PHYS 101 Midterm Examination #1 (version D)

October 7, 2011

Time: 50 minutes

Last Name : Key

First Name : ______

Student No. : ______

Computing ID : ______

Tutorial Section : ______

	score	***Maximum***
Multiple Choice		***7***
Written # 1		***5***
Written # 2		***5***
Written # 3		***5***
Total		***22***

Part I (Multiple choice questions. 1 mark each.)

C

1. John and James dive from an overhang into the lake below. John simply drops straight down from the edge. James takes a running start and jumps with an initial horizontal velocity of 8 m/s. Compare the time it takes each to reach the lake below.
   A) James reaches the surface of the lake first.
   B) John reaches the surface of the lake first.
   (C) James and John will reach the surface of the lake at the same time.
   D) Cannot be determined without knowing the mass of both James and John.
   E) Cannot be determined without knowing the height of the overhang.

A

2. The acceleration of a particle in projectile motion
   (A) is directed down at all times.
   B. points along the path of the particle.
   C. is directed horizontally.
   D. vanishes at the particle's highest point.
   E. is zero

E

3. Does the centripetal force acting on an object do work on the object?
   A) Yes, since a force acts and the object moves, and work is force times distance.
   B) Yes, since it takes energy to turn an object.
   C) No, because the object has constant speed.
   D) No, because the object's displacement is zero.
   (E) No, because the force and the displacement of the object are perpendicular.

D

4. A baseball of mass 0.15 kg moving at 10.0 m/s strikes the glove of a catcher. The glove recoils a distance of 5.0 cm. The magnitude of the average force applied by the ball on the glove is
   A) 667 N
   B) 600 N
   C) 60 N
   (D) 150 N
   E) 15 N

$F \cdot d = \frac{1}{2} m v^2$

$F = \frac{m v^2}{2d} = \frac{0.15 \times 10^2}{2 \times 0.05}$

→ x

$\left(W_{net} = \Delta K, \quad -Fd = 0 - \frac{1}{2} m v^2 \right)$

C

5. A 0.15-kg baseball is dropped from rest. It has a speed of 1.2 m/s just before it hits the ground. It rebounds with a speed of 1.0 m/s. The ball is in contact with the ground for 0.0015 s. What is the average force exerted by the ground on the ball during that time?
   A) 40 N
   B) 100 N
   (C) 220 N
   D) 240 N
   E) 140 N

$\vec{F} \Delta t = \Delta \vec{p}$

$F \Delta t = m v_f - m v_i$

$= m(v_f - v_i)$

$F = \frac{m(v_f - v_i)}{\Delta t}$

$= \frac{0.15[1.0 - (-1.2)]}{0.0015} = 220\ N$

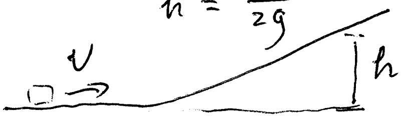
E

6. A lightweight object and a very heavy object are sliding with equal speeds along a level frictionless surface. They both slide up the same frictionless hill. Which rises to a greater height?

A) The heavy object, because it has greater kinetic energy.
B) The light object, because it has smaller kinetic energy.
C) The lightweight object, because it weighs less.
D) The heavy object, because it weighs more.
(E) They both slide to the same height.

$\frac{1}{2}mv^2 = mgh$.

$h = \frac{v^2}{2g}$



h — independent of mass.

B

7. A car and a minivan collide and stick together. Consider the total momentum and the total kinetic energy of the two vehicles before and after the collision. Which of the following statements is true?

(A) Both the total momentum and total kinetic energy are conserved.
(B) The total momentum is conserved but the total kinetic energy is not conserved.
(C) Neither the total momentum nor the total kinetic energy is conserved.
(D) The total kinetic energy is conserved but the total momentum is not conserved.
(E) The change in total momentum equals the change in total kinetic energy.

Part II (Full solution questions, 5 marks each. **SHOW ALL WORK FOR FULL MARKS!**)

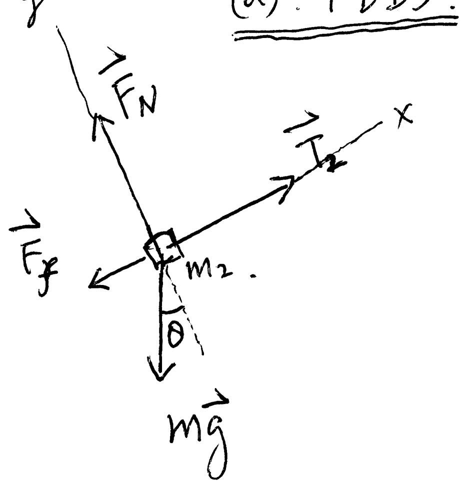
8. Suppose the coefficient of kinetic friction between block 2 and the inclined plane in the figure is 0.10, and the mass of block 1 is the same as that of block 2, (m_1=m_2=5.0kg). Ignore the mass of cable and the friction of the pulley.
(a) Draw a free body diagram for each block;
(b) As block 1 moves down, determine the magnitude of the acceleration of m_1 and m_2, given $\theta = 35°$.
(c) Determine the magnitude of the tension in the cable.

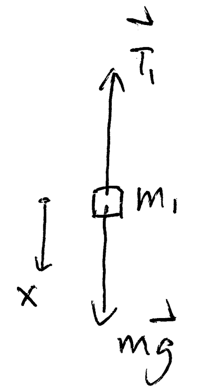
$m_1 = m_2 = m$

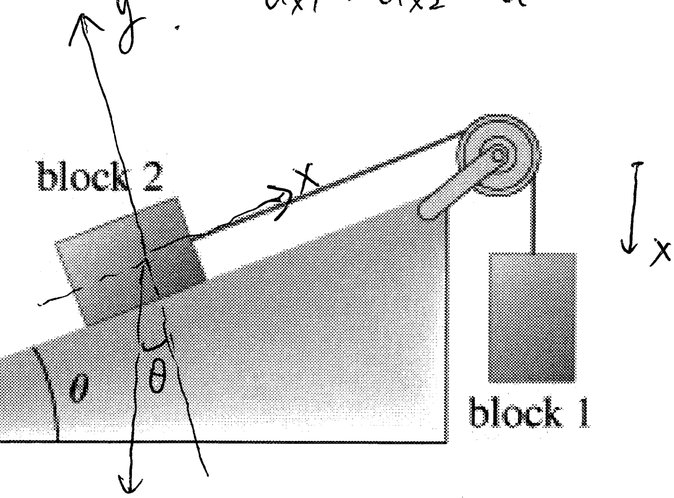
$T_1 = T_2 = T$.

$a_{x1} = a_{x2} = a$

(a). FBDs.







$\vec{F} = m\vec{a}$:

(b).
$$\begin{cases} mg - T = ma & (1) \\ T - \mu_k F_N - mg\sin\theta = ma & (2) \\ F_N - mg\cos\theta = 0 & (3) \end{cases}$$

(1)+(2): $mg - \mu_k F_N - mg\sin\theta = 2ma$.

(3): $F_N = mg\cos\theta$

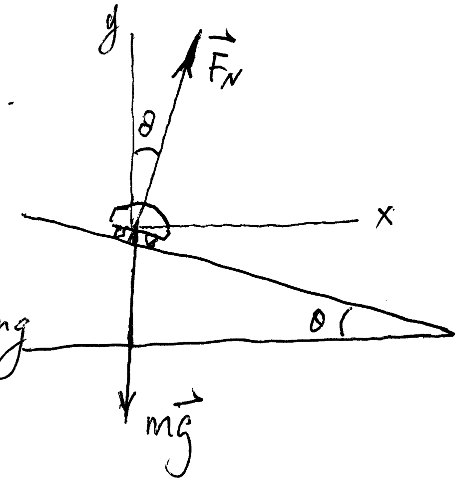
∴ $mg - \mu_k mg\cos\theta - mg\sin\theta = 2am$.

$a = \frac{g}{2}(1 - \mu_k\cos\theta - \sin\theta) = 4.9(1 - 0.1\times\cos 35° - \sin 35°) = 1.69 \simeq 1.7\ m/s^2$

(c). $T = mg - ma = m(g-a) = 5.0(9.8 - 1.7) = 40.5 \simeq 41\ (N)$

9. (**Show the free-body-diagrams for full marks**). At the entrance of a free way, a curve of radius 100m is banked for a design speed of 54 km/h.
(a) Determine the banking angle (so that no friction is reuired if the speed is 54km/h).
(b) If the coefficient of static friction is 0.10, what is the maximum speed at which a car can safely handle the curve?

$R = 100\ m, \quad v = 54\ km/h = 15\ m/s.$

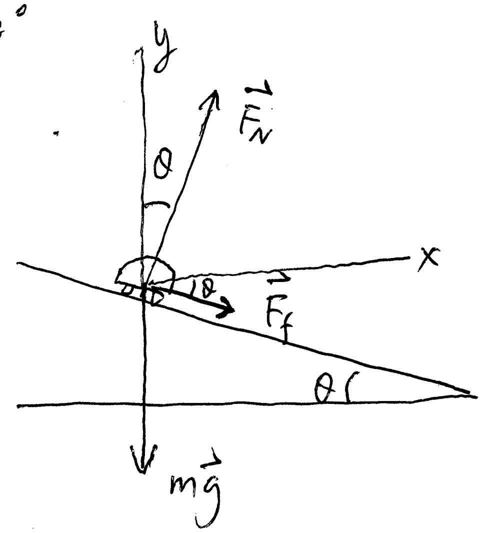


(a) No friction.

$$\vec{F} = m\vec{a}: \begin{cases} F_N \sin\theta = m\dfrac{v^2}{R} \\ F_N \cos\theta - mg = 0 \Rightarrow F_N\cos\theta = mg \end{cases}$$

$$\tan\theta = \frac{v^2}{Rg} = \frac{15^2}{100 \times 9.8} = 0.2296$$

$$\theta = \tan^{-1} 0.2296 = 12.9^\circ \approx 13^\circ$$



(b). $F_f = F_N \mu_s$ — max static friction.

$$\begin{cases} F_N \sin\theta + \mu_s F_N \cos\theta = m\dfrac{v^2}{R} & ① \\ F_N \cos\theta - \mu_s F_N \sin\theta - mg = 0 & ② \end{cases}$$

② ⇒. $F_N \cos\theta - \mu_s F_N \sin\theta = mg$ ③

①/③: $\dfrac{\sin\theta + \mu_s \cos\theta}{\cos\theta - \mu_s \sin\theta} = \dfrac{v^2}{Rg}$.

$$v_{max} = \sqrt{Rg\,\frac{\sin\theta + \mu_s\cos\theta}{\cos\theta - \mu_s\sin\theta}} = \sqrt{100\times 9.8\,\frac{\sin 12.9^\circ + 0.10 \times \cos 12.9^\circ}{\cos 12.9^\circ - 0.10 \times \sin 12.9^\circ}}$$

$$= \sqrt{980\,\frac{0.3207}{0.9524}} = 18.2\ m/s = 65\ km/h.$$

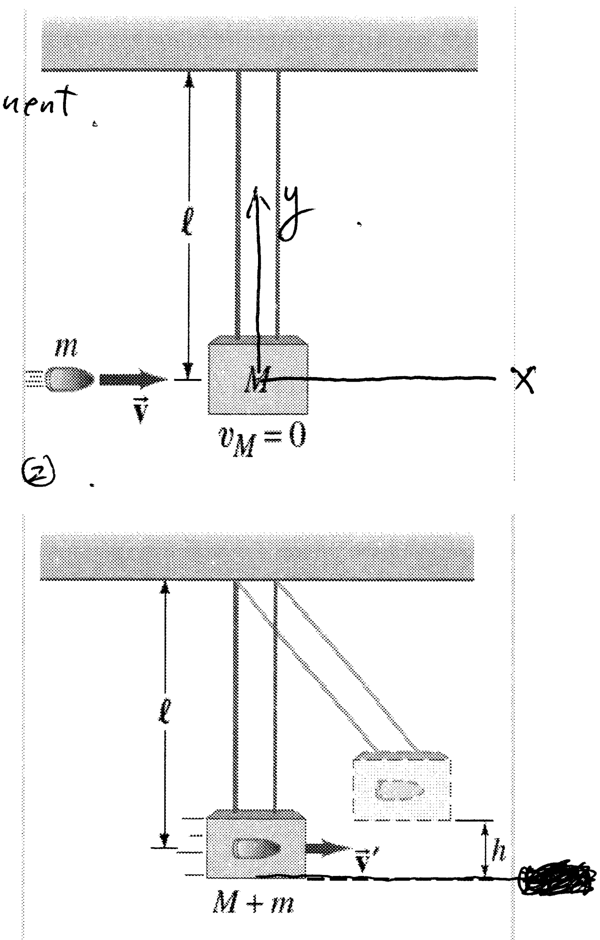
10. The ballistic pendulum is a device used to measure the speed of a projectile, such as a bullet. The projectile, of mass *m*, is fired into a large wooden block of mass *M*, which is suspended like a pendulum. As a result of the collision, the pendulum and projectile together swing up to a maximum height *h*.
(a) Determine the relationship between the initial horizontal speed of the projectile, *v*, and the maximum height *h*.
(b) If the mass of the bullet is m=50g, the mass of the wooden block is M=7.5kg, and the maximum height is h=30cm, what is the initial speed of the bullet?

(a). Hit and stick:
conservation of momentum in x-component.

$$mv = (M+m)v' \quad ①$$

Swing:
conservation of Mechanical Energy:

$$\frac{1}{2}(M+m)v'^2 = (M+m)gh. \quad ②$$



from ①: $v'^2 = \frac{m^2}{(M+m)^2} v^2$.

sub. into ②:

$$\frac{1}{2}\frac{m^2}{(M+m)^2} v^2 = gh.$$

$$v = \frac{M+m}{m}\sqrt{2gh}.$$

(b). $v = \frac{7.5+0.05}{0.05}\sqrt{2 \times 9.8 \times 0.3} = 366 \text{ m/s}.$

Physics 101 Formula Sheet (for Midterm #1)

Constant acceleration (2-11): $x = x_0 + v_0 t + \frac{1}{2}at^2$, $v = v_0 + at$, $v^2 = {v_0}^2 + 2a(x - x_0)$

Vector components (3-3, 3-4): $V_x = V\cos\theta$; $V_y = V\sin\theta$

$V = \sqrt{V_x^2 + V_y^2}$; $\tan\theta = \frac{V_y}{V_x}$

Relative velocity (3-6): $\vec{v}_{BS} = \vec{v}_{BW} + \vec{v}_{WS}$

Circular motion (5-1): $a_R = \frac{v^2}{r}$, $v = \frac{2\pi r}{T}$, $T = \frac{1}{f}$

Newton's law of gravitation (5-4): $F = G\frac{m_1 m_2}{r^2}$; where $G = 6.67\times 10^{-11} N\cdot m^2/kg^2$

Work (6-1): $W = \vec{F}\cdot\vec{d} = Fd\cos(\theta)$

Kinetic Energy (6-3): $K = \frac{1}{2}mv^2$

Work energy principle (6-2, 6-4): $W_{net} = \Delta K = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$

Potential Energy: Gravity (near surface of the earth) (6-6): $PE_{grav} = mgy$

Spring (6-9) $U = \frac{1}{2}kx^2$

Power (6-17): $P = \frac{W}{\Delta t} = \vec{F}\cdot\vec{v}$

Momentum (7-1): $\vec{p} = m\vec{v}$

Centre of mass (7-9): $\vec{r}_{CM} = \frac{\sum m_i \vec{r}_i}{M}$

Sine and Cosine Laws: $\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$

$c^2 = a^2 + b^2 - 2ab\cos C$

PHYS 101 Midterm Examination #1 (version E)

October 7, 2011

Time: 50 minutes

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Computing ID : ____________________

Tutorial Section : ____________________

	score	*Maximum*
Multiple Choice		**7**
Written # 1		**5**
Written # 2		**5**
Written # 3		**5**
Total		**22**

Part I (Multiple choice questions. 1 mark each.)

D

1. The acceleration of a particle in projectile motion
   - A. points along the path of the particle.
   - B. is directed horizontally.
   - C. vanishes at the particle's highest point.
   - (D) is directed down at all times.
   - E. is zero

C

2. James and John dive from an overhang into the lake below. James simply drops straight down from the edge. John takes a running start and jumps with an initial horizontal velocity of 8 m/s. Compare the time it takes each to reach the lake below.
   - A) James reaches the surface of the lake first.
   - B) John reaches the surface of the lake first.
   - (C) James and John will reach the surface of the lake at the same time.
   - D) Cannot be determined without knowing the mass of both James and John.
   - E) Cannot be determined without knowing the height of the overhang.

E

3. Does the centripetal force acting on an object do work on the object?
   - A) Yes, since a force acts and the object moves, and work is force times distance.
   - B) Yes, since it takes energy to turn an object.
   - C) No, because the object has constant speed.
   - D) No, because the object's displacement is zero.
   - (E) No, because the force and the displacement of the object are perpendicular.

B

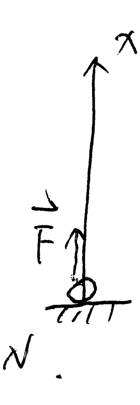
4. A baseball of mass 0.15 kg moving at 20.0 m/s strikes the glove of a catcher. The glove recoils a distance of 5.0 cm. The magnitude of the average force applied by the ball on the glove is
   - A) 667 N
   - (B) 600 N
   - C) 60 N
   - D) 150 N
   - E) 15 N

$$W = \Delta K$$
$$-Fd = 0 - \tfrac{1}{2} m v^2$$
$$F = \frac{mv^2}{2d} = \frac{0.15 \times 20^2}{2 \times 0.05} = \frac{60}{0.1} = 600\,N.$$

D

5. A 0.15-kg baseball is dropped from rest. It has a speed of 1.4 m/s just before it hits the ground. It rebounds with a speed of 1.0 m/s. The ball is in contact with the ground for 0.0015 s. What is the average force exerted by the ground on the ball during that time?
   - A) 40 N
   - B) 100 N
   - C) 220 N
   - (D) 240 N
   - E) 140 N

$$\vec{F}\Delta t = \Delta \vec{p}$$
$$F_x \Delta t = P_{fx} - P_{ix}.$$
$$F_x = \frac{m(V_f - V_i)}{\Delta t} = \frac{0.15\,[1.0 - (-1.4)]}{0.0015} = 240\,N.$$



E

6. A lightweight object and a very heavy object are sliding with equal speeds along a level frictionless surface. They both slide up the same frictionless hill. Which rises to a greater height?

A) The heavy object, because it has greater kinetic energy.
B) The light object, because it has smaller kinetic energy.
C) The lightweight object, because it weighs less.
D) The heavy object, because it weighs more.
(E) They both slide to the same height.

$\frac{1}{2}mv^2 = mgh$. $h = \frac{v^2}{2g}$ ind. of m.

A

7. A car and a minivan collide and stick together. Consider the total momentum and the total kinetic energy of the two vehicles before and after the collision. Which of the following statements is true?

(A) The total momentum is conserved but the total kinetic energy is not conserved.
(B) Both the total momentum and total kinetic energy are conserved.
(C) Neither the total momentum nor the total kinetic energy is conserved.
(D) The total kinetic energy is conserved but the total momentum is not conserved.
(E) The change in total momentum equals the change in total kinetic energy.

Part II (Full solution questions, 5 marks each. **SHOW ALL WORK FOR FULL MARKS!**)

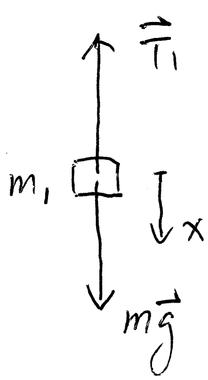
8. Suppose the coefficient of kinetic friction between block 2 and the inclined plane in the figure is 0.10, and the mass of block 1 is the same as that of block 2, (m_1=m_2=5.0kg). Ignore the mass of cable and the friction of the pulley.
(a) Draw a free body diagram for each block;
(b) As block 1 moves down, determine the magnitude of the acceleration of m_1 and m_2, given $\theta = 25°$.
(c) Determine the magnitude of the tension in the cable.

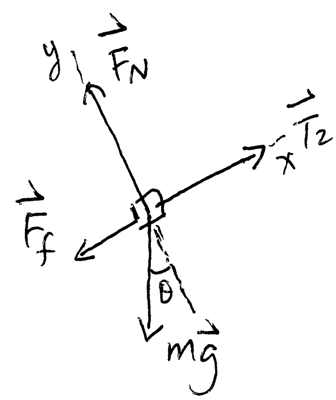
$m_1 = m_2 = m$

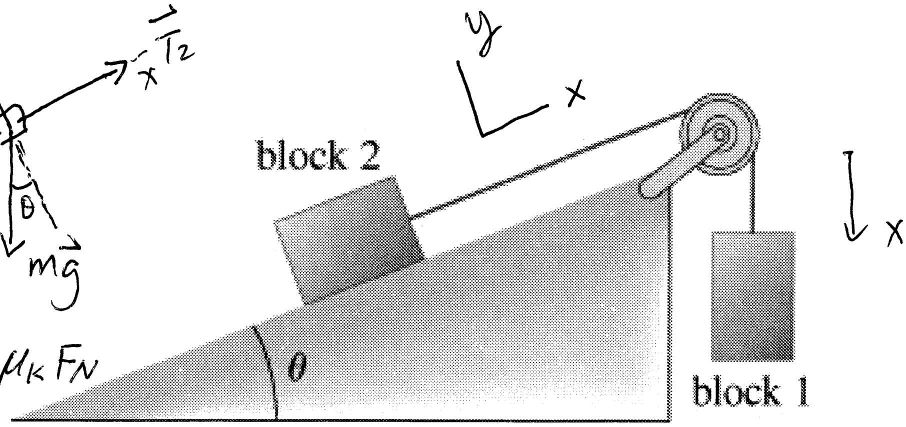
$T_1 = T_2 = T$

$a_{x1} = a_{x2} = a$

(a). FBDs







$F_f = \mu_k F_N$

(b). $\vec{F} = m\vec{a}$

$$\begin{cases} mg - T = ma & (1) \\ T - \mu_k F_N - mg\sin\theta = ma. & (2) \\ F_N - mg\cos\theta = 0 & (3) \end{cases}$$

(1) + (2): $mg - \mu_k F_N - mg\sin\theta = 2ma$.

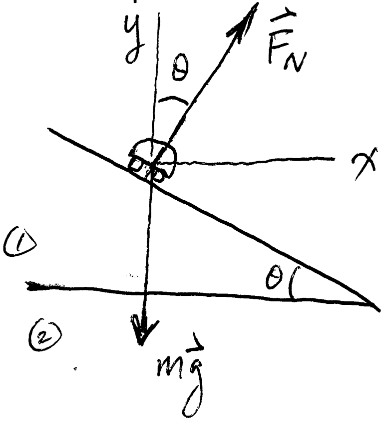
(3): $F_N = mg\cos\theta$.

$\therefore$ $mg - \mu_k mg\cos\theta - mg\sin\theta = 2ma$.

$a = \frac{1}{2} \cdot g(1 - \mu_k\cos\theta - \sin\theta) = 4.9(1 - 0.1 \times \cos 25° - \sin 25°) = 2.4 \ m/s^2$

(c). from (1): $T = m(g-a) = 5.0(9.8 - 2.4) = 37\ N$.

9. (**Show the free-body-diagrams for full marks**). At the entrance of a free way, a curve of radius 200m is banked for a design speed of 72 km/h.
(a) Determine the banking angle (so that no friction is reuired if the speed is 72km/h).
(b) If the coefficient of static friction is 0.10, what is the maximum speed at which a car can safely handle the curve?



$R = 200\ m, \quad v = 72\ km/h = 20\ m/s$

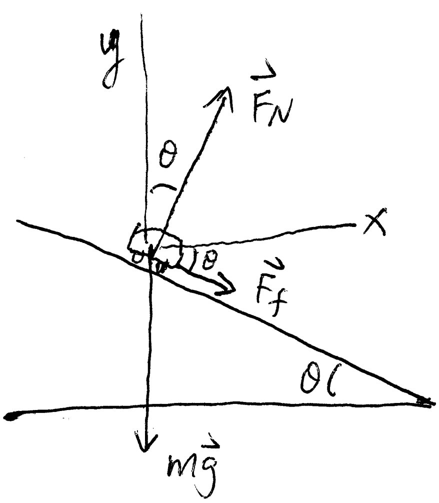
(a). No friction

$$\vec{F} = m\vec{a}: \begin{cases} F_N \sin\theta = m\frac{v^2}{R} & ① \\ F_N\cos\theta - mg = 0 \Rightarrow F_N\cos\theta = mg & ② \end{cases}$$

$$①/② : \tan\theta = \frac{v^2}{Rg} = \frac{20^2}{200\times 9.8} = 0.2041$$

$$\theta = \tan^{-1} 0.2041 = 11.5^\circ$$

(b). $F_f = \mu_s F_N$ — max static friction



$$F_N\sin\theta + \mu_s F_N\cos\theta = m\frac{v^2}{R} \quad ①$$

$$F_N\cos\theta - \mu_s F_N\sin\theta - mg = 0 \quad ②$$

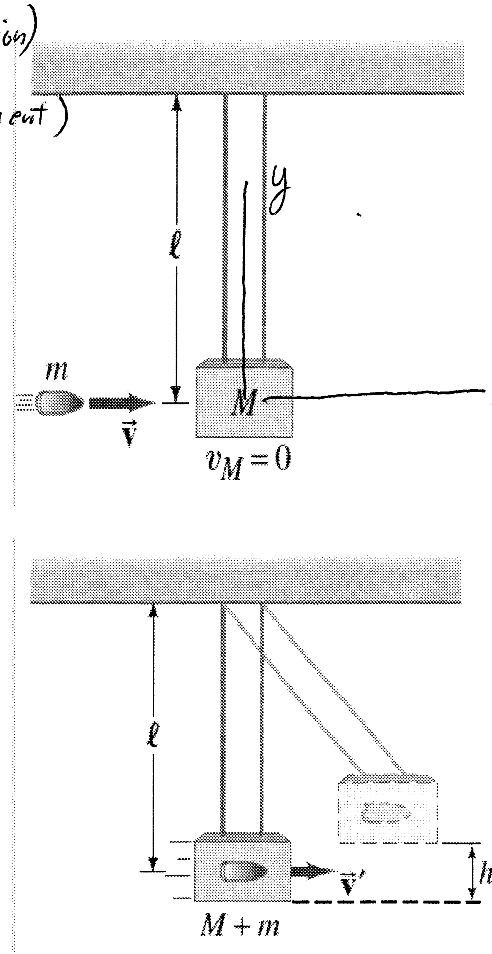
② becomes: $F_N\cos\theta - \mu_s F_N \sin\theta = mg. \quad ③$

$$\frac{①}{③} : \frac{\sin\theta + \mu_s\cos\theta}{\cos\theta - \mu_s\sin\theta} = \frac{v^2}{Rg}.$$

$$\therefore v_{max} = \sqrt{Rg\frac{\sin\theta + \mu_s\cos\theta}{\cos\theta - \mu_s\sin\theta}} = \sqrt{200\times 9.8\ \frac{\sin 11.5^\circ + 0.10\times\cos 11.5^\circ}{\cos 11.5^\circ - 0.10\sin 11.5^\circ}}.$$

$$= \sqrt{1960\times\frac{0.2974}{0.9600}} = 24.6\ m/s \simeq 88.7\ km/h.$$

10. The ballistic pendulum is a device used to measure the speed of a projectile, such as a bullet. The projectile, of mass *m*, is fired into a large wooden block of mass *M*, which is suspended like a pendulum. As a result of the collision, the pendulum and projectile together swing up to a maximum height *h*.
(a) Determine the relationship between the initial horizontal speed of the projectile, *v*, and the maximum height *h*.
(b) If the mass of the bullet is m=60g, the mass of the wooden block is M=7.5kg, and the maximum height is h=40cm, what is the initial speed of the bullet?



(a). Hit and stick (completely inelastic collission)

Conservation of momentum (x-component)

$mv = (M+m)v'$ ①

Swing:

Conservation of mechanical energy.

$\frac{1}{2}(M+m)v'^2 = (M+m)gh$ ②

i.e: $\frac{1}{2}v'^2 = gh$. ③.

from ①: $v' = \frac{mv}{M+m}$

sub. into ③: $\frac{1}{2}\left(\frac{m}{M+m}\right)^2 \cdot v^2 = gh$.

Solve for v: $v = \frac{M+m}{m}\sqrt{2gh}$.

(b). $v = \frac{7.5+0.06}{0.06}\sqrt{2\times 9.8\times 0.4} = 353$ m/s