**Physics 201, Exam 2** **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) Which of the following statements about work is/are true? (Circle every correct answer.)

(a) Negative net work done on an object always reduces the object's kinetic energy.
(b) If the work done on an object by a force is zero, then either the force or the displacement must have zero magnitude
(c) ~~If a force acts downward, it does negative work.~~
(d) The formula $W = F\,d\cos\theta$ can only be used if the force is constant over the distance $d$.

2. (5) Spring # 1 has a force constant of $k$ and spring # 2 has a force constant of $2k$. Both springs are attached to the ceiling, identical weights are hooked to their ends, and the weights are allowed to stretch the springs. The ratio of the energy stored by spring # 1 to that stored by spring # 2 is

(a) 1:1
(b) 1:2
(c) 2:1
(d) $1:\sqrt{2}$
(e) $\sqrt{2}:1$

3. (5) An air bag acts like a spring with an effective force constant $k$. During a collision, the driver continues moving forward with a velocity $v$ and an effective mass $m$. So the problem is equivalent to a spring with force constant $k$ being compressed by a distance $x_{max}$ as it brings a mass $m$ with velocity $v$ to a halt. What is $x_{max}$?

(a) $v\sqrt{m/k}$
(b) $v^2\sqrt{m/k}$
(c) $vm/k$
(d) $v^2 m/k$
(e) $2v^2 m/k$

4. (5) As in the movie "Gravity", an astronaut is floating just outside her space station, which is orbiting the earth at a distance above the earth's surface equal to 1 earth radius. The astronaut's weight is

(a) a function of her orbital velocity
(b) zero
(c) equal to her normal weight on earth
(d) 1/2 her normal weight on earth
(e) 1/4 her normal weight on earth

5. (5) For each of two objects with *different* masses, the gravitational potential energy is 250 J. They are released from rest and fall to the ground. Which of the following statements is/are true? (Circle every correct answer.)

(a) Both objects are released from the same height.
(b) Both objects will have the same kinetic energy when they reach the ground.
(c) Both objects will have the same speed when they reach the ground.
(d) Both objects will accelerate toward the ground at the same rate
(E) Both objects reach the ground at the same time.

6. (5) A stone of mass $m$ is attached to a strong string and whirled in a vertical circle of radius $R$. At the exact top of the path, the tension in the string is three times the stone's weight. At this point, the stone's speed is

(a) $\sqrt{4gR}$
(b) $4\sqrt{gR}$ either or both
(c) $\sqrt{3gR}$
(d) $3\sqrt{gR}$
(e) $\sqrt{2gR}$
(f) $2\sqrt{gR}$

7. A 3 kg block of wood is suspended from vertical 4 m wires. A bullet, with mass 20 grams, is fired at the block and becomes embedded in it. The combined mass swings upward until it has reached a height of 0.6 m when it stops and begins to swing back.

(a) (4) Calculate the potential energy of the system (bullet plus block) at the highest point.

potential energy at highest point = 17.8 J

$(3 + 0.020)(9.8)(0.6) = \boxed{17.8}\ J$

[other version: 18.0 J]

(b) (4) Calculate the velocity of the system (bullet plus block) at the lowest point.

velocity at lowest point = 3.4 m/s

$\frac{1}{2} \cancel{M} v^2 = \cancel{M} g h \Rightarrow \boxed{v =} \sqrt{2gh} = \sqrt{(2)(9.8)(0.6)} = \boxed{3.4\ \frac{m}{s}}$

[other version: 4.2 m/s]

(c) (8) Calculate the speed of the bullet before it hit the block.

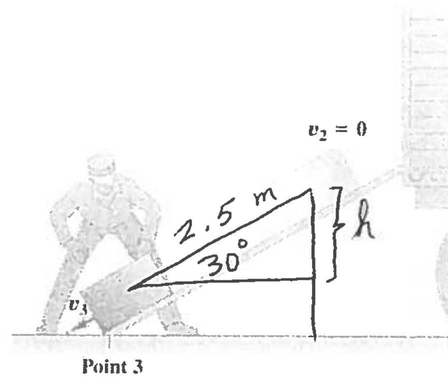
speed of bullet before it hit block = 513 m/s

$mV = (M+m) v$

$\Rightarrow \boxed{V =} \frac{M+m}{m} v = \frac{3 + 0.020}{0.020} (3.4) = \boxed{513\ m/s}$

[other version: 214 m/s]

8. A workman shoves a crate up a ramp with an initial velocity $v_1 = 6$ m/s. The crate slides up along the ramp through a distance of 2.5 m (as measured along the ramp) to point 2, where it momentarily comes to a stop: $v_2 = 0$. It then slides back down to point 3, where its velocity is $v_3$. The mass of the crate is 8 kg. The angle of the ramp with the horizontal is 30°. The acceleration of gravity is 9.8 $\text{m/s}^2$.




(a) (3) Calculate the initial kinetic energy of the crate, at point 1, where its velocity is $v_1$.

initial kinetic energy = 144 J

$\boxed{\frac{1}{2} m v_1^2 =} \frac{1}{2}(8)(6)^2 = \boxed{144\ \text{J}}$

[other version: 108 J]

(b) (3) Calculate the increase in gravitational potential energy when the crate rises from point 1 to point 2.

increase in potential energy = 98 J

$\boxed{mgh =} (8)(9.8)(2.5 \sin 30°) = \boxed{98\ \text{J}}$

[other version: 73.5 J]

(c) (3) Calculate the work done on the crate by friction as it rises from point 1 to point 2.

work done by friction = −46 J

$\boxed{\text{work} =} 98 - 144 = \boxed{-46\ \text{J}}$

[other version: −34.5 J]

(d) (3) Calculate the frictional force $f$.

$f =$ 18.4 N

$-f \cdot (2.5) = -46 \Rightarrow \boxed{f = 18.4\ \text{N}}$

[other version: 13.8 N]

(e) (3) Calculate the kinetic energy when the crate reaches the bottom, at point 3.

kinetic energy at point 3 = 52 J

total work $= 2 \cdot (-46\ \text{J}) = 92$ J

$\boxed{\frac{1}{2} m v_3^2 =} 144 - 92 = \boxed{52\ \text{J}}$ [or $98 - 46 = 52$ J]

[other version: 39 J]

(f) (3) Calculate the velocity $v_3$ at the bottom.

$v_3 =$ 3.6 $\frac{m}{s}$.

$\boxed{v_3 =} \sqrt{\frac{(2)(52)}{8}} = \boxed{3.6\ \text{m/s}}$

[other version: 3.6 m/s]

9. A satellite of mass $m$ revolves around the Earth in a circular orbit, at a distance of 8000 km above the Earth's surface. The mass $M$ of the Earth is $5.97 \times 10^{24}$ kg and the radius of the Earth is 6380 km.

(a) (3) Let us begin with the general problem of a mass $m$, moving with a speed $v$ around another mass $M$, in a circular orbit of radius $r$. Obtain the expression for $v$ in terms of $r$ and the period of revolution $T$.

$$\boxed{v = \frac{2\pi r}{T}}$$


(b) (3) Write down the two expressions for the force $F$ on $m$, first as the radial (centripetal) force in terms of $m$, $v$, and $r$, and then as the gravitational force in terms of $G$, $m$, $M$, and $r$. Here $G = 6.67 \times 10^{-11}$ N m$^2$ / kg$^2$ is the gravitational constant.

$$F = m \frac{v^2}{r}$$

$$F = G \frac{mM}{r^2}$$

(c) (3) Equating these expressions to each other, obtain the expression for $v$ in terms of $G$, $M$, and $r$.

$$\cancel{m} \frac{v^2}{\cancel{r}} = G \frac{\cancel{m} M}{r^{\cancel{2}}} \Rightarrow v^2 = \frac{GM}{r} \Rightarrow \boxed{v = \sqrt{\frac{GM}{r}}}$$

(d) (3) Calculate the speed $v$ of the satellite described at the top of this page.

speed = 5260 m/s

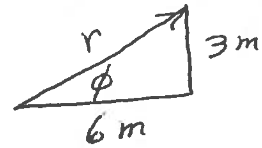
$$\boxed{v =} \sqrt{\frac{(6.67 \times 10^{-11})(5.97 \times 10^{24})}{6.38 \times 10^{6} + 8 \times 10^{6}}} = \boxed{5260 \text{ m/s}}$$

[other version: 5920 m/s]

10. A 3000 kg Hummer traveling due north collides with a 6000 kg truck traveling due east. The two vehicles stick together and slide as one object. The coefficient of kinetic friction between their tires and the pavement is 0.6. The two enmeshed vehicles slide to a halt at a point 3 m north and 6 m east of the impact point.

Let $\phi$ be the angle between a line that is due east and the line along which the vehicles slide after impact.

You are encouraged to draw a schematic picture showing north, east, the line along which the enmeshed vehicles slide, and the angle $\phi$.

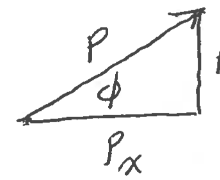



(a) (3) Calculate the angle $\phi$.

Answer: $\phi$ = $26.6^\circ$

$$\tan\phi = \frac{3\,m}{6\,m} \Rightarrow \boxed{\phi = 26.6^\circ}$$

[other version: $63.4^\circ$]




(b) (3) Calculate the distance that the vehicles slide after impact.

Answer: distance = 6.71 m

$$\boxed{r =} \sqrt{x^2+y^2} = \sqrt{3^2+6^2} = \boxed{6.71\ m}$$

[other version: 6.71 m]

(c) (6) Calculate the work done by friction on this system (the two vehicles).

Answer: work = −355,000 J

$$\boxed{\text{Work} =} -fr = -\mu_k \cdot Mg \cdot r$$

$$= -(0.6)(9000)(9.8)(6.71)$$

$$= \boxed{-355{,}000\ J}$$

[$f = \mu_k n$, $n = Mg$, $M = 3000 + 6000 = 9000$ kg]

[with our conventions for rounding, using = signs, leaving off units in intermediate steps]

[other version: − 316,000 J]

(d) (3) Calculate the magnitude $P$ of the momentum $\vec{P}$ of this system (the two vehicles) immediately after impact.

Answer: $P =$ 80,000 kg m/s

$$0 = \frac{P^2}{2M} + \text{work}$$

$$\Rightarrow \frac{P^2}{2M} = 355{,}000 \text{ J}$$

$$\Rightarrow \boxed{P =} \sqrt{(2)(9000)(355{,}000)}$$

$$= \boxed{80{,}000 \text{ kg m/s}}$$

[other version: 71,100 kg m/s]

(e) (3) Calculate the x and y components of $\vec{P}$.

Answer: $P_x =$ 71,500 kg m/s , $P_y =$ 32,000 kg m/s

$$P_x = P \cos\phi = (80{,}000)\cos(26.6°) = 71{,}500 \text{ kg m/s}$$

$$P_y = P \sin\phi = (80{,}000)\sin(26.6°) = 36{,}000 \text{ kg m/s}$$

[other version: $P_x = 31{,}800$ kg m/s and $P_y = 63{,}600$ kg m/s]

(f) (3) Calculate the velocity of the Hummer before the collision.

Answer: velocity = 12 m/s

$$\boxed{v_{Hummer} =} \frac{36{,}000}{3000} = \boxed{12 \text{ m/s}}$$

[other version: 21.2 m/s]

(g) (3) Calculate the velocity of the truck before the collision.

Answer: velocity = 12 m/s

$$\boxed{v_{truck} =} \frac{71{,}500}{6000} = \boxed{12 \text{ m/s}}$$

[other version: 6.4 m/s]

11. (extra credit) Recall the estimates given in class, to within a factor of two, for each of the following. (Or make your own estimates, again required to be accurate to within a factor of 2.)

(a) (3) We did a demonstration of power by asking the Editor-in-Chief of the physics journal of the Royal Swedish Academy of Sciences to climb the steps in our classroom. (She was a good sport!) Roughly how much power did she generate, expressed using the standard unit for power in the British system of units ?

roughly $\frac{1}{2}$ horsepower

(b) (2) At roughly what rate does an average resting human body emit energy, expressed using the standard metric system unit for power ?

roughly 100 W