 times the mass of an electron.) Suppose that they are released from rest simultaneously. If, after a certain time, the change in momentum of the proton is \( \Delta p \), what is the magnitude of the change in momentum of the electron?

(a) \( \Delta p / 1840 \)

(b) \( \Delta p \)

(c) \( 1840 \Delta p \)
Work and Energy

- A block slides along a frictionless surface before colliding with a spring. The block is brought momentarily to rest by the spring after traveling some distance. The four scenarios shown in the diagrams below are labeled with the mass of the block, the initial speed of the block, and the spring constant.
- Rank the scenarios in order of the distance the block travels, listing the largest distance first.

(a) B, A, C = D
(b) B, C, A, D
(c) B, C = D, A
(d) C = B, A, D
(e) C = B = D, A

Work and Energy

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(a) B, A, C = D
(b) B, C, A, D
(c) B, C = D, A
(d) C = B, A, D
(e) C = B = D, A
Newton’s Laws

- Two boxes are connected to each other as shown. The system is released from rest and the 1.00 kg box falls through a distance of 1.00 m. The surface of the table is frictionless. What is the kinetic energy of box B just before it reaches the floor? \((g=9.81 \text{ m/s}^2)\)

(a) 2.45 J
(b) 4.90 J
(c) 9.80 J
(d) 9.24 J
(e) 9.32 J

Work and Energy

- If it takes 5.35 J of work to stretch a Hooke’s law spring 12.2 cm from its un-stretched length, how much work is required to stretch an identical spring by 17.2 cm from its un-stretched length?

(a) 0.90 J
(b) 5.3 J
(c) 7.2 J
(d) 10.6 J
(e) 11.0 J
Work and Energy

• If it takes 5.35 J of work to stretch a Hooke’s law spring 12.2 cm from its un-stretched length, how much work is required to stretch an identical spring by 17.2 cm from its un-stretched length?

(a) 0.90 J
(b) 5.3 J
(c) 7.2 J
(d) 10.6 J
(e) 11.0 J

Work and Forces

• A 25.0 kg chair is pushed 2.00 m at constant speed along a horizontal surface with a constant force acting at 30.0 degrees below the horizontal. If the friction force between the chair and the surface is 55.4 N, what is the work done by the pushing force?

(a) 85 J
(b) 98 J
(c) 111 J
(d) 113 J
(e) 128 J
Work and Forces

- A 25.0 kg chair is pushed 2.00 m at constant speed along a horizontal surface with a constant force acting at 30.0 degrees below the horizontal. If the friction force between the chair and the surface is 55.4 N, what is the work done by the pushing force?

(a) 85 J
(b) 98 J
(c) 111 J
(d) 113 J
(e) 128 J

Work and Power

- A 100 kg elevator is carrying 6 people, each weighing 70 kg. They all want to travel to the top floor, 75 m from the floor they entered at. How much power will the elevator motor supply to lift this in 45 seconds at constant speed?

(a) $1.2 \times 10^2$ W
(b) $7.0 \times 10^2$ W
(c) $8.7 \times 10^2$ W
(d) $6.9 \times 10^3$ W
(e) $8.5 \times 10^3$ W
Work and Power

A 100 kg elevator is carrying 6 people, each weighing 70 kg. They all want to travel to the top floor, 75 m from the floor they entered at. How much power will the elevator motor supply to lift this in 45 seconds at constant speed?

(a) $1.2 \cdot 10^2$ W
(b) $7.0 \cdot 10^2$ W
(c) $8.7 \cdot 10^2$ W
(d) $6.9 \cdot 10^3$ W
(e) $8.5 \cdot 10^3$ W

Conservation of Momentum

A woman is skating to the right with a speed of 12.0 m/s when she is hit in the stomach by a giant snowball moving to the left. The mass of the snowball is 2.00 kg, its speed is 25.0 m/s and it sticks to the woman's stomach. If the mass of the woman is 60.0 kg, what is her speed after the collision?

(a) 10.8 m/s
(b) 11.2 m/s
(c) 12.4 m/s
(d) 12.8 m/s
Conservation of Momentum

- A woman is skating to the right with a speed of 12.0 m/s when she is hit in the stomach by a giant snowball moving to the left. The mass of the snowball is 2.00 kg, its speed is 25.0 m/s and it sticks to the woman's stomach. If the mass of the woman is 60.0 kg, what is her speed after the collision?

(a) 10.8 m/s

(b) 11.2 m/s

(c) 12.4 m/s

(d) 12.8 m/s

Momentum and Impulse

- A stunt man jumps from the roof of a tall building, but no injury occurs because the person lands on a large, air-filled bag. Which one of the following statements best describes why no injury occurs?

(a) The bag provides the necessary force to stop the person.

(b) The bag reduces the impulse to the person.

(c) The bag reduces the change in momentum.

(d) The bag decreases the amount of time during which the momentum is changing and reduces the average force on the person.

(e) The bag increases the amount of time during which the momentum is changing and reduces the average force on the person.
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Newton’s Laws

- Two sleds are hooked together in tandem. The front sled is twice as massive as the rear sled. The sleds are pulled along a frictionless surface by a force $F$, applied to the more massive sled. The tension in the rope between the sleds is $T$. Determine the ratio of the magnitudes of the two forces, $T/F$.

(a) 0.33
(b) 0.50
(c) 0.67
(d) 1.5
(e) 2.0
(f) 3.0
Momentum and Impulse

Two blocks of mass $m_1 = M$ and $m_2 = 2M$ are both sliding towards you on a frictionless surface. The linear momentum of block 1 is half the linear momentum of block 2. You apply the same constant force to both objects in order to bring them to rest. What is the ratio of the two stopping distances $d_2/d_1$?

(a) $1/2$
(b) $1/2^{1/2}$
(c) $1$
(d) $2^{1/2}$
(e) $2$
(f) Cannot be determined without knowing the masses of the objects and their velocities.
A mass, 11 kg, slides down a frictionless circular path of radius, 5.0 m, as shown in the figure. Initially it moves only vertically and, at the end, only horizontally (1/4 of a circle all told). Gravity, 10 m/s², acts along the vertical.

If the initial velocity is 2 m/s downward then

(a) What is the work done by gravity on the mass?

(b) What is the final speed of the mass when it reaches the bottom?

(c) What is the normal force on the mass when it reaches the bottom

\[ W = mgR = 11 \times 10 \times 5 = 550 \text{ J} \]

\[ \frac{1}{2} mv_f^2 = \frac{1}{2} m v_i^2 + mgR = 22 \text{ J} + 550 \text{ J} = 572 \text{ J} \]

\[ v_f = \left( \frac{1144}{11} \right)^{\frac{1}{2}} \text{ m/s} \]
Work, Energy & Circular Motion

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If the initial velocity is 2 m/s downward then

(c) What is the normal force on the mass when it reaches the bottom

\[ \Sigma F_y = m \, a_c = N - mg = m \, \frac{v^2}{R} \]

\[ N = mg + m \, \frac{v^2}{R} = (110 + 11 \times \frac{1144}{11}) \, N = 1254 \, N = 1300 \, N \]

Work and Energy

An object is acted upon by only two forces, one conservative and one nonconservative, as it moves from point A to point B. The kinetic energy of the object at points A and B are equal if

A. the sum of the two forces’ work is zero
B. the work of the nonconservative force is zero
C. the work of the conservative force is zero
D. the work of the conservative force is equal to the work of the nonconservative force
E. None of the above will make them equal
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Work and Energy

A 6.0 kg block is pushed up against an ideal Hooke’s law spring (of spring constant 3750 N/m) until the spring is compressed a distance x. When it is released, the block travels along a track from one level to a higher level, by moving through an intermediate valley (as shown in the diagram). The track is frictionless until the block reaches the higher level. There is a frictional force stops the block in a distance of 1.2 m. If the coefficient of friction between the block and the surface is 0.60, what is x? (Let g = 9.81 m/s\(^2\))

(a) 0.11 m
(b) 0.24 m
(c) 0.39 m
(d) 0.48 m
(e) 0.56 m
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