"First Problem" (30,000 points) ***Multiple-Guess-Pick-The-Best-Answer-Fill-In-The-Bubbles***

1.) (a) If you want the fastest acceleration in a car, you must use _______ friction.
A = Static B = Kinetic C = Potential D = Radial Inward
E =Tangent F = Radial Outward
(A) (B) (C) (D) (E) (F)

(b) For an object undergoing Uniform Circular Motion, the velocity vector is _______ to the circular path.
A = Static B = Kinetic C = Potential D = Radial Inward
E =Tangent F = Radial Outward
(A) (B) (C) (D) **(E)** (F)

(c) A rock dropped from the top of a building will gain in _______ and …
A = Static B = Kinetic C = Potential D = Radial Inward
E =Tangent F = Radial Outward
(A) **(B)** (C) (D) (E) (F)

(d) … lose in _________ Energy.
A = Static B = Kinetic C = Potential D = Radial Inward
E =Tangent F = Radial Outward
(A) (B) **(C)** (D) (E) (F)

(e) _________ Energy must change if a net force does work on a body.
A = Static B = Kinetic C = Potential D = Radial Inward
E =Tangent F = Radial Outward
(A) **(B)** (C) (D) (E) (F)

(f) The old trick of starting a fire by rubbing two sticks together uses ___________ friction to generate heat.
A = Static B = Kinetic C = Potential D = Radial Inward
E =Tangent F = Radial Outward
(A) **(B)** (C) (D) (E) (F)

In parts (g)-(h), select which of Newton's 3 laws or the 2 Conservation laws that *best describes* the situation.

(g) A car accelerating up to 55 mph.
A = Newton's 1st B = Newton's 2nd C = Newton's 3rd
D = Momentum E =Energy F = None of these
(A) **(B)** (C) (D) (E) (F)

(h) The forces acting on your head as it lays on your pillow while you sleep.
A = Newton's 1st B = Newton's 2nd C = Newton's 3rd
D = Momentum E =Energy F = None of these
(A) (B) (C) (D) (E) (F)

In parts (i)-(j), select the *best answer* for the situation described.

(i) Two 1.00 kg toys smash head on into each other totally inelastically. If one toy is moving at 12.0 m/s and the other is moving at –11.0 m/s, then the wreck moves at _______________. $m_1v_1 - m_2v_2 = (m_1 + m_2)V$

+12.0kg·m/s - 11.0kg·m/s = +1.00kg·m/s ; +1.00kg·m/s ÷ 2.00kg = +0.500m/s

A = –0.500 m/s B = –1.00 m/s C = 0 m/s
D = +0.500 m/s E = +1.00 m/s F = None of these
(A) (B) (C) **(D)** (E) (F)

(j) Two 1.00 kg toys bounce off each other totally elastically. If one toy was moving at 1.00 m/s and the other was moving at –1.00 m/s, then the simple solution for the first toy is that afterward it moves at ___________.

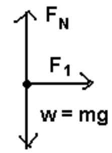
Have to conserve both momentum and K.E., so since identical, they just bounce the other way.
Recall the Executive Time Waster Toy.

A = –0.500 m/s B = –1.00 m/s C = 0 m/s
D = +0.500 m/s E = +1.00 m/s F = None of these
(A) **(B)** (C) (D) (E) (F)

The 2007 America's Cup Sailboat Race – The Louis Vuitton Cup Round (35,000 points)

2.) Right now, off the coast of Spain, very expensive sailboats are competing in a regatta to determine who will race against the Swiss boat *Alinghi* for the America's Cup in a few weeks. (a) The Italian boat ITA-94 *Luna Rossa*, m = 22,400 kg, starts off from the line at rest and in the first few moments, accelerates at $a_x = 4.00\ m/s^2$. Find the force F_1 of the wind pushing on the sails making the boat go.

$$F_1 = ma = (22{,}400kg)(4.00m/s^2) = 89{,}600N$$



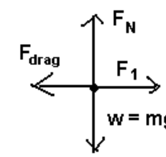
(b) It takes 40 seconds for the boat to get up to its top speed. During that time the boat travels a distance of 160. meters. Find the work done by the force F_1 of the wind. *If you did not get an answer to (a), use a force of 105,000 N.*

$$W = Fd = (89{,}600N)(160.m) = 14{,}336{,}000J$$

(c) Once the boat has reached its top speed of 5.59 m/s (12.5 mph), the boat no longer accelerates even though the wind is still pushing on the sails. Give the vector force F_{drag} due to the hydrodynamic drag (water resistance) of the boat sliding through the water.

Assume boat is traveling in the +x direction.
Now apply Newton's 1st Law.

$$\sum F_x = F_1 - F_{drag} = 0$$
$$F_{drag} = F_1 = 89{,}600N$$
$$\vec{F}_{drag} = 89{,}600N\ @180°$$



(d) Find the Kinetic Energy of the boat at its top speed of 5.59 m/s (12.5 mph).

$$KE = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(22{,}400kg)(5.59m/s)^2 = 350{,}000J$$

(e) At a speed of 5.59 m/s (12.5 mph), the boat makes a sharp turn in the water of radius $r = 40.0$ *meters*. Find the magnitude of the centripetal acceleration a_c and the centripetal force F_c.

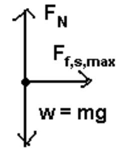
$$a_c = \frac{v^2}{r} = \frac{(5.59m/s)^2}{40.0m} = 0.7812m/s^2$$

$$F_c = ma_c = (22{,}400kg)(0.7812m/s^2) = 17{,}500N$$

"Bad Boys, Bad Boys, Whatcha Gonna Do When, They Come for You…" **COPS (35,000 points)**

3.) (a) A criminal races in a car of m = 2110 kg along the highway at 88 mph (39.3 m/s). A police Tahoe SUV, m = 2580 kg, accelerates as fast as it can. Find the maximum force of friction, if the coefficients of friction between rubber tires and the road are 0.910 and 0.610.

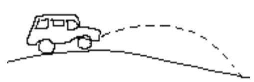
$$F_N = w = mg = (2580kg)(9.81m/s^2) = 25{,}310N$$
$$F_{f,s,\max} = \mu_s F_N = (0.910)(25{,}310N)$$
$$= 23{,}030N$$



(b) Use the Work-Energy Theorem to find the distance *d* it takes for the police car to go from rest to 39.3 m/s.

$$W = \Delta KE$$
$$Fd = KE_f - KE_i = KE_f = \tfrac{1}{2}mv^2$$
$$d = \frac{KE_f}{F} = \frac{\frac{1}{2}mv^2}{F}$$
$$= \frac{\frac{1}{2}(2580kg)(39.3)^2}{23{,}030N} = 86.51m$$

(c) The fleeing car is going too fast and at 39.3 m/s it flies off the top of a small hill. Use Conservation of Energy to find out how fast the car is going when it falls back onto the road 2.40 meters below the top of the hill.

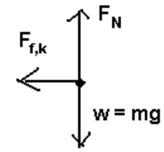


$$h_1 = 2.40m \;;\; h_2 = 0$$
$$mgh_1 + \tfrac{1}{2}mv_1^2 = mgh_2 + \tfrac{1}{2}mv_2^2$$
$$mgh_1 + \tfrac{1}{2}mv_1^2 = \tfrac{1}{2}mv_2^2$$
$$2gh_1 + v_1^2 = v_2^2$$
$$v_2 = \sqrt{2gh_1 + v_1^2}$$
$$= \sqrt{2(9.81m/s^2)(2.40m) + (39.3m/s)^2}$$
$$= 39.89m/s$$

(d) The police would like to try a PIT maneuver, where one of the police cars gets behind and just off to the side of the fleeing car and then rams it, to try to make the driver lose control and slide to a stop. With what acceleration would the car slide to a stop?

The sliding car would be using kinetic friction.

$$F_N = w = mg = (2110kg)(9.81m/s^2) = 20{,}700N$$
$$F_{f,k} = \mu_k F_N = (0.610)(20{,}700N)$$
$$= 12{,}630N$$
$$F = ma$$
$$a = \frac{F}{m} = \frac{12{,}630N}{2110kg} = 5.986m/s^2$$



(e) Unfortunately the next traffic light is red and the fleeing car, m = 2110 kg and driving at 39.3 m/s, slams into a stopped car of mass 2220 kg. If they collide in a totally inelastic collision, what is the speed *V* of the wreck?

$$p_{before} = p_{after}$$
$$m_1v_1 + m_2v_2 = (m_1 + m_2)V$$
$$m_1v_1 = (m_1 + m_2)V$$
$$V = \frac{m_1v_1}{(m_1 + m_2)} = \frac{(2110kg)(39.3m/s)}{(2110kg + 2220kg)}$$
$$= 19.15m/s$$