Fall 2014 RED barcode here
Physics 105, sections 1 and 3
Exam 1
Colton

Please write your CID__________
so that you can get your exam back

No time limit. A handwritten 3” x 5” note card is allowed. No books. Student calculators allowed. All problems equal weight.

Constants/Materials parameters:

g = 9.8 m/s^2
$G = 6.67 \times 10^{-11}$ N·m^2/kg^2
$k_B = 1.381 \times 10^{-23}$ J/K
$N_A = 6.022 \times 10^{23}$
$R = k_B \cdot N_A$ = 8.314 J/mol·K
$\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4
Mass of Sun = 1.991×10^{30} kg
Mass of Earth = 5.98×10^{24} kg

Radius of Earth = 6.38×10^6 m
Radius of Earth’s orbit = 1.496×10^{11} m
Density of water: 1000 kg/m^3
Density of air: 1.29 kg/m^3
Linear exp. coeff. of copper: 17×10^{-6} /°C
Linear exp. coeff. of steel: 11×10^{-6} /°C
Specific heat of water: 4186 J/kg·°C
Specific heat of ice: 2090 J/kg·°C

Specific heat of steam: 2010 J/kg·°C
Specific heat of alum.: 900 J/kg·°C
Latent heat of melting (water): 3.33×10^5 J/kg
Latent heat of boiling (water): 2.26×10^6 J/kg
Thermal conduct. of alum.: 238 J/s·m·°C
v_{sound} = 343 m/s at 20°C

Conversion factors

1 inch = 2.54 cm
1 foot = 0.3048 m
1 mile = 1.609 km
1 mi/hr = 1 mph = 0.44704 m/s

1 m^3 = 1000 L
1 gallon = 3.785 L = 3785 cm^3
1 atm = 1.013×10^5 Pa = 14.7 psi

$$T_F = \tfrac{9}{5}T_C + 32$$
$$T_K = T_C + 273.15$$

Instructions:

- Write your CID at the top of the page, otherwise you may not get this exam booklet back.
- Circle your answers in this booklet if you wish to record them, but be sure to **mark your answers on the bubble sheet**. (You will not get the bubble sheet back.)
- Unless otherwise specified, **ignore air resistance** in all problems.
- Use g = 9.8 m/s^2.

Some notes on the answer ranges:

If a set of answers is given like this

a. Less than 30 N
b. 30 – 40
c. 40 – 50
d. 50 – 60
e. More than 60 N

you can generally consider choice (a) to mean “20 – 30 N”, and choice (e) to mean “60 – 70 N”. I often write them like that so that if I’ve made a mistake when making up the answer ranges, and the answer is really less than 20 N, or larger than 70 N, then there is still an answer that is correct.

I randomize the answer choices, so the first and last choices should receive their statistical fair share of answers.

Any units and/or exponents given in the first and last answer choices also apply to the middle choices.

$V = A \cdot$ thickness

$\rightarrow$ thickness $= \text{Vol}/\text{area}$

$\boxed{\text{Exam 1 Solutions, Dr Colton, Fall 2014}}$

1. One gallon of paint covers an area of 350 ft^2. What is the thickness of the paint on the wall?
   a. ~~Less than~~ 0.08 mm
   b. 0.08 – 0.09
   c. 0.09 – 0.10
   d. 0.10 – 0.11
   e. 0.11 – 0.12
   f. 0.12 – 0.13
   g. 0.13 – 0.14
   h. More than 0.14 mm

$A = 350\ ft^2 \times \left(\frac{.3048\ m}{1\ ft}\right)^2 = 32.52\ m^2$

$V = 1\ gal \times \frac{3.785\ L}{1\ gal} \times \frac{1\ m^3}{1000\ L} = .003785\ m^3$

$t = \frac{V}{A} = \frac{.003785\ m^3}{32.52\ m^2} = 1.164 \cdot 10^{-4}\ m$

$= \boxed{.116\ mm}$

2. A motorist drives north for 0.75 hr at 80 km/h and then stops for 0.25 hr. He then continues north, traveling 100 km in 2.00 hr. What is his average velocity for the entire trip?
   a. Less than 30 km/h
   b. 30 – 35
   c. 35 – 40
   d. 40 – 45
   e. 45 – 50
   f. 50 – 55
   g. 55 – 60
   h. More than 55 km/hr

100 km in 2 hr

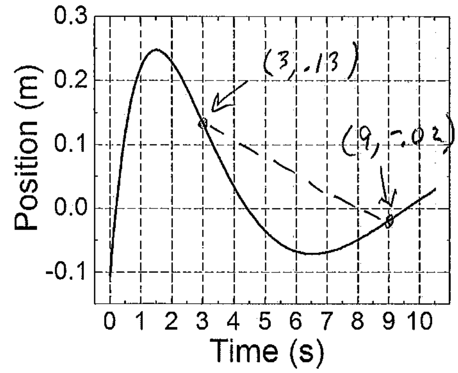
.25 hr

.75 hr @ 80 km/hr

$\rightarrow = 60$ km

$V_{ave} = \frac{\Delta x}{\Delta t} = \frac{60\ km + 100\ km}{(.75 + .25 + 2)\ hr} = \boxed{53.33\ km/hr}$

3. On the right is a position vs. time graph of a car moving along a road. Positive means “to the right”. What is the magnitude of the car’s average velocity between the times of 3 and 9 seconds?
   a. ~~Less than~~ 1.5 cm/s
   b. ~~1.5~~ – 2.0
   c. ~~2.0~~ – 2.5
   d. ~~2.5~~ – 3.0
   e. ~~3.0~~ – 3.5
   f. ~~3.5~~ – 4.0
   g. ~~4.0~~ – 4.5 cm/s
   h. ~~More than 4.5 cm/s~~



$V_{ave} = \frac{\Delta x}{\Delta t}$ = slope of dashed line

$= \frac{-0.02 - .13}{9 - 3}\ \frac{m}{s}$

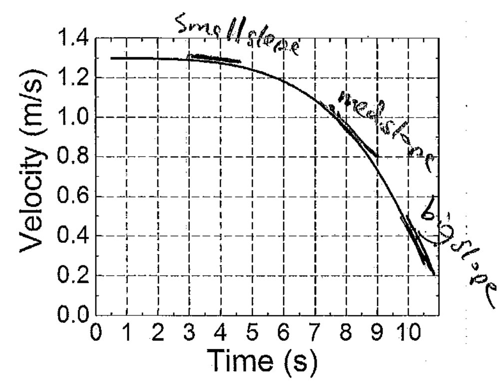
$= -.025\ m/s$

$= \boxed{-2.5\ cm/s}$

magnitude = 2.5 cm/s

4. On the right is a velocity vs time graph of a car moving along a road. Positive means "to the right". During the time shown, the car's acceleration is:
   a. increasing in magnitude
   b. decreasing in magnitude
   c. constant in magnitude

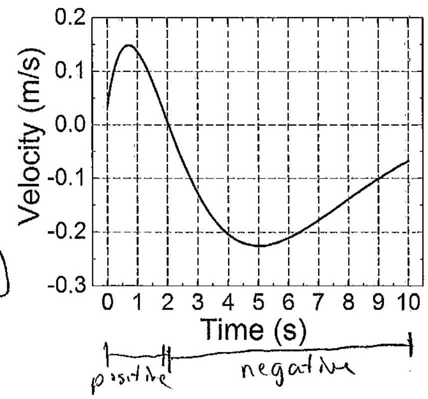
slope of graph



5. On the right is a velocity vs time graph of a car moving along a road. Positive means "to the right". During the time shown, what fraction of the time did the car spend moving to the left? (Choose the closest answer.)
   a. 10 %
   b. 20
   c. 30
   d. 40
   e. 50
   f. 60
   g. 70
   h. 80
   i. 90 %

negative velocity

V is negative from 2 to 10 s, which is $\boxed{80\% \text{ of time}}$



6. A certain car's specs says that it can go from 0 to 60 mi/hr in 7.0 seconds. How many g's of acceleration would the driver experience in such a situation?
   a. Less than 0.10 g's
   b. 0.10 – 0.15
   c. 0.15 – 0.20
   d. 0.20 – 0.25
   e. 0.25 – 0.30
   f. 0.30 – 0.35
   g. 0.35 – 0.40
   h. More than 0.40 g's

$v_f = 60\frac{mi}{hr} \times \frac{.44704\ m/s}{1\ mi/hr} = 26.8224\ m/s$

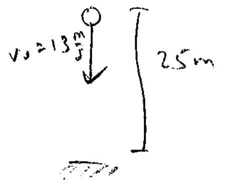
$a = \frac{\Delta v}{\Delta t}$

$a = \frac{26.8224\ m/s - 0}{7\ sec} = 3.832\ m/s^2$

divide by $9.8\ m/s^2$ to convert to "g's"

$= \boxed{0.391\ g's}$

7. A ball is thrown directly downward, with an initial speed of 13 m/s, from a height of 25 m. After what interval of time does the ball strike the ground?
   a. Less than 0.9 s
   b. 0.9 – 1.0
   c. 1.0 – 1.1
   d. 1.1 – 1.2
   e. 1.2 – 1.3
   f. 1.3 – 1.4
   g. 1.4 – 1.5
   h. More than 1.5 s



Given position, want time. Could solve $y = y_0 + v_{0y}t - \frac{1}{2}gt^2$ for time, but requires quadratic formula.

Instead, I'll solve for v_f first:

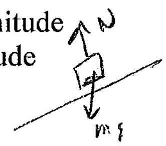
$v_f^2 = v_0^2 - 2g\Delta y \rightarrow v_f = \sqrt{13^2 - 2(9.8)(-25)}$

$v_f = 25.67\ m/s$ downward

Then $v = v_0 - gt$

$\rightarrow t = \frac{v - v_0}{-g} = \frac{-25.67\frac{m}{s} - (-13\ m/s)}{-9.8\ m/s^2} = \boxed{1.29\ s}$

8. A toy car on a ramp is given a quick upward push. As a result of the push, the car travels up the ramp a bit, slows down and stops, then rolls back down again. As the car is moving up the ramp, the net force on it is:
   a. Up the ramp, and increasing in magnitude
   b. Up the ramp, and decreasing in magnitude
   c. Up the ramp, and constant in magnitude
   d. Zero
   e. Down the ramp, and increasing in magnitude
   f. Down the ramp, and decreasing in magnitude
   g. Down the ramp, and constant in magnitude



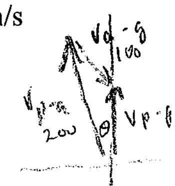
because that's direction of acceleration

because N and mg aren't changing

9. Same situation. Right at the top of the car's motion, the net force on it is:
   a. Up the ramp, and increasing in magnitude
   b. Up the ramp, and decreasing in magnitude
   c. Up the ramp, and constant
   d. Zero
   e. Down the ramp, and increasing in magnitude
   f. Down the ramp, and decreasing in magnitude
   g. Down the ramp, and constant

Nothing is different here. It's just like the peak of a thrown ball's motion.

10. Jenna wishes to fly an airplane due north in a 100 km/h wind that is blowing exactly to the south-east. The airspeed of the airplane (i.e.$v_{plane-air}$) is 200 km/h. What speed relative to the ground will the airplane be going? Hint: Draw a picture. If you draw it correctly, you should notice that the x-component of $v_{plane-air}$ must cancel with the x-component of $v_{air-ground}$. That allows you to find the angle of $v_{plane-air}$, which is helpful.
   a. Less than 80 m/s
   b. 80 – 90
   c. 90 – 100
   d. 100 – 110
   e. 110 – 120
   f. 120 – 130
   g. 130 – 140
   h. More than 140 m/s



$\vec{V}_{p-a} + \vec{V}_{a-g} = \vec{V}_{p-g}$

	x	y
V_{p-a}	$-200\cos\theta$	$200\sin\theta$
V_{a-g}	$100\cos 45°$	$-100\sin 45°$
total	0	the answer

From x: $-200\cos\theta + 100\cos 45° = 0 \rightarrow \cos\theta = \frac{100\cos 45°}{200°}$

$\theta = 69.295°$

From y: answer $= 200\sin\theta - 100\sin 45°$

$= 200\sin(69.295°) - 100\sin 45°$

$= \boxed{116.4\ km/hr}$

my apologies - I wrote the answer choices in m/s instead of km/hr as I had intended. If you convert 116.4 km/hr to m/s, you get 32.33 m/s. I therefore accepted answer A as well as E.

11. A firefighter, 20 m away from a burning building, directs a stream of water from a ground level fire hose at an angle of 55° above the horizontal. If the speed of the stream as it leaves the hose is 30 m/s, at what height above the ground will the stream of water strike the building?

time from x-direction

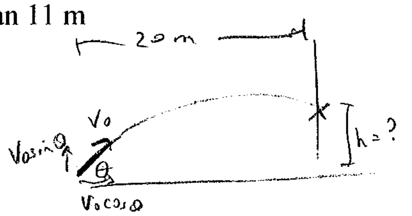
$x = \cancel{x_0} + v_{x}t \rightarrow t = \frac{x}{v_{0x}} = \frac{20\,m}{30\frac{m}{s}\cos 55^\circ} = \underline{1.162\ sec}$

height from y-direction

$y = \cancel{y_0} + v_{0y}t - \frac{1}{2}gt^2$

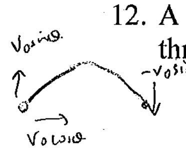
$= (30\tfrac{m}{s}\sin 55^\circ)(1.162s) - \frac{1}{2}(9.8\tfrac{m}{s^2})(1.162s)^2$

$= \boxed{21.9\ m}$



a. Less than 11 m
b. 11 – 13
c. 13 – 15
d. 15 – 17
e. 17 – 19
f. 19 – 21
g. 21 – 23
h. More than 23 m

12. A pitcher throws a baseball at a 45° angle and finds that it travels 50 m horizontally. How high will it go if he throws it straight up with the same initial velocity? (Choose the closest answer.)



a. 11 m
b. 13
c. 15
d. 17
e. 19
f. 21
g. 23
h. 25 m

(There may be an easier method...)

For 45° case equations are:

$x = V_{0x}\,t$ $\qquad V_{fy} = V_{0y} - gt$

$50 = (V_0 \cos 45)t$ $\qquad -V_0 \sin 45 = V_0 \sin 45 - gt$

$gt = 2 V_0 \sin 45^\circ$

2 eqns, 2 unknowns
Solve for t and plug in to get V_0

$t = \frac{50}{V_0 \cos 45}$ $\qquad g\left(\frac{50}{V_0 \cos 45}\right) = 2 V_0 \sin 45$

$\frac{g \cdot 50}{2 \sin 45 \cos 45} = V_0^2$

$V_0 = \sqrt{\frac{9.8 \cdot 50}{2 \sin 45 \cos 45}} = \underline{22.13\ m/s}$

Then use that velocity to get h

$V_f^2 = V_0^2 - 2g\Delta y$

0, at peak

$0 = (22.13)^2 - 2(9.8)\Delta y$

$\Delta y = \frac{(22.13)^2}{2 \cdot 9.8} = \boxed{25\,m}$

13. Angela is in a spaceship and throws her physics book out the window (somehow). How much force would have to be exerted on the book in order to have it keep traveling with constant velocity after it has left the spaceship?

a. a force equal to the book's acceleration
b. a force equal to the book's mass
c. a force equal to the book's velocity
d. a force equal to the book's mass times its velocity
e. zero

If no acceleration, no force

14. From the perspective of Newton's Second Law, what force on a car causes it to accelerate forward when the gas pedal is pushed?

a. The car pushing backward on the road
b. The car pushing forward on the road
c. The road pushing backward on the car
d. The road pushing forward on the car

15. In class Dr. Colton demonstrated Newton's Third Law by pushing against a wall so hard that he went flying backwards. What is the Newton's Third Law partner force to the force of Dr. Colton on the wall?

a. $F_{building\text{-}wall}$
b. $F_{Colton\text{-}wall}$
c. $F_{wall\text{-}building}$
d. $F_{wall\text{-}Colton}$

N3: $\vec{F}_{12} = -\vec{F}_{21}$

16. Cosmo applies a force of 500 N on a refrigerator, which then begins to accelerate at 0.5 m/s². There is a backwards frictional force of 100 N. What is the mass of the refrigerator?

a. Less than 780 kg
b. 780 – 820
c. 820 – 860
d. 860 – 900
e. 900 – 940
f. 940 – 980
g. 980 – 1020
h. More than 1020 kg

100N ← [ ] → 500N

$\Sigma F = ma$

$500N - 100N = m(.5\,m/s^2)$

$m = 800\ kg$

$\boxed{\ } \rightarrow 2000\,N$ $\quad \Sigma F = ma \rightarrow a = \frac{2000\ N}{300\ kg} = 6.667\ m/s^2$

17. A forward force of 2000 N is applied to accelerate a 300 kg spaceship for 4 seconds. The spaceship is initially traveling at 5 m/s. How fast is it traveling at the end of the time interval?
    a. Less than 32 m/s
    b. 32 – 34
    c. 34 – 36
    d. 36 – 38
    e. 38 – 40
    f. 40 – 42
    g. 42 – 44
    h. More than 44 m/s

$v_f = v_i + at$

$v_f = 5\ m/s + (6.667\ m/s^2)(4\ s)$

$= \boxed{31.667\ m/s}$

18. It is past midnight and Sue is sliding down a rope from her third floor window to meet her boyfriend. As she slides down the rope faster and faster she becomes alarmed and gradually tightens her grip on the rope. This slows her down a little at first, but then more and more as her grip tightens. What happens to the tension in the rope as she does this? Hint: consider the forces on Sue.
    a. The tension gradually decreases.
    b. The tension gradually increases.
    c. The tension remains constant.

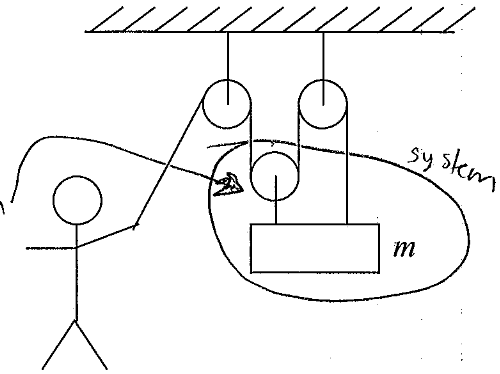
$\uparrow F_{rope\text{-}sue}$

$\boxed{Sue}$

$\downarrow mg$ (not changing)

If acceleration is changing, $F_{rope\text{-}sue}$ must be changing (increasing). $F_{rope\text{-}sue}$ is the tension! (Because it's equal to $F_{sue\text{-}rope}$)

19. Scott pulls on the rope as shown in order to very slowly lift a block (mass *m*). The top two pulleys are suspended from the ceiling, unable to move vertically, but the bottom pulley is free to move up and down. The block is attached to the rope, and also to the middle pulley as shown. All ropes and all pulleys are massless. What is the tension in the main rope (i.e. the one Scott's pulling on, that's also attached to the block on the right)? Consider system



    a. *mg*
    b. *mg*/2
    c. *mg*/3
    d. *mg*/4
    e. *mg*/5
    f. *mg*/6
    g. *mg*/7
    h. *mg*/7 Sorry, double answer choice. Fortunately it wasn't correct.

T T T (up), mg (down)

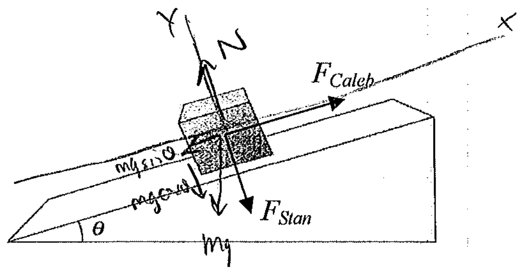
very slow = no acceleration

$\Sigma F = 0$

$3T - mg = 0$

$\boxed{T = \frac{1}{3} mg}$

20. Caleb is attempting to push a large block up a frictionless ramp. His force is parallel to the ramp surface. His father, Stan, wanting to make his life more difficult, pushes down on the block. Stan's angle is such that the block gets pushed straight into the ramp as shown (i.e. perpendicularly to the ramp). The block is motionless. What's the normal force between the block and the ramp? → no acceleration



    a. $F_{Caleb} + mg\cos\theta$
    b. $F_{Caleb} + mg\sin\theta$
    c. $F_{Caleb} + F_{Stan} + mg\cos\theta$
    d. $F_{Caleb} + F_{Stan} + mg\sin\theta$
    e. $F_{Stan} + mg\cos\theta$
    f. $F_{Stan} + mg\sin\theta$
    g. $mg\cos\theta$
    h. $mg\sin\theta$

$\Sigma F_x = 0$

$F_{Caleb} - mg\sin\theta = 0$

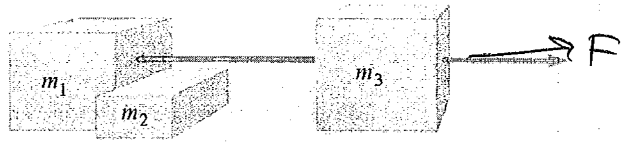
$\Sigma F_y = 0$

$N - mg\cos\theta - F_{Stan} = 0$

only need this to solve for N

$\boxed{N = F_{Stan} + mg\cos\theta}$

21. Three blocks are assembled as shown in the figure: there is a rope connecting m_1 and m_3, and m_2 is resting up against the right hand side of m_1. There is no friction. Elena pulls to the right on m_3 with a force F. How much force is exerted by m_1 on m_2?



a. $\frac{1}{2}F$
b. $\frac{1}{3}F$
c. F
d. $\frac{1}{2}\left(\frac{m_2}{m_1+m_2+m_3}\right)F$
e. $\frac{1}{3}\left(\frac{m_2}{m_1+m_2+m_3}\right)F$
f. $\frac{m_2}{m_1+m_2+m_3}F$
g. $\frac{1}{2}\left(\frac{m_1+m_2}{m_1+m_2+m_3}\right)F$
h. $\frac{1}{3}\left(\frac{m_1+m_2}{m_1+m_2+m_3}\right)F$
i. $\frac{m_1+m_2}{m_1+m_2+m_3}F$

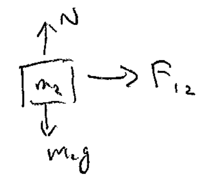
First, find acceleration by considering all 3 as a group

$\Sigma F_{group} = m_{group}\, a$

$F = (m_1+m_2+m_3)\, a$

$a = \frac{F}{m_1+m_2+m_3}$

Now consider FBD of m_2 only



There's only one horizontal force

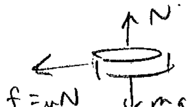
$\Sigma F_2 = m_2 a$

$F_{12} = m_2 a$

$$\boxed{F_{12} = m_2 \cdot \frac{F}{m_1+m_2+m_3}}$$

22. Same situation. How does the force exerted by m_1 on m_2 compare with the force exerted by m_2 on m_1? Compare magnitudes only.
a. $F_{1\text{-}2} < F_{2\text{-}1}$
b. $F_{1\text{-}2} > F_{2\text{-}1}$
c. $F_{1\text{-}2} = F_{2\text{-}1}$ ← Equal, by Newton's Third Law

23. A hockey puck is hit on a frozen lake and starts moving with a speed of 13 m/s. Friction slows it down, and 5 seconds later, the puck's speed is 7 m/s. What is the value of the coefficient of kinetic friction between the puck and the ice? Note: perhaps surprisingly, the answer doesn't depend on the mass of the puck.
a. Less than 0.07
b. 0.07 – 0.08
c. 0.08 – 0.09
d. 0.09 – 0.10
e. 0.10 – 0.11
f. 0.11 – 0.12
g. 0.12 – 0.13
h. More than 0.14



$\Sigma F_y = 0 \rightarrow N = mg$

$\Sigma F_x = ma$ → get a from kinematics: $a = \Delta v/\Delta t = \frac{7-13\text{ m/s}}{5\text{ s}} = -1.2\text{ m/s}^2$

$-\mu N = m(-1.2\text{ m/s}^2)$

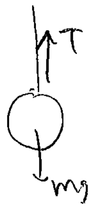
$\mu = \frac{m\,1.2\text{ m/s}^2}{N} = \frac{\cancel{m}\,1.2\text{ m/s}^2}{\cancel{m}g} = \frac{1.2\text{ m/s}^2}{9.8\text{ m/s}^2}$

$= \boxed{0.122}$

24. You are a back-seat passenger in a car, not wearing your seat belt. Without increasing or decreasing its speed, the car makes a sharp left turn, and you find yourself colliding with the right-hand door. Which is the correct analysis of the situation according to Newton's laws?
a. Before and after the collision with the door, there is a rightward force pushing you into the door. → False, it's your own inertia that causes that
b. Starting at the time of collision with the door, the door exerts a leftward force on you. → True, it causes you to turn left.
c. Both of the above
d. Neither of the above

$v = \frac{2\pi r}{\text{period}} = \frac{2\pi(.6m)}{1 \text{ sec}} = 3.7699 \text{ m/s}$

25. Phil swings a gallon of milk (3.91 kg) around in a vertical circle. The milk jug moves around at a constant speed, at a rate of 1 revolution per second, and Phil's arm is 0.6 m long. What is the tension in his arm when the jug is at its lowest point?
   a. Less than 85 N
   b. 85 – 95
   c. 95 – 105
   d. 105 – 115
   e. 115 – 125
   f. 125 – 135
   g. 135 – 145
   h. More than 145 N



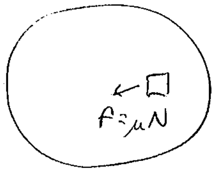
$\Sigma F = ma_c$

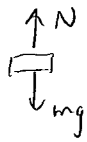
$T - mg = \frac{mv^2}{r}$

$T = mg + \frac{mv^2}{r}$

$T = (3.91kg)(9.8 \text{ m/s}^2) + \frac{(3.91kg)(3.7699 \text{ m/s})^2}{.6m} = \boxed{130.9N}$

26. A small block (mass m) rests on a rotating turntable a distance r from the center. The coefficient of static friction between the two objects is μ_s. How fast can the turntable spin before the block starts to slip?
   a. $(1/\mu)\sqrt{rg}$
   b. $\mu\sqrt{rg}$
   c. $\sqrt{\mu rg}$
   d. $\sqrt{rg/\mu}$
   e. $(1/(\mu m))\sqrt{rg}$
   f. $\mu m\sqrt{rg}$
   g. $\sqrt{\mu mrg}$
   h. $\sqrt{rg/(\mu m)}$





$\Sigma F_y = 0$

$N = mg$

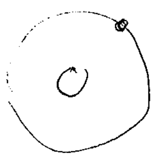
$\Sigma F_x = ma_c$

$\mu N = \frac{mv^2}{r}$

$\mu \cancel{m} g = \frac{\cancel{m}v^2}{r}$

$\boxed{v = \sqrt{\mu r g}}$

27. Suppose an alien astronaut in a circular orbit around the alien homeworld, 9000 km from the planet's center, has an orbital speed of 7 km/s. How long would it take the alien to make one complete orbit?
   a. Less than 140 min
   b. 140 – 150
   c. 150 – 160
   d. 160 – 170
   e. 170 – 180
   f. 180 – 190
   g. 190 – 200
   h. More than 200 min

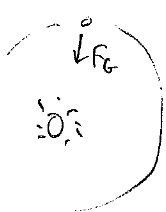


$v = \frac{2\pi r}{T} \rightarrow T = \frac{2\pi r}{v}$

$= \frac{2\pi(9000 \cdot 10^3 m)}{7 \cdot 10^3 \text{ m/s}}$

$T = 8078 \text{ sec} \times \frac{1 \text{ min}}{60 \text{ sec}} = \boxed{134.6 \text{ min}}$

28. Astronomers observe an Earth-like planet orbiting a distant sun-like star. If the planet's orbital speed and orbital radius are measured to be 30000 m/s and 1.5×10^{11} m, respectively, what must the star's mass be?
   a. Less than 1.8×10^{30} kg
   b. 1.8 – 1.9
   c. 1.9 – 2.0
   d. 2.0 – 2.1
   e. 2.1 – 2.2
   f. 2.2 – 2.3
   g. 2.3 – 2.4
   h. More than 2.4×10^{30} kg



$\Sigma F = ma_c$

$\frac{GM\cancel{m}}{r^{\cancel{2}}} = \frac{\cancel{m}v^2}{\cancel{r}}$

$M = \frac{v^2 r}{G} = \frac{(30000 \text{ m/s})^2(1.5 \cdot 10^{11} m)}{(6.67 \cdot 10^{-11} \frac{Nm^2}{kg^2})}$

$= \boxed{2.024 \cdot 10^{30} \text{ kg}}$