ics 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 fill-in-the-blank and multiple-choice problems carry no partial credit.

Put your answer in the **underlined space** below each **fill-in-the-blank problem**.

Circle the correct answer or answers for each **multiple-choice problem**.

(An answer is approximately correct if it is correct to 2 significant figures.)

In the **work-out problems**, you are graded on **your well-organized 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.

---

1. (5) If you see the current movie Wonder Woman, you will not be surprised to see that she is a good swimmer. (Almost as good as the amazing members of the Aggie women's swim team.) But she still has to contend with the viscous drag force of the water. Dragging (future boyfriend) Steve Trevor, she initially accelerates at 1.5 m/s^2. The drag force backward is 200 N. Their combined mass is 120 kg. What is her thrust force forward?

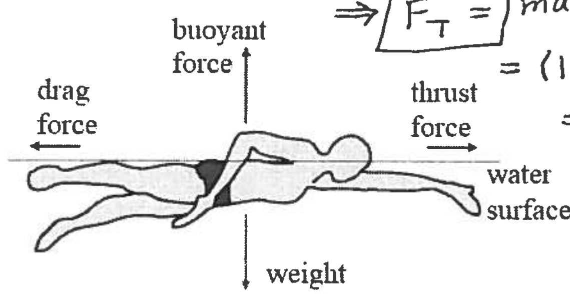
$\boxed{380 \text{ N}}$ **[Include the units always!]**

$$F_T - T_D = ma$$

$$\Rightarrow \boxed{F_T =} ma + F_D$$

$$= (120)(1.5) + 200$$

$$= \boxed{380 \text{ N}}$$



Picture credits: http://www.real-world-physics-problems.com/physics-of-swimming.html
https://www.psychologytoday.com/blog/the-real-superheroes/201706/wonder-woman-psychology

2. (5) Three books are at rest on a horizontal table, as shown. The *net* force on the middle book is

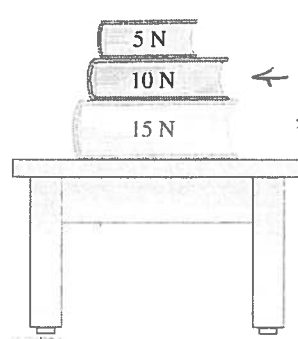
(a) 0 N

(b) 15 N downward

(c) 15 N upward

(d) 5 N downward

(e) 5 N upward



← equilibrium

⇒ zero net force

3. (5) A vector $\vec{A}$ has components of $A_x = -5$ and $A_y = -12$, then the magnitude of the vector is

$$A = \sqrt{(-5)^2 + (-12)^2} = \sqrt{169} = 13$$

(a) -7

(b) -17

(c) 7

(d) 17

(e) -13

(f) 13

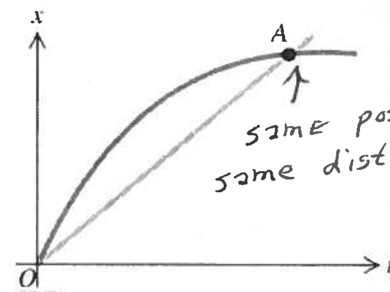
4. (5) The Aggie women field hockey team upset No. 6 Stanford on October 8, 2013. Jamie Garcia, with an assist from Cloey LemMon and Hannah Drawbridge, blasted the winning shot, after Drawbridge had brought the ball to a perfect stop.

If the ball left Garcia's stick at 30 m/s, and her stick was in contact with the ball for 0.040 second, what was the average acceleration?

Answer $\boxed{750 \frac{m}{s^2}}$ **[Include the units always!]**

$$a_{av} = \frac{\Delta v}{\Delta t} = \frac{30 \text{ m/s}}{0.040 \text{ s}} = 750 \frac{m}{s^2}$$

5. (5) Two objects start at the same place at the same time and move along the same straight line. The figure shows the position x of each object as a function of the time t. At point A, what must be true about the motion of these objects. (More than one statement may be true.)



same position, same distance

(a) Both have the same velocity.

(b) Both have the same speed.

(c) Both had the same initial speed.

(c) Both are at the same position.

(d) Both have traveled the same distance.

[Circle the correct answer or answers.]

6. (5) A stone is thrown horizontally with a speed of 15 m/s from the top of a vertical cliff at the edge of a lake. If the stone hits the water 3.0 s later, what is the height of the cliff?

Answer $\boxed{44.1 \text{ m}}$ **[Include the units always!]**

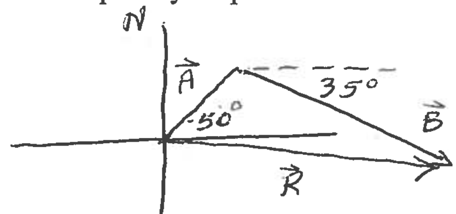
$$y = y_0 + \underbrace{v_{0y}}_{=0} t + \frac{1}{2} \underbrace{a_y}_{=-g} t^2 \Rightarrow y - y_0 = \frac{1}{2}\left(-9.8 \frac{m}{s^2}\right)(3.0 \text{ s})^2$$

$$= -44.1 \text{ m}$$

$$\Rightarrow \text{height} = 44.1 \text{ m}$$

7. A plane leaves Fairbanks, Alaska, and flies 70 mi at 50° north of east. It then changes direction and flies 110 mi at 35° south of east, where it makes an emergency landing. The Fairbanks airport subsequently dispatches a rescue crew.

Draw a small rough sketch to the right, with the x axis pointing east and the y axis pointing north.



$\vec{R} = \vec{A} + \vec{B}$

(a) (3) Calculate the x and y components of the first displacement (at 50°).

Answers: x component = 45.0 mi y component = 53.6 mi

$A_x = (70)\cos 50° = 45.0$ mi   [other version:

$A_y = (70)\sin 50° = 53.6$ mi   57.3 mi, 40.2 mi]

(b) (3) Calculate the x and y components of the second displacement (at 35°).

Answers: x component = 90.1 mi y component = −63.1 mi

$B_x = (110)\cos(-35°) = 90.1$ mi   [other version: 70.7 mi, −84.3 mi]

$B_y = (110)\sin(-35°) = -63.1$ mi

or $\sin(360° - 35°) = \sin(325°) = -0.574$

[$\sin(-35°) = -0.574$]

(c) (3) Calculate the distance flown by the rescue crew.

Answer: distance = 135 mi

$R_x = A_x + B_x = 135.1$ mi

$R_y = A_y + B_y = -9.5$ mi

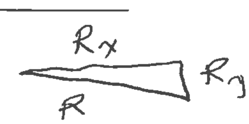
$\boxed{R =} \sqrt{(135.1)^2 + (9.5)^2} = \boxed{135 \text{ mi}}$

[other version: 135 mi]

(d) (3) Calculate the direction in which the rescue crew flies, expressed as an angle with respect to the positive x axis (with the counterclockwise direction being positive).

Answer: angle with respect to positive x axis (or easterly direction) = −4.0°   [or 356°] $\boxed{\text{or } 4° \text{ South of East}}$

$\tan\theta = \dfrac{R_y}{R_x} = \dfrac{-9.5}{135.1} = -0.0703$



$\Rightarrow \boxed{\theta = -4.0°}$

[other version: −19°]

8. A uniform 20 kg chain is 1 m long. It supports a 50 kg chandelier in the lobby of a hotel. Find the following:

(a) (3) Tension in bottom link of chain.

$$F_B = (50\text{ kg})(9.8\ \tfrac{m}{s^2})$$

$$= 490\text{ N}$$

[other version: 294 N]

Answer = $\boxed{490\text{ N}}$

(b) (3) Tension in top link of chain.

$$F_T = (50\text{ kg} + 20\text{ kg})(9.8\ \tfrac{m}{s^2})$$

$$= 686\text{ N}$$

[other version: 441 N]

Answer = $\boxed{686\text{ N}}$

(c) (3) Tension in middle link of chain.

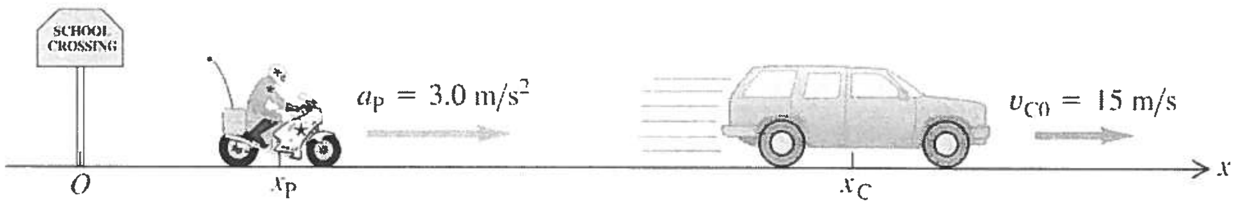
$$F_M = (50\text{ kg} + 10\text{ kg})(9.8\ \tfrac{m}{s^2})$$

$$= 588\text{ N}$$

[other version: 368 N]

Answer = $\boxed{588\text{ N}}$

9. You are blissfully driving along at 15 m/s when you do not notice the school crossing sign saying that the speed limit is 10 m/s. At the moment you pass the school sign, a motorcycle policeman starts from the same point with an acceleration of 3.0 m/s^2. (Your velocity is constant, his acceleration is constant, and you leave the same point at the same time.)



(a) (3) How much time passes before he catches up with you?

$$\frac{1}{2} a_p t^2 = v_{c0} t \Rightarrow t = 0 \quad \text{or} \quad \boxed{t =} \frac{2 v_{c0}}{a_p}$$

$$= \frac{(2)(15)}{3.0}$$

$$= \boxed{10\ s}$$

Answer = 10 s

(b) (3) What is his speed at that point?

$$\boxed{v_p =} a_p t = (3.0 \tfrac{m}{s^2})(10\ s) = \boxed{30\ \tfrac{m}{s}}$$

Answer = $30\ \frac{m}{s}$

(c) (3) What is the total distance he has traveled at that point?

$$\boxed{x_p =} \frac{1}{2} a_p t^2$$

$$= \frac{1}{2} (3.0 \tfrac{m}{s^2})(10\ s)^2$$

$$= \boxed{150\ m}$$

Answer = 150 m

10. You stand on a cliff that is 10 m above the surface of the ocean below, and you hurl a rock at 30 m/s straight out in the horizontal direction

(a) (3) Calculate the total time that passes after you release the rock until it splashes into the ocean.

$$\underbrace{y - y_0}_{= -10\text{ m}} = \underbrace{v_{0y}}_{=0} t + \frac{1}{2} \underbrace{a_y}_{=-g} t^2 \Rightarrow -10 \text{ m} = -4.9 t^2$$

$$\Rightarrow \boxed{t =} \sqrt{\frac{10}{4.9}}$$

$$= \boxed{1.43 \text{ s}}$$

[other version: 2.02 s]

(b) (3) Calculate the distance traveled by the rock in the horizontal direction, from your hand to the point where it enters the water.

$$\boxed{x - x_0 =} v_{0x} t + \frac{1}{2} \underbrace{a_x}_{=0} t^2$$

$$= (30 \tfrac{\text{m}}{\text{s}})(1.43 \text{ s})$$

$$= \boxed{43 \text{ m}}$$

[other version: 61 m]

(c) (3) Calculate the magnitude of the velocity of the rock when it enters the water.

$$v_y = a_y t = (\underbrace{-g}_{=9.8 \frac{\text{m}}{\text{s}^2}})(1.43 \text{ s}) = -14.0 \text{ m/s} \quad , \quad v_x = v_{0x}$$

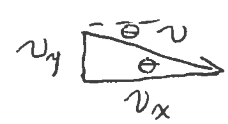
$$\boxed{v =} \sqrt{v_{0x}^2 + v_y^2}$$

$$= \sqrt{30^2 + (-14.0)^2}$$

$$= \boxed{33 \tfrac{\text{m}}{\text{s}}}$$

[other version: 36 $\frac{\text{m}}{\text{s}}$]

(d) (3) Calculate the direction of this final velocity, by giving the angle of the final velocity vector below the horizontal (as the rock enters the water).



$$\tan \theta = \frac{v_y}{v_x}$$

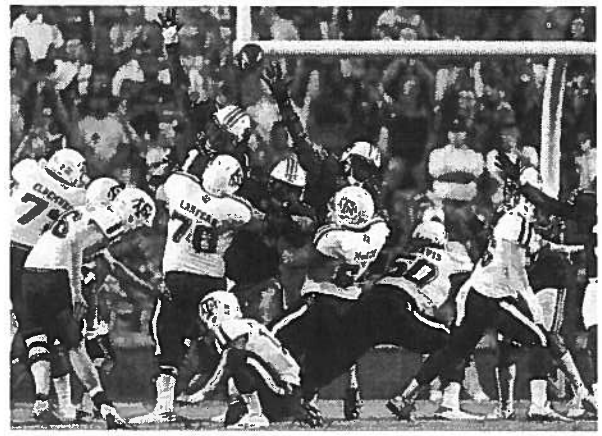
$$= \frac{-14}{30}$$

$$= -0.467$$

$$\Rightarrow \boxed{\theta = -25^\circ} \quad \text{or } 25^\circ \text{ below the horizontal}$$

[other version: -33°]

11. Aggie place kicker Daniel LaCamera (36, at left) kicks a field goal against the Auburn Tigers during the second quarter (Sept. 17, 2016).

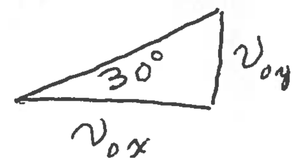


Let us now consider the general problem of a field goal kicker who kicks the ball upward at an angle of $30°$ with a speed of 35 m/s.

The crossbar across the field goal posts (see the figure) is at a height of 3.05 m.

(a) (4) Calculate the x and y components of the initial velocity $\vec{v}_0$.

$v_{0x} = (35\ \frac{m}{s})\cos 30°$ $\qquad v_{0y} = (35\ \frac{m}{s})\sin 30°$



Answers: $v_{0x} =$ $30.3\ \frac{m}{s}$, $v_{0y} =$ $17.5\ \frac{m}{s}$

(b) (6) Calculate the two times t_1 and t_2 when the ball is at the height of the crossbar.

$$\underbrace{y - y_0}_{3.05\ m} = v_{0y}t + \frac{1}{2}\underbrace{a_y}_{-g}t^2 \Rightarrow 3.05 = (17.5)t - 4.9t^2$$

$$\underbrace{4.9}_{a}t^2 \underbrace{- (17.5)}_{b}t + \underbrace{3.05}_{c} = 0$$

$$\boxed{t =} \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-(-17.5) \pm \sqrt{(-17.5)^2 - 4(4.9)(3.05)}}{2(4.9)}$$

$$= 1.79 \pm 1.60$$

$$= \boxed{3.39\ s,\ 0.19\ s}$$

Answers: $t_1 =$ $0.19\ s$, $t_2 =$ $3.39\ s$

(c) (4) In order for the kicker to be successful, the ball must not be below the crossbar when it reaches it. Calculate the smallest and largest distances from the crossbar required for a successful kick.

$t_1 : \boxed{x - x_0 =} v_{0x}t = (30.3\ \frac{m}{s})(0.19\ s) = \boxed{5.8\ m}$ [not really relevant, inside 10 yards!]

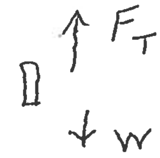
$t_2 : \boxed{x - x_0 =} (30.3\ \frac{m}{s})(3.39\ s) = \boxed{103\ m}$ [outside 100 yards, superhuman kicker!]

Answers: smallest distance = $6\ m$, largest distance = $103\ m$

12. A spacecraft descends vertically near the surface of Planet Z. An upward thrust of 30 N from its engines slows down its descent at a rate of 1.5 m/s^2. But when the upward thrust is only 15 N, its descent speeds up at a rate of 1.0 m/s^2.

(a) (2) In each case, what is the **direction of the acceleration**? Specify **upward** or **downward**.

first thrust, 30 N upward   second thrust, 15 N downward



(b) (2) Draw a free-body diagram for the spacecraft (to the right).
In each case, what is the **direction of the net force** on the spacecraft?
Specify **upward** or **downward**.

[$W \neq mg$]

first thrust, 30 N upward   second thrust, 15 N downward

(c) (4) Use the above information to set up 2 equations in the 2 unknowns m = mass of spacecraft and W = weight of spacecraft on this planet.

① $F_1 - W = m a_1 \Rightarrow 30 - W = m(+1.5)$

② $F_2 - W = m a_2 \Rightarrow 15 - W = m(-1.0)$

[leaving off units in intermediate steps]

(d) (6) Solve these two equations to find the mass and weight.

① $\Rightarrow W = F_1 - m a_1$

Then ② $\Rightarrow F_2 - (F_1 - m a_1) = m a_2$

$\Rightarrow F_2 - F_1 = m a_2 - m a_1 = m(a_2 - a_1)$

$\Rightarrow \boxed{m =} \dfrac{F_2 - F_1}{a_2 - a_1} = \dfrac{F_1 - F_2}{a_1 - a_2} = \dfrac{30\text{ N} - 15\text{ N}}{1.5\text{ m/s}^2 - (-1.0\text{ m/s}^2)}$

$= \dfrac{15\text{ N}}{2.5\text{ m/s}^2} = \boxed{6\text{ kg}}$ [light spacecraft!]

Then ① $\Rightarrow \boxed{W =} 30\text{ N} - (6\text{ kg})(1.5\,\tfrac{\text{m}}{\text{s}^2}) = \boxed{21\text{ N}}$

Using just numbers:

① $\Rightarrow W = 30 - 1.5m$

Then ② $\Rightarrow 15 - (30 - 1.5m) = -1.0m$

$\Rightarrow -15 + 1.5m + 1.0m = 0$

$\Rightarrow 2.5m = 15 \Rightarrow \boxed{m = 6\text{ kg}}$ & $\boxed{W =} 30 - 1.5(6)$

$= 30 - 9$

$= \boxed{21\text{ N}}$

Answers: $m =$ 6 kg $W =$ 21 N