Physics 123H - Final Exam

Note. All physical quantities below are measured in SI units.

1. A puck of mass \( m = 0.1 \) moves on a frictionless horizontal surface with velocity vector

\[ \vec{v}_1 = 12\hat{i} - 7\hat{j} \]

At some point during the motion the puck hits a wall and bounces back with velocity vector

\[ \vec{v}_2 = 9\hat{i} + 5\hat{j}. \]

Here \((x, y)\) are coordinates in the horizontal plane. Compute the impulse of the force acting on the puck during the collision with the wall.

- a) \(0.2\hat{i} + 1.4\hat{j}\)
- b) \(-0.5\hat{i} - 0.2\hat{j}\)
- c) \(0.4\hat{i} - 0.9\hat{j}\)
- d) \(-0.3\hat{i} + 1.2\hat{j}\)
- e) 0

Solution.

\[ \vec{J} = \Delta \vec{p}_{puck} = m(\vec{v}_2 - \vec{v}_1) = 0.1 \times (-3\hat{i} + 12\hat{j}) = -0.3\hat{i} + 1.2\hat{j} \]

2. A ball of clay of mass \( m = 0.1 \) moves on a frictionless horizontal surface with velocity vector

\[ \vec{v} = -8\hat{i} + 11\hat{j} \]

At some point during the motion the ball hits a wall and remains stuck to it. Here \((x, y)\) are coordinates in the horizontal plane. Compute the impulse of the force acting on the ball during the collision with the wall.

- a) 0
b) $-0.8\hat{i} - 1.1\hat{j}$
c) $-0.8\hat{i} + 1.1\hat{j}$
d) $0.8\hat{i} + 1.1\hat{j}$
e) $0.8\hat{i} - 1.1\hat{j}$

**Solution.**

\[
\vec{J} = \Delta \vec{p}_{\text{ball}} = 0.1 \times (8\hat{i} - 11\hat{j}) = 0.8\hat{i} - 1.1\hat{j}
\]

3. A toy gun placed on a frictionless horizontal table fires a ball with velocity vector

\[
\vec{v} = 5.4\hat{i}
\]

where \(\hat{i}\) is horizontal and points to the right as usual. The mass of the *loaded* gun is \(M\) and the mass of the ball is \(m = M/10\). Compute the \(x\)-component of the recoil velocity of the gun.

a) $-0.6$
b) $0.2$
c) $-0.3$
d) $0.4$
e) $-0.5$

**Solution.**

\[
(M - m)u_x + mv_x = 0
\]

\[
u_x = -\frac{m}{M - m}v_x = -\frac{5.4}{9} = -0.6.
\]

4. In the figure below a block of mass \(m\) moves up and down a frictionless ramp of angle \(\theta = 30^\circ\) under the action of a spring force directed along the ramp. The spring constant is \(k\) and the maximum **elongation** of the spring
along the ramp during the motion is \( d \). The speed of the block when the spring is relaxed is
\[
v = \frac{3}{2} \sqrt{gd}.
\]
Note that
\[
\sin(30^\circ) = \frac{1}{2}, \quad \cos(30^\circ) = \frac{\sqrt{3}}{2}.
\]
Compute the ratio
\[
\frac{kd}{mg}.
\]
a) \( \frac{3}{4} \)
b) \( \frac{5}{4} \)
c) \( \frac{9}{4} \)
d) \( \frac{7}{4} \)
e) 1

\[ \text{Solution.} \]
\[
\frac{kd^2}{2} + mgd\sin(\theta) = \frac{mv^2}{2},
\]
\[
kd^2 = \frac{9}{4} mgd - mgd = \frac{5}{4} mgd,
\]
\[
\frac{kd}{mg} = \frac{5}{4}.
\]

5. A block of mass \( m = 4 \) moves back and forth along the \( x \)-axis under the action of two spring forces as shown below. The first spring has constant
$k_1 = 7$ while the second has constant $k_2 = 9$ and they both stretch along the $x$-axis. The loose ends of the springs are connected to two fixed walls. Initially the block is at rest, the first spring is elongated a distance $d$ while the second is compressed the same distance $d$ with respect to their undeformed configuration. There is no friction acting on the block. At some moment after the block is released both springs reach their undeformed configuration at the same time. The speed of the block at this moment is $v = 0.5$. Find $d$.

a) 0.25  
b) 0.15  
c) 0.35  
d) 0.5  
e) 0.45

![diagram of two springs stretched along x-axis with block and fixed walls]

**Solution**

\[
\frac{k_1 d^2}{2} + \frac{k_2 d^2}{2} = \frac{mv^2}{2}
\]

\[
d = \sqrt{\frac{mv^2}{k_1 + k_2}} = \sqrt{\frac{4 \times 0.25}{16}} = 0.25
\]

6. A small block of mass $m$ is launched horizontally up a circular ramp of radius $R$ as shown below. The initial velocity of the block is horizontal and has magnitude

\[
v = \sqrt{3gR}
\]
The magnitude of the work done by kinetic friction along the ramp during the motion is

\[ |W_{fk}| = \frac{mgR}{4}. \]

Compute the maximum height \( h \) reached by the block above the top of the ramp.

a) \( \frac{R}{2} \)
b) \( \frac{R}{3} \)
c) \( \frac{R}{4} \)
d) \( R \)
e) \( 0 \)

**Solution.**

\[ |W_{fk}| = \frac{mv^2}{2} - mg(h + R) \]

\[ mgh + mgR = \frac{3mgR}{2} - \frac{mgR}{4} = \frac{5mgR}{4} \]

\[ h = \frac{R}{4} \]

7. A spring of constant \( k \) pushes a block of mass \( m \) along a rough horizontal floor.
In the initial configuration the spring is compressed a distance \( d \) such that 

\[
kd = \frac{2}{3} mg
\]

and the block has zero initial velocity. The block moves a distance \( 4d/5 \) along the table, then stops. Compute the kinetic friction coefficient between the block and the floor. The free fall acceleration is \( g \) and there is no air drag.

a) \( \frac{3}{8} \)

b) \( \frac{1}{4} \)

c) \( \frac{2}{5} \)

d) \( \frac{1}{3} \)

e) \( \frac{5}{8} \)

**Solution.**

\[
\frac{kd^2}{2} = \mu_k mg \times \frac{4d}{5} + \frac{k}{2} \left( \frac{d}{5} \right)^2
\]

\[
\frac{kd}{2} = \frac{4}{5} \mu_k mg + \frac{kd}{50}
\]

\[
\frac{1}{3} = \frac{4}{5} \mu_k + \frac{1}{75}
\]

\[
25 = 60\mu_k + 1
\]

\[
\mu_k = \frac{24}{60} = \frac{2}{5},
\]

8. A block of mass \( m = 0.1 \) is connected to one end of an ideal spring of constant \( k = 16 \) as shown below. The other end of the spring is held fixed. The spring is initially compressed a distance \( d = 0.2 \) and the surface of the table is rough. The block is given a horizontal initial velocity of magnitude \( v_0 = 5 \). The velocity of the block when the spring reaches its
relaxed configuration is \( v_1 = 4 \). Find the amount of thermal energy released during this part of the motion.

(a) 1.23  
(b) 0.77  
(c) 0.81  
(d) 0.59  
(e) 0.93

\[ v_0 \]

**Solution.**

By conservation of total energy

\[
\Delta E_{mec} + \Delta E_{th} = 0
\]

\[
\Delta E_{th} = -\Delta E_{mec} = -\frac{mv_1^2}{2} + \frac{mv_0^2}{2} + \frac{kd^2}{2} = 0.77 \text{J}
\]

9. A spring of launches a block of mass \( m \) horizontally along a rough surface with zero initial velocity. The spring is initially compressed a distance \( d \) with respect to its relaxed configuration. The block then climbs a curved ramp and reaches the top of the ramp with speed

\[ v = \sqrt{gh} \]

The magnitude of total work done by kinetic friction during the motion is

\[ |W_{fk}| = \frac{2mgh}{5} \]
Let \( U_s \) be initial elastic potential energy of the spring. Compute the ratio

\[
\frac{U_s}{mgh}
\]

The free fall acceleration is \( g \) and air drag is negligible.

(a) 2.1
(b) 2.2
(c) 1.9
(d) 1.2
(e) 1.7

The work done by friction equals the variation of the mechanical energy:

\[
\frac{kd^2}{2} = mgh + \frac{mv^2}{2} + |W_{fk}|
\]

\[
\frac{kd^2}{2} = mgh + \frac{mgh}{2} + \frac{2mgh}{5} = 1.9mgh.
\]

10. A uniform square plate is dropped with zero initial velocity in uniform gravitational field as shown below. The length of each side of the square is \( d \) and the center of the plate is initially at height

\[
h = 3d\sqrt{2}
\]

above the floor. The free fall acceleration is \( g \) and air drag is negligible.
Let $K$ be kinetic energy of the plate when its lower corner hits the floor. Then the ratio \[
\frac{K}{mgd}
\]
is:

(a) $5\sqrt{2}/2$

(b) $3\sqrt{2}/2$

(c) $2/\sqrt{2}$

(d) $3/2$

(e) $5/2$

Energy conservation for the motion of the COM

\[mg(h - d\sqrt{2}/2) = K\]

Hence

\[K = mg \times (3 - 1/2)\sqrt{2}d = \frac{5\sqrt{2}}{2}mgd.\]
11. A hard small object of mass \( m = 0.15 \) moves on a frictionless horizontal with constant velocity of magnitude \( 3.4\sqrt{2} \). The object hits a wall such that the collision is elastic and changes the direction of motion of the object by \( 90^\circ \).

![Diagram of object moving and colliding with wall]

Note that
\[
\sin(45^\circ) = \cos(45^\circ) = \frac{\sqrt{2}}{2}.
\]

Then the magnitude of the impulse of the normal force acting on the object during collision is:

(a) 0.88
(b) 1.02
(c) 1.06
(d) 0.76
(e) 1.12

Note that
\[
\sin(45^\circ) = \cos(45^\circ) = \frac{\sqrt{2}}{2}.
\]
Solution.

\[ J_\perp = 2mv_\perp = 2mv\frac{\sqrt{2}}{2} = mv\sqrt{2} = 2 \times 0.15 \times 3.4 = 1.02. \]

12. A ball of mass \( m = 0.3 \) moves on a smooth horizontal surface with constant velocity vector \( \vec{v} = 10\hat{i} \) and hits a half spherical wall of radius \( R \) as shown below. The direction of \( \vec{v} \) is parallel with the central symmetry axis of the wall and the distance \( h \) is \( h = 3R/5 \). Suppose there is no friction between the ball and the wall and the ball starts sliding along the inner surface of the wall immediately after collision. What is the kinetic energy of the ball after collision?

\begin{center}
\includegraphics[width=0.5\textwidth]{diagram.png}
\end{center}

(a) 4.6  
(b) 5.4  
(c) 6.2  
(d) 3.8  
(e) 8.4

Solution.

Since there is no friction between the ball and the wall, the only force acting on the ball during the collision is the normal force which is radial.
Therefore the tangential component of the momentum is conserved. This yields

\[ mv_f = m \cdot v \sin \theta = \frac{h}{R} \cdot mv \]

hence

\[ v_f = \frac{3v}{5} = 6. \]

Then \( K_f = \frac{1}{2} \times 0.3 \times 36 = 5.4. \)

---

**13.** A satellite moves around a planet on an elliptical orbit with semi-major axis \( a \). The speed of the satellite when it reaches a point on the trajectory at distance \( r \) from the center of the planet is

\[ v = \sqrt{\frac{5GM}{a}}. \]

Then the ratio \( r/a \) is:

- a) 1/4
- b) 3/4
- c) 1/2
- d) 2/3
- e) 1/3
The total mechanical energy at distance $r$ is

$$\frac{1}{2}mv^2 - \frac{GmM}{r} = -\frac{GmM}{2a}$$

This yields

$$\frac{5}{2a} + \frac{1}{2a} = \frac{1}{r}$$

Hence

$$\frac{3}{a} = \frac{1}{r}$$

$$r/a = 1/3.$$ 

14. A very narrow tunnel is cut straight through the center of a uniform spherical planet of radius $R$ and mass $M$. A ball of mass $m$ is shot from the center of the planet along the tunnel as shown below.

The minimum value of the initial kinetic energy of the ball such that the ball reaches a distance $d = 2R/3$ from the center is $K$. Then the ratio

$$\frac{RK}{GmM}$$

is:

a) $2/3$
b) 2/9
c) 1/3
d) 4/9
e) 3/2

**Solution.** The force acting on the ball is a spring force \( F_r = -kr \), with constant
\[
k = \frac{GMm}{R^3}.
\]
Hence
\[
K = \frac{1}{2} \frac{GMm}{R^3} \left( \frac{2R}{3} \right)^2 = \frac{2GMm}{9R}.
\]

**15.** A solid uniform sphere has mass \( M \) and radius \( R \). A spherical cavity of radius \( R/2 \) is cut out as shown below. The cavity is also connected to the opposite point on the surface by a very narrow frictionless radial tunnel. Note that mass of the sphere was \( M \) before removing the spherical cavity. A pointlike particle of mass \( m \) is placed inside the tunnel, at distance \( R/2 \) from the center.
Let \( a \) be the magnitude of the acceleration of the particle. Then the ratio \( \frac{a R^2}{GM} \) is:

a) 0  
b) 1/4  
c) 3/8  
d) 1/8  
e) 5/8

The mass removed from the cavity is \( M' = \frac{M}{8} \). By superposition,

\[
\frac{GmM}{R^3} \times \frac{R}{2} = F_g + \frac{Gm(M/8)}{R^2}
\]

\[
F_g = \frac{GmM}{2R^2} - \frac{GmM}{8R^2} = \frac{3GmM}{8R^2}
\]

\[a = \frac{3GM}{8R^2}\]

16. Two blocks of masses \( m_1 = 1 \) and \( m_2 = 4 \) are connected by an ideal spring. The whole system is placed on a rough horizontal table, the spring being initially compressed. Suppose both blocks start sliding in opposite directions along the table as soon as the spring is released.

Let \( a \) be the magnitude of the acceleration of the center of mass of the two blocks during their motion along the table. The free fall acceleration is
and air drag is negligible. Compute the ratio

\[
\frac{a}{g}
\]

if the kinetic friction coefficient between the blocks and the table is \( \mu_k = 0.3 \).

a) 0.22  
b) 0.18  
c) Cannot be determined; need to know the spring constant.  
d) 0.24  
e) 0.16

Solution.

\[
(m_1 + m_2)a = \mu_k(m_2 - m_1)g
\]

\[
a = 0.3 \times (3/5)g = 0.18g
\]

17. Two particles of masses \( m_1 = m \), \( m_2 = 2m \) are initially a distance \( d \) apart in vacuum, far away from other sources of gravitational field. The particles start moving simultaneously toward each other as a result of gravitational attraction with zero initial velocities. There is no friction or air drag. Let \( K \) be the total kinetic energy in the system when the separation between particles is \( 5d/8 \). Then the ratio

\[
\frac{dK}{Gm^2}
\]

is:

a) 8/5  
b) 4/5  
c) 6/5  
d) 2/5  
e) 1
Solution.

\[- \frac{2Gm^2}{d} = - \frac{16Gm^2}{5d} + K\]

\[K = \frac{Gm^2}{d}(16/5 - 2) = \frac{6Gm^2}{5d}\]

18. In the figure below, planet 1 is a uniform solid sphere of radius \(R\), while planet 2 is a uniform thick shell of outer radius \(R\) and inner radius \(r < R\). The ratio of their masses is

\[\frac{M_2}{M_1} = \frac{5}{7}\]

Compute the ratio

\[\frac{g_2}{g_1}\]

between the magnitude of the free fall acceleration at the surface of planet 2 and that of planet 1.

a) Cannot be determined; need to know \(r\).

b) \(2/7\)

c) \(5/7\)

d) \(3/7\)

e) 1
Solution.

\[ g_1 = \frac{GM_1}{R^2}, \quad g_2 = \frac{GM_2}{R^2} \]

\[ \frac{g_2}{g_1} = \frac{M_2}{M_1} = \frac{5}{7}. \]

19. A dumbbell consists of two identical blocks connected by an ideal rigid rod of length \( d \) of negligible mass. The size of each block is also negligible compared to \( d \). The dumbbell is placed in the gravitational field of a massive uniform ball of mass \( M \) such that the rod is along the radial direction as shown below. The distance between block 1 and the center of the massive particle is \( d \).

Let \( a \) the magnitude of the acceleration of the center of mass of the dumbbell. Then the ratio \( \frac{ad^2}{GM} \) is:

a) 3/4

b) 1/2
c) 4/3
d) 5/6
e) 5/8

Solution.

\[ 2ma = \frac{GmM}{d^2} + \frac{GmM}{4d^2} = \frac{5GmM}{4d^2} \]
\[ a = \frac{5GM}{8d^2} \]

**20.** A particle falls radially in the gravitational field of a uniform spherical planet of radius \( R \) and mass \( M \). The particle starts falling from distance \( d = 4R/3 \) from the center of the planet with zero initial velocity. The kinetic energy of the particle when it hits the surface is

\[ K = \frac{GmM}{6R}. \]

Let \( W_{th} \) be the thermal energy released as a result of air friction during the fall. Then the ratio \( \frac{RW_{th}}{GmM} \) is:

a) 1/4
b) 1/12
c) 1/6
d) 5/6
e) 5/12

**Solution.**

\[-\frac{3GmM}{4R} = -\frac{GmM}{R} + K + W_{th} \]

\[ W_{th} = \frac{GmM}{4R} - \frac{GmM}{6R} = \frac{GmM}{12R}. \]

**21.** A leaf blown by the wind lands on the horizontal surface of a still lake with velocity vector

\[ \vec{v} = 5\hat{i} - 3\hat{j} \]

Here \( \hat{i} \) is horizontal and \( \hat{j} \) is vertical as usual. Suppose the friction force between the leaf and the water surface is negligible, and the leaf slides along the surface of the lake after collision with constant speed \( v_f \). Then \( v_f \) is:
a) 2  
b) 5  
c) 4  
d) 3  
e) Cannot be determined.

Solution. Since there is no friction, the horizontal component of the momentum is conserved. Hence
\[ v_f = 5. \]

22. Two blocks connected by a loose ideal cord are placed on a frictionless horizontal table. Block 2 is suddenly launched with horizontal initial velocity \( \vec{v} = 3\hat{i} \) as shown below.

What is the final speed of the center of mass of the system after the cord is stretched taut and the first block starts moving as well. Their masses are \( m_1 = 3 \), \( m_3 = 7 \).

a) 0.9  
b) 1.2  
c) 2.4  
d) 1.8  
e) 2.1
Solution. Since there is no friction, the horizontal component of the momentum is conserved.

\[ v_{\text{com}} = \frac{m_2 v}{m_1 + m_2} = 0.7v = 2.1. \]

23. A block of mass \( m \) moves with constant velocity on a frictionless horizontal table \( \vec{v} = \hat{i} \). The block collides head on a second block of mass \( 3m \), which is initially static. After collision, the relative velocity of the first block with respect to the second block is

\[ \vec{v}_{\text{rel}} = -0.6\hat{i}. \]

Compute the speed of the second block after collision relative to the table.

a) 0.6
b) 0.2
c) 0.4
d) 0.8
e) 1.0

Solution. Momentum is conserved

\[ m_1 v_{1x} + m_2 v_{2x} = m_1 v \]

Also

\[ v_{1x} - v_{2x} = -0.6v \]

Hence

\[ v_{2x} = 1.6 \times \frac{m_1 v}{m_1 + m_2} = 0.4v \]

24. A block of mass \( m \) moves with constant velocity \( \vec{v} = 6\hat{i} \) on a frictionless horizontal table. At some point during the motion a smaller block of mass 0.2\( m \) falls vertically on top of the moving block and gets stuck to it. What is the speed of the composite object after collision?

a) 5
b) 6

c) 4

d) 3

e) 2

**Solution.** The horizontal momentum is conserved

\[ v_f = \frac{m v}{1.2 \times m} = \frac{6}{1.2} = 5 \]

25. A particle moving with velocity

\[ \vec{v}_1 = -1.2 \hat{i} + 4.8 \hat{j} \]

collides a second particle moving with unknown velocity \( \vec{v}_2 \). The velocity of the center of mass of the two particles after collision is

\[ \vec{v}_{\text{com}} = 0.3 \hat{i} + 2.4 \hat{j} \]

The ratio of the masses of the two particles is \( m_1/m_2 = 2/3 \). Find \( \vec{v}_2 \).

a) \(-2.3 \hat{i} + 1.8 \hat{j}\)

b) \(1.7 \hat{i} - 3.1 \hat{j}\)

c) \(1.2 \hat{i} - 0.7 \hat{j}\)

d) \(1.3 \hat{i} - 0.8 \hat{j}\)

e) \(1.3 \hat{i} + 0.8 \hat{j}\)

**Solution**

\[ m_1 \vec{v}_1 + m_2 \vec{v}_2 = (m_1 + m_2) \vec{v}_{\text{com}} \]

\[ \vec{v}_2 = \frac{5}{3} \vec{v}_{\text{com}} - \frac{2}{3} \vec{v}_1 = 1.3 \hat{i} + 0.8 \hat{j} \]

26. A completely inelastic collision occurs among two particles with initial velocity vectors

\[ \vec{v}_1 = 8\hat{i} - 5\hat{j}, \quad \vec{v}_2 = -4\hat{i} + 7\hat{j}. \]
The two particles have masses $m_1 = 0.2$ and $m_3 = 0.3$. What is the final velocity vector of the composite particle after collision?

a) $0.8 \hat{i} + 2.2 \hat{j}$
b) $1.4 \hat{i} - 1.8 \hat{j}$
c) $-1.2 \hat{i} + 2.6 \hat{j}$
d) $\hat{i} - 2.8 \hat{j}$
e) $2.4 \hat{i} + 0.2 \hat{j}$

**Solution.**

$$\vec{V} = \frac{1}{5}(2\vec{v}_1 + 3\vec{v}_2) = \frac{1}{5}(4\hat{i} + 11\hat{j}) = 0.8\hat{i} + 2.2\hat{j}.$$ 

**27.** Two identical blocks slide simultaneously on back to back inclined planes as shown below. Both ramps are frictionless and make $45^\circ$ angles with the horizontal. The free fall acceleration is $g$ and there is no air drag. Compute the magnitude of the acceleration of the COM of the two blocks.

![Diagram of two blocks on inclined planes](image)

a) $g$
b) $g/\sqrt{2}$
c) $g\sqrt{2}$
d) 0

e) \frac{g}{2}.

Note that 
\[
\sin(45^\circ) = \cos(45^\circ) = \frac{\sqrt{2}}{2}.
\]

**Solution.**
\[
\vec{a}_1 = \frac{g}{2}(-\hat{i} - \hat{j}) \\
\vec{a}_2 = \frac{g}{2}(\hat{i} - \hat{j}) \\
\vec{a}_{com} = (\vec{a}_1 + \vec{a}_2)/2 = -(g/2)\hat{j}
\]

28. In a two particle elastic collision, the masses of the two particles are 
\(m_1 = 0.4 \text{ g}\) and \(m_2 = 0.1 \text{ g}\). The initial velocity vectors are
\[
\vec{v}_{1i} = -8\hat{i}, \quad \vec{v}_{2i} = 4\hat{i}
\]
in \(m/s\). Compute the final velocity vector of particle 1.

a) 3.6\hat{i}  

b) -3.2\hat{i}  

c) -3.8\hat{i}  

d) 4.4\hat{i}  

e) -2.6\hat{i}

**Solution.**
\[
v_{1f} = \frac{m_1 - m_2}{m_1 + m_2}v_{1i} + \frac{2m_2}{m_1 + m_2}v_{2i}
\]
\[
v_{1f} = 3 \times v_{1i}/5 + 2v_{2i}/5 = -24/5 + 8/5 = -16/5 = -3.2 \text{ m/s}.
\]

29. Three identical uniform spherical objects of mass \(M\) are placed at equal intervals on a circle of radius \(R\) as shown below. A small projectile
is launched from the center of the circle such that its initial velocity $\vec{v}$ is perpendicular to the plane of the circle. Compute the minimum initial speed $v$ such that the projectile travels an infinite distance away from the system of spherical objects. The latter are assumed static during the motion and there is no friction or air drag.

![Diagram of projectile motion](image)

a) $\sqrt{3GM/R}$

b) $\sqrt{6GM/R}$

c) $\sqrt{2GM/R}$

d) $\sqrt{4GM/R}$

e) $\sqrt{8GM/R}$

Solution. Conservation of energy:

$$\frac{mv^2}{2} - 3\frac{GmM}{R} = 0$$

$$v = \sqrt{\frac{6GM}{R}}$$

30. A small block of mass $m$ slides on the concave frictionless face of a bigger block of mass $M = 2m$ placed on a horizontal table. The small block starts sliding at height $h$ from the table with zero initial velocity. The bigger concave block is free to slide along the table without friction.
The magnitude of the free fall acceleration is $g$ and there is no air drag. Compute the final speed of the bigger concave block after the smaller block reaches the table and they move away from each other.

a) $\sqrt{gh/3}$
b) $\sqrt{gh}$
c) $\sqrt{3gh/2}$
d) $\sqrt{gh/2}$
e) $\sqrt{2gh/3}$

**Solution.** Energy is conserved. Horizontal momentum is conserved.

\[ Mu = mv \]
\[ Mu^2/2 + mv^2/2 = mgh. \]

\[ v = 2u \]
\[ u^2 + v^2/2 = gh \]
\[ 3u^2 = gh \]
\[ u = \sqrt{gh/3} \]