Physics 201, Exam 1 **Name (printed)** Solution

On my honor as a Texas A&M University student, I will neither give nor receive unauthorized help on this exam.

Name (signed) ____________________

The multiple-choice problems carry no partial credit.
Circle the correct answer or answers. **An answer is approximately correct if it is correct to 2 significant figures.**
In the work-out problems, you are graded on your work, with partial credit.
(The answer by itself is not enough, and you receive credit only for your work.)
Be sure to include the correct units in the answers, and give your work in the space provided.

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1. (5) [This happens somewhere else – not in Texas where we are more careful!] A bullet is shot straight up into the air with an initial velocity of 300 m/s. If air resistance is neglected, approximately how high does it rise?

(a) 9.18 km
(b) 4.59 km ← circled
(c) 2.30 km
(d) 30.6 m
(e) 15.3 m
(f) 7.65 m

$v_y^2 = v_{oy}^2 + 2a_y(y - y_i)$, with $v_y = 0$, $v_{oy}^2 = (300)^2$, $a_y = -g = -9.80$

[leaving out units in intermediate steps]

$\Rightarrow \boxed{y - y_0} = \frac{(300)^2}{(2)(9.8)} = 4592 \text{ m} \boxed{\approx 4.59 \text{ km}}$

2. (5) This actually happened to a friend of my son when they were in high school and on a carnival ride together: At the top of the ride, about 15 meters above the ground, the friend's cellphone fell out of his pocket. If the cellphone started from rest, it fell straight down, and air resistance is neglected, what was its approximate speed when it hit the ground?

(a) 147 m/s
(b) 12 m/s
(c) 294 m/s
(d) 17 m/s ← circled
(e) 52 m/s

3. (5) Approximately how long did it take to reach the ground?

(a) 1.53 s
(b) 3.06 s
(c) 2.42 s
(d) 1.24 s
(e) 1.75 s ← circled

4. (5) A river flows due south with a speed of 4 m/s. A woman steers a motorboat across the river. Her velocity relative to the water is 3 m/s due east. The river is 600 m wide. What is the magnitude of her velocity relative to the earth?

(a) 1 m/s
(b) 3 m/s
(c) 4 m/s
(d) 5 m/s
(e) 7 m/s

5. (5) What is the approximate direction of her velocity relative to the earth?

(a) 49° south of east
(b) 53° south of east
(c) 41° south of east
(d) 37° south of east
(e) 31° south of east

6. (5) How much time is required for the woman to cross the river?

(a) 200 s
(b) 150 s
(c) 120 s
(d) 300 s
(e) 600 s

7. (10) A 2020 BMW with superb tires (developed by Aggie engineers) can round a curve with a maximum radial acceleration of $1.2\,g$, where $g = 9.8\ \text{m/s}^2$. If the car is traveling at a constant speed of 25 m/s, what is the minimum radius of curvature that the car can negotiate without skidding off to the side?

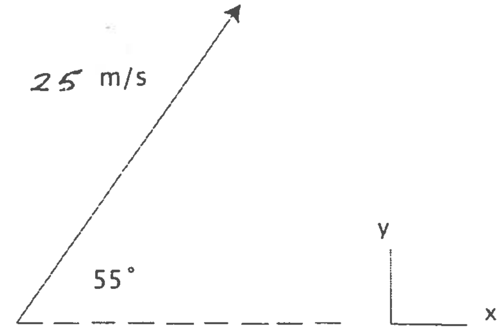
Answer: minimum radius of curvature = ____________________

$$a_{rad} = \frac{v^2}{R} \Rightarrow \boxed{R =} \frac{v^2}{a_{rad}} = \frac{(25)^2}{(1.2)(9.8)} = \boxed{53\ \text{m}}$$

[other version: 136 m]

8. On Oct. 22, 2016, the Aggie defensive line holds on third down and Alabama is forced to punt. The ball leaves the kicker's foot approximately at ground level with a speed v_0 of 25 m/s at an angle of 55° above the horizontal.

(a) (5) Calculate the components of the initial velocity.



v_{0x} = 14.3 m/s $\qquad$ v_{0y} = 20.5 m/s

$v_{0x} = (25)\cos 55° = 14.3$ m/s

$v_{0y} = (25)\sin 55° = 20.5$ m/s

[other version: 8.60 m/s and 12.3 m/s]

(b) (5) Calculate the time required for the ball to return to the ground.

time = 4.18 s

$y - y_0 = v_{0y} t + \frac{1}{2} a_y t^2$, with $y - y_0 = 0$, $v_{0y} = 20.5$, $a_y = -g = -9.8$

$\Rightarrow t = 0$ or $t = \frac{2 v_{0y}}{g} = \frac{2(20.5)}{9.8} = 4.18$ s

[other version: 2.51 s]

(c) (5) Calculate the distance that the ball travels downfield before it returns to the ground.

distance = 59.8 m

$x - x_0 = v_{0x} t + \frac{1}{2} a_x t^2 = (14.3)(4.18) = 59.8$ m, with $v_{0x} = 14.3$, $a_x = 0$

[other version: 21.6 m]

9. At the surface of Jupiter's moon Io, the acceleration due to gravity is 1.81 m/s^2 . A piece of ice weighs 75 N at the surface of the Earth.

(a) (5) What is the mass of this piece of ice at the Earth's surface?

Answer: mass at Earth's surface = 7.65 kg

$$W = mg \Rightarrow \boxed{m =} \frac{75\ N}{9.8\ m/s^2} = \boxed{7.65\ kg}$$

[other version: 3.57 kg]

(b) (2) What is its mass at the surface of Io?

Answer: mass at Io's surface = 7.65 k

(c) (5) What is its weight at Io's surface?

Answer: weight at Io's surface = 13.8 N

$$\boxed{W_{Io} =} m g_{Io} = (7.65)(1.81) = \boxed{13.8\ N}$$

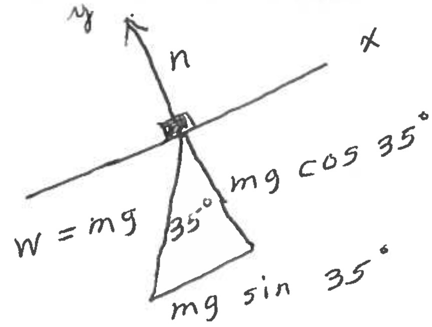
[other version: 6.46 N]

10. Lucy is working for a shipping company, sliding packages up to Ethel along a ramp that is 10.0 meters long and inclined at 35° above the horizontal. The coefficient of kinetic friction between the packages and the ramp is 0.30.

(a) (8) Lucy wishes the package to reach the top of the ramp with exactly zero velocity (making it easy for Ethel to catch). Calculate the initial speed that Lucy must give the package to accomplish this.

Answer: initial speed = 12.7 m/s

$v_x^2 = v_{0x}^2 + 2a_x(x - x_0)$, with $v_x = 0$, $v_{0x} = ?$, $x - x_0 = 10$



$\mu_k = 0.30$

$n = mg \cos 35°$

$m a_x = -mg \sin 35° - \mu_k \cdot mg \cos 35°$

$\Rightarrow a_x = -(9.8)(0.574) - (0.30)(9.8)(0.819)$

$= -5.63 - 2.41$

$= -8.04 \text{ m/s}^2$

Then $v_{0x}^2 = 2(8.04)(10) = 161$

$\Rightarrow \boxed{v_{0x} = 12.7 \text{ m/s}}$ [other version: 8.97 m/s]

(b) (7) Ethel misses a package and it slides back down the ramp. What is its speed when it returns to Lucy?

Answer: speed at bottom when it returns = 8.02 m/s

Now $m a_x = -mg \sin 35° + \mu_k \cdot mg \cos 35°$

$\Rightarrow a_x = -5.63 + 2.41$

$= -3.22 \text{ m/s}^2$

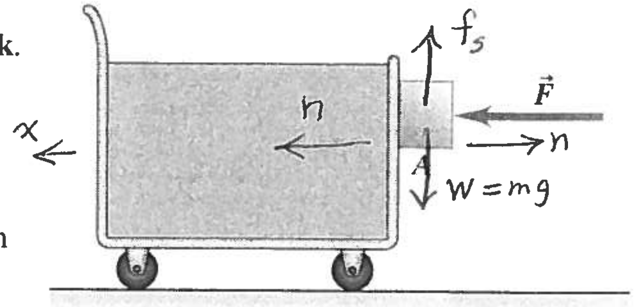
Then $v_x^2 = v_{0x}^2 + 2a_x(x - x_0)$, with $v_{0x} = 0$, $a_x = -3.22$, $x - x_0 = -10$ — with different $v_x, v_{0x}, a_x, x - x_0$

$= (2)(-3.22)(-10)$

$= 64.4$

$\Rightarrow \boxed{v_x = 8.02 \text{ m/s}}$ [other version: 5.67 m/s]

11. A block with mass m is placed against the vertical front of a cart with mass M, as shown in the figure. The cart is free to roll without friction, and the coefficient of static friction between the block and the cart is μ_s.



[Hint: For parts (a), (b), and (c) consider the forces acting on the **block**. Then in part (d) consider the forces acting on the **cart**.]

(a) (3) Obtain an expression which relates the normal force n on the block to m, the acceleration of gravity g, and μ_s, if the maximum possible frictional force is to exactly balance the gravitational force on the block.

$f_s = mg$ with $f_s = \mu_s n$

$$\Rightarrow \boxed{n =} \frac{f_s}{\mu_s} = \boxed{\frac{mg}{\mu_s}}$$

(b) (3) Obtain an expression for the force F in terms of the normal force n, the acceleration a of the block, and its mass m.

$$F - n = ma \Rightarrow \boxed{F = n + ma}$$

(c) (3) Using the answers to (a) and (b), obtain an expression for F in terms of m, g, μ_s, and a.

$$\boxed{F = \frac{mg}{\mu_s} + ma}$$

(d) (3) Obtain an expression relating the normal force n to the mass M of the cart and its acceleration a .

$$\boxed{n = Ma}$$

(e) (3) Using the answers to parts (a) and (d), obtain an expression for a in terms of m, g, μ_s, and M .

$$\boxed{a =} \frac{n}{M} = \boxed{\frac{mg}{M\mu_s}}$$

(f) (3) Using the answers to parts (a), (b), and (e), determine the minimum force F that is required to keep the block from sliding down, in terms of m, g, μ_s, and the mass ratio m/M .

$$\boxed{F =} \frac{mg}{\mu_s} + m\frac{mg}{M\mu_s}$$

$$= \boxed{\frac{mg}{\mu_s}\left(1 + \frac{m}{M}\right)}$$

12. **Please be brief but specific and clear.**

(a) (3) Give 3 examples of Newton's 3rd law (involving "action-reaction" pairs) .

examples:

Earth pulls on you, you pull on Earth through gravity.

You push down on chair, chair pushes up to support you.

Jumping, you push down on floor, floor pushes up to make you rise.

[different objects]

(b) (2) Give 2 examples of static equilibrium.

Gravity pulls down on you, chair pushes up on you, and you remain at rest.

You pull on box, and static friction force on box is in opposite direction, so box remains at rest.

[same object]