

Multiple choice questions [60 points]

Answer all of the following questions. Read each question carefully. **Fill the correct bubble on your scantron sheet.** Each correct answer is worth 4 points. Each question has exactly one correct answer.

1. A woman runs up a flight of stairs. The gain in her gravitational potential energy is U . If she runs up the same stairs with twice the speed, what is her gain in potential energy?

- A. \underline{U} The gravitational potential energy depends only on the change in elevation.
- B. $\underline{2U}$
- C. $\underline{U/2}$
- D. $\underline{4U}$
- E. $\underline{U/4}$

2.

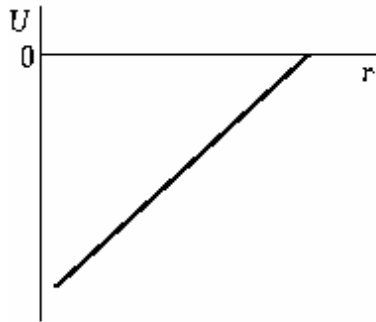


Figure A

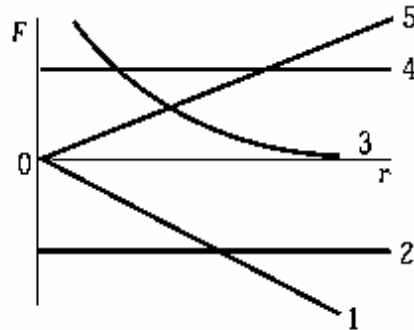
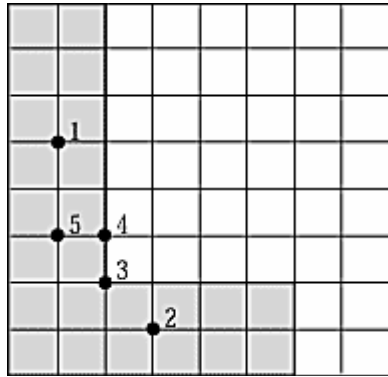


Figure B

When the potential energy $U(r)$ is given as in Figure A, then the force is given in Figure B by curve

- A. $\underline{1}$
- B. $\underline{2}$ Use $F = -dU/dr$
- C. $\underline{3}$
- D. $\underline{4}$
- E. $\underline{5}$

3.

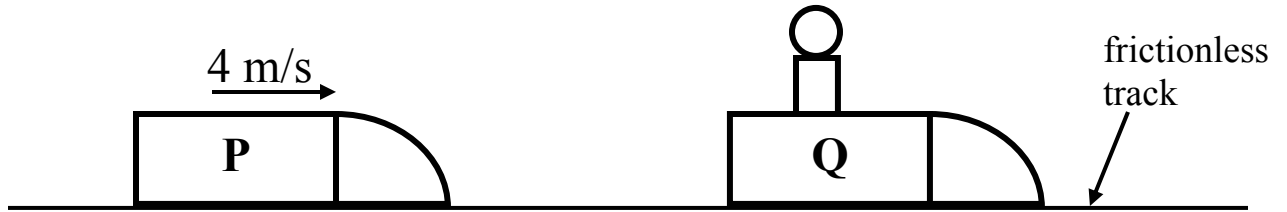


An L-shaped piece, represented by the shaded area on the figure, is cut from a metal plate of uniform thickness. The point that corresponds to the center of mass of the L-shaped piece is

- A. 1
 - B. 2
 - C. 3
 - D. $\frac{4}{5}$
 - E. $\frac{5}{5}$
4. The condition necessary for the conservation of momentum in a given system is that
- A. energy is conserved.
 - B. one body is at rest.
 - C. the net external force is zero.
 - D. internal forces equal external forces.

Questions 5 through 11 all refer to the same problem.

An empty bobsled (labeled P) of mass 150 kg travels at 4m/s toward an identical stationary bobsled (labeled Q) containing an athlete of unknown mass. Ignore friction between the sleds and the track in this problem.



5 In a one-second interval, the center of mass of the system composed of P and Q moves a distance

- A. greater than 4 m
- B. equal to 4 m
- C. less than 4 m ($v_{CM} = \frac{m_P v_P + m_Q v_Q}{m_P + m_Q} = \frac{m_P v_P}{m_P + m_Q} < v_P$)

6 When the centers of mass of P and Q are 20 m apart, the center of mass of the system composed of P and Q is 8 m from the center of mass of sled Q. The mass of the athlete is therefore:

- A. 100 kg
 - B. 150 kg
 - C. 120 kg
 - D. 75 kg
 - E. 60 kg
- 12 m ● 8 m ●
 150 kg 300+m kg 150+m kg
 $12(300+m) = 20(150+m)$
 $m = 75\text{kg}$

When the two sleds collide, they stick together and then move along the track.

7 During the collision, the force exerted on bobsled P by bobsled Q is:

- A. greater than the force exerted on bobsled Q by bobsled P
- B. less than the force exerted on bobsled Q by bobsled P
- C. equal to the force exerted on bobsled Q by bobsled P (Newton's third law)
- D. there is not enough information to say

8 The change in momentum of bobsled P as a result of the collision is:

- A. directed to the right
 - B. directed to the left
 - C. zero
- Before

After

→

←

\vec{p}_P^{before}

\vec{p}_P^{after} $\Delta\vec{p}_P$

The velocity of P after the collision is equal to the velocity of the center of mass which is less than the initial velocity of P.

Name: _____ Total Points: _____
(Last) (First)

9 the final speed of the system composed of P and Q is

A. 4 m/s

B. 1.6 m/s $v_{CM} = \frac{m_P v_P + m_Q v_Q}{m_P + m_Q} = \frac{m_P v_P}{m_P + m_Q} = \frac{150 * 4}{150 + 150 + 75} = 1.6 \text{ m/s}$

C. 2.7 m/s

D. 0 m/s

E. Other

10 When the sleds are moving together along the track after the collision, the force exerted on bobsled P by bobsled Q is

A. directed to the right

B. directed to the left

C. zero (P doesn't accelerate)

D. there is not enough information to answer

11 For the system composed of P and Q, how does the total kinetic energy after the collision (KE_f) compare with the total kinetic energy before the collision (KE_i)?

A. $KE_f > KE_i$

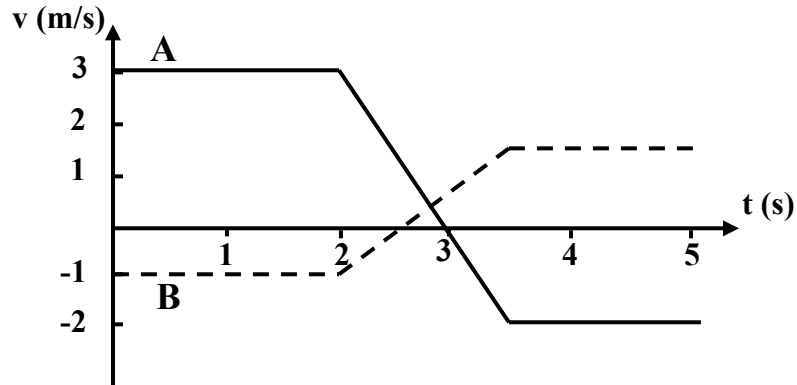
B. $KE_f = KE_i$

C. $KE_f < KE_i$ (inelastic collision)

D. $KE_f = -KE_i$

Questions 12 through 15 all refer to the same problem.

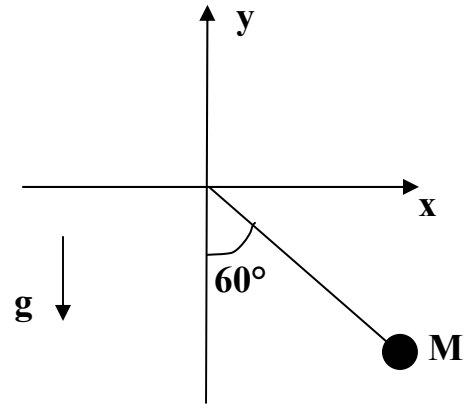
Two carts collide on a level frictionless track that is oriented in the x direction. A graph of the velocities versus time is shown below. The mass of cart A is 1.0 kg and the mass of cart B is 2.0 kg.



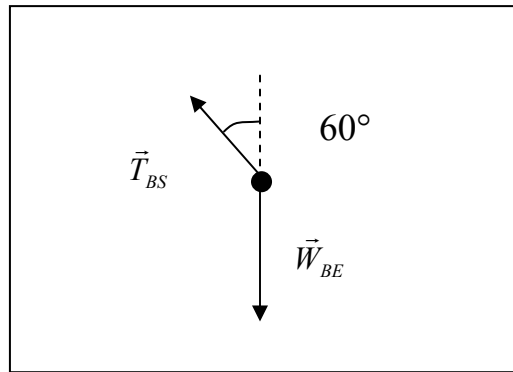
- 12 At what time does the collision begin?
- 0 s
 - 1 s
 - 2 s (The velocities start changing)
 - 3 s
 - 4 s
- 13 What is the total momentum of the system of carts before the collision (in kg m/s)?
- 0
 - 1 ($=3*1 + (-1)*2$)
 - 2
 - 3
 - 4
- 14 What impulse does the collision impart to cart A (in kg m/s)?
- 0
 - 1
 - 3
 - 5 ($|\vec{I}_A| = |\Delta\vec{p}_A| = |(-2)*1 - 3*1|$)
 - 8
- 15 The collision is
- elastic
 - inelastic
 - partially elastic
 $KE_f = ((-2)^2*1 + (1.5)^2*2)/2 = 8.5/2 \text{ J} < KE_i = (3^2*1 + (-1)^2*2)/2 = 11/2 \text{ J}$
 and $\vec{v}_A^{final} \neq \vec{v}_B^{final}$ (A and B don't stick together)
 - impossible
 - super elastic

PROBLEM [40 points]

A pendulum consisting of a string and a ball of mass M has just been released at $t=0$ at rest with an initial angle of 60 degrees from the vertical. The string has length L . Ignore air resistance. The acceleration of gravity is g .



- 1). [5 pts] In the box below, draw a free body diagram for the ball just after the pendulum is released. Clearly label all of the forces.



- 2). [5 pts] What is the value of the radial acceleration (a_{\perp}) just after the pendulum has been released? Explain.

$$a_{\perp} = \frac{v^2}{L} = 0 \text{ m/s}^2 \text{ since } v=0 \text{ just after the release of the pendulum}$$

- 3). [10 pts] What is the magnitude of the tension in the string just after the pendulum has been released? Circle your answer and explain your reasoning (no credit given without an explanation)

A) 0 B) $\frac{1}{2}Mg$ C) $\frac{\sqrt{3}}{2} Mg$ D) Mg E) $2Mg$

$$\vec{T}_{BS} + \vec{W}_{BE} = M \vec{a}$$

Project the equation along the direction of \vec{T}_{BS}

$$T_{BS} - Mg \cos 60 = Ma_{\perp} = 0$$

$$T_{BS} = \frac{Mg}{2}$$

Name: _____ Total Points: _____
 (Last) (First)

A short time t_1 later, the pendulum is still descending and you observe that the angle of the pendulum is 30 degrees.

- 4). [5 pts] What is the work done by the tension on the ball by the string between $t=0$ and $t=t_1$? Explain

The tension is always perpendicular to the displacement: $W_{T_{BS}} = 0$

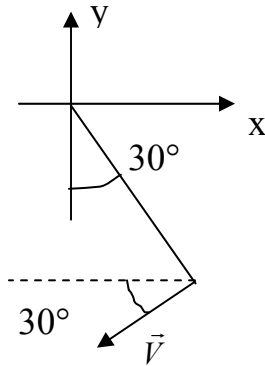
- 5). [5 pts] What is the sign of the work done by gravity between $t=0$ and $t=t_1$? (Circle your answer and explain your reasoning)
 A) 0 B) positive C) negative

The angle between the weight and the displacement is less than 90°

- 6). [5 pts] What is the direction of the instantaneous velocity vector of the ball at $t=t_1$? Express your answer in terms of the unit vectors \hat{x} and \hat{y} (circle your answer and explain your reasoning).

A) $-\frac{1}{2}\hat{x} - \frac{\sqrt{3}}{2}\hat{y}$ B) $-\frac{\sqrt{3}}{2}\hat{x} - \frac{1}{2}\hat{y}$ C) $\frac{1}{2}\hat{x} - \frac{\sqrt{3}}{2}\hat{y}$ D) $\frac{\sqrt{3}}{2}\hat{x} + \frac{1}{2}\hat{y}$

Use the following figure: \vec{V} has the direction $-\cos(30)\hat{x} - \sin(30)\hat{y}$



A short time t_2 later, the pendulum is at its lowest position moving to the left.

- 7). [5 pts] What is the direction of the acceleration vector at $t=t_2$? Express your answer in terms of the unit vectors \hat{x} and \hat{y} .

The acceleration is in the direction of the net force. At the lowest point, the tension on the ball by the string is straight up. The weight is straight down. The acceleration must be along $\pm \hat{y}$. Also, the acceleration should point toward the inside of the trajectory. Thus, the acceleration is straight up (along $+\hat{y}$).

Note: you can also find the direction by looking at the direction of $\Delta\vec{V}$ at the lowest point.