Name:______________________________ ID:______________________________

Physics 201

Final Exam

12/11/2024

Collaboration is not allowed. Allowed on your desk are: ten 8.5 x 11 inch doubled sided sheets of notes that are bound together, non-communicating graphing scientific calculator, a page of scratch paper, writing utensils, and the exam. You will have 110 minutes to complete this exam.

For questions 1 through 6 **fill in the square** next to all correct answers. A given problem may have more than one correct answer. Each correctly bubbled answer will receive two points. There are **10** correct answers in this section and only the first **10** filled in answers will be graded. There is no partial credit.

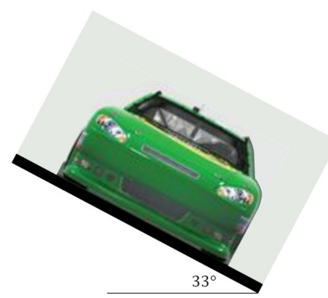
1. The time it takes for one cycle of a simple pendulum can be determined knowing only the acceleration due gravity, **g**, and how long the pendulum is, $\boldsymbol{\ell}$. Which of the following expressions could represent the time it takes for one cycle of a pendulum?
   - □ (a) g/ℓ
   - □ (b) $g\ell^2$
   - □ (c) $g\ell$
   - □ (d) $(g\ell)^{0.5}$
   - ✓ (e) $(\ell/g)^{0.5}$

$[g] = m/s^2$ want [time] = s

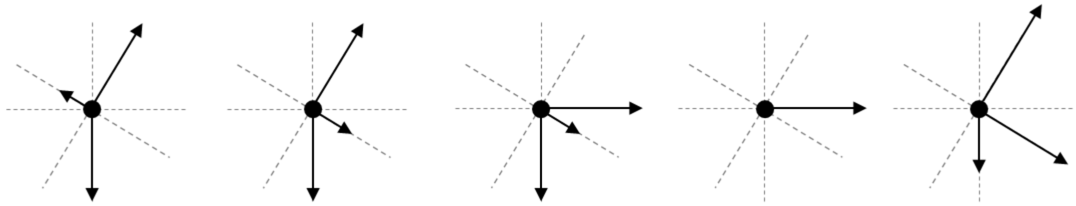
$[\ell] = m$ $\sqrt{\frac{\ell}{g}} = \left(\frac{m}{m/s^2}\right)^{1/2} = \left(\cancel{m}\,\frac{s^2}{\cancel{m}}\right)^{1/2} = s$ ✓

2. Which of the following statements regarding momentum and kinetic energy are true.
   - □ (a) If a force acts perpendicular to an object's velocity it cannot change its momentum. $\vec{p}$ $\vec{F}$ ⇒ UCM
   - ☑ (b) If a force acts perpendicular to an object's velocity it cannot change its kinetic energy.
   - □ (c) If the same force acts on two different mass objects for equal amounts of time, it will change their momentum by different amounts.
   - ✓ (d) If the same force acts on two different mass objects for equal amounts of time, it will change their momentum by the same amount. $\underbrace{F\Delta t}_{same} = \underbrace{\Delta p}_{same} = m\Delta v$
   - □ (e) If the same force acts on two different mass objects for equal displacements, it will change their kinetic energy by different amounts.
   - ✓ (f) If the same force acts on two different mass objects for equal displacements, it will change their kinetic energy by the same amount. $\underbrace{F\Delta x}_{same} = \underbrace{\Delta KE}_{same} = \frac{1}{2}mv^2$

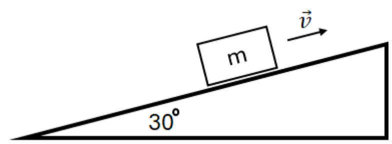
3. At Talladega Superspeedway turns are banked at a 33 degree incline with respect to the horizontal. Pictured is a car, travelling around the curved track. The car is turning to its left as it travels out of the page, which is to the right in the picture provided. Which of the following could represent a free body diagram of the car travelling at the maximum speed it could drive around the corner without sliding. You may assume that the coefficient of static friction between road and tires is about 1.0.



□ (a) □ (b) □ (c) □ (d) ✓ (e)



4. A wood block is sliding up a wooden slope. The surface makes an angle of 30 degrees with the horizontal. The coefficient of static friction between the two surfaces is 0.4. The coefficient of kinetic friction between the surfaces is 0.3. Which of the following is the most appropriate force analysis? Assume a rotated coordinate system with the positive x-axis pointed up the slope and the positive y-axis is perpendicular to the surface.

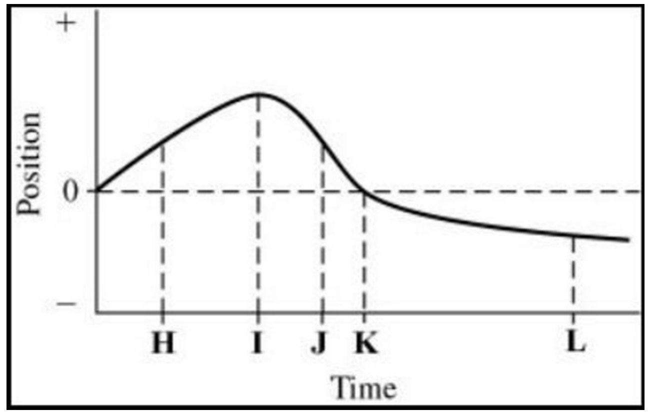


- ☑ (a) X: $-mg\ \sin 30^{\circ} - (0.3)mg\cos 30^{\circ} = ma_x$
  Y: $F^N - mg\cos 30^{\circ} = 0$
- ☐ (b) X: $+mg\ \sin 30^{\circ} - (0.4)mg\cos 30^{\circ} = ma_x$
  Y: $F^N - mg\cos 30^{\circ} = 0$
- ☐ (c) X: $-mg\ \sin 30^{\circ} - (0.4)mg\cos 30^{\circ} = ma_x$
  Y: $F^N - mg\cos 30^{\circ} = 0$
- ☐ (d) X: $+mg\ \sin 30^{\circ} - (0.3)mg\cos 30^{\circ} = ma_x$
  Y: $F^N - mg\cos 30^{\circ} = 0$

5. A gerbil in your hand is being raised up at a constant velocity. Which of the following statements are true regarding this situation?
   - ☐ (a) The normal force acting on the gerbil must be larger than the gravitational force.
   - ☑ (b) The impulse acting on the gerbil is zero.
   - ☑ (c) The gerbil travels through equal distances over equal time intervals.
   - ☐ (d) The normal force does no work on the gerbil.
   - ☐ (e) The kinetic energy of the gerbil increases from one second to the next.

6. A spaceship is traveling in the galactic southeast direction. The ship's thrusters then create a large, constant force in the galactic north direction. Which of the following statements ***must*** be true during the time after the thrusters have fired?
   - ☐ (a) The ship will be moving in the eastern direction.
   - ☐ (b) The ship's velocity will eventually be due north.
   - ☑ (c) The ship's velocity will eventually have both northern and eastern components.
   - ☐ (d) The ship's displacement will be in the galactic north direction.
   - ☐ (e) The ship's displacement will be in the galactic east direction.
   - ☐ (f) The change in the ship's velocity will be in the eastern direction.
   - ☑ (g) The change in the ship's velocity will be in the northern direction.

7. (8 points) The plot shows the position (1-D) of an object as a function of time. The letters H-L represent particular moments of time that you are asked to rank in various physical quantities. If two options appear very close, then comment that they appear approximately equal.



(a) Rank the displacement from zero of the object, starting with the most negative.

$L < K < H = J < I$

(b) Rank the total distance traveled by the object, starting with the least distance value.

H, I, J, K, L

(c) Rank the velocity of the object, starting with the most negative.

slope

$v = 0$

$J < K < L < I < H$

(d) Rank the acceleration of the object, starting with the most negative.

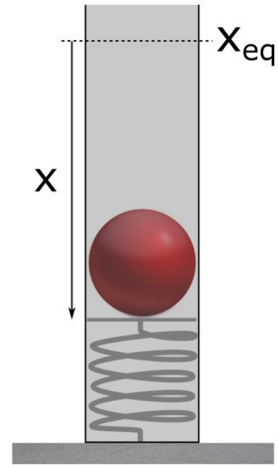
$a > 0 \Rightarrow$

$\Rightarrow$

all $= 0$ (const v)

$I < H = J = L < K$

8. (5 points) A ball, starting from equilibrium, is pressed down with a hand against a linear ideal spring that is aligned vertically, as shown in the figure. When the hand no longer pushes down, the ball is released from rest and flies upward. The ball reaches a maximum height of 2.30 meters above the equilibrium position of the spring and then falls back down, compressing the spring again. When answering the following questions do not ignore air resistance and use a system that consists of the ball, the spring, and the Earth (but not the air or the hand). Air resistance is a force that acts opposite the direction of the ball's motion.



(a) Use the descriptive representation (words) to describe the relevant energy transformations and transfers from the point the hand begins to push down on the ball all the way to the point when the ball recompresses the spring and is momentarily at rest.

(b) Do you expect the spring to compress the same distance when the ball comes back down as it originally did when the hand released the ball? Explain your reasoning.

(a) the hand does positive external work on system, adding energy, as it compresses spring.

when hand releases, spring potential energy is transfered to grav. potential energy & KE within system.

after spring reaches equilib. position, spring potential energy is zero. KE is now converting into U^g.

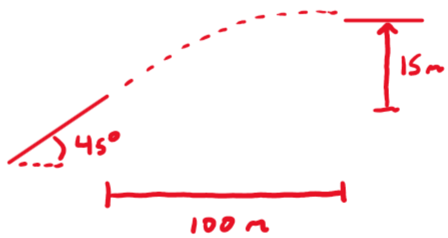
technically, this starts when $F^g > F^{spring} = kx$, a little before x_{eq}

As ball travels through the air, $W^{ext}_{air} = \vec{F}^{air} \cdot \Delta\vec{r} = |\vec{F}^{air}||\Delta\vec{r}|\underbrace{\cos(180^\circ)}_{-1}$ is negative, meaning energy is leaving system.

Ball goes up until energy in system is all in U^g & $KE=0$, then falls. U^g is converted back to KE, then both convert back to U^{spring}. The air does negative external work as the ball falls.

(b) no, the air does negative external work on the way up & on the way down. There is therefore less energy in the system $\Rightarrow$ less $U^s = \frac{1}{2}kx^2$ at the end $\Rightarrow$ x is smaller

9. (8 points) A stuntman is attempting to jump a canyon on a motorcycle. They have a launch ramp set at an angle of 45° with respect to the horizontal. The width of the canyon is 100 m and the landing point is 15 m higher than the launch. What's the minimum speed they must achieve to make the jump? Ignore air resistance.



Kinematics.
two dimensions!
(one object, one stage)

y

$\Delta y = 15\text{m}$ $\quad \Delta t = ?$

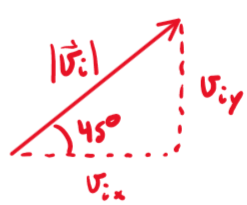
$v_{fy} = 0$ $\quad v_{iy} = ?$

$a_y = -g$

(3) $\Rightarrow$ $v_{fy}^2 = v_{iy}^2 + 2a_y\Delta y$

$0 = v_{iy}^2 + 2(-9.8\,\text{m/s}^2)(15\text{m})$

$\Rightarrow v_{iy}^2 = 294\ \text{m}^2/\text{s}^2$



$\Rightarrow |\vec{v}_i|^2 = v_{iy}^2 + v_{ix}^2$

$= v_{iy}^2 + v_{iy}^2$

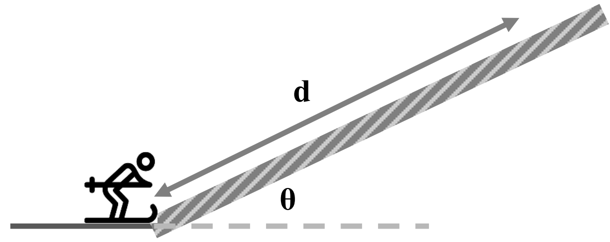
$45° \Rightarrow v_{iy} = v_{ix}$

$\Rightarrow |\vec{v}_i|^2 = 2\,v_{iy}^2$

$\Rightarrow \boxed{|\vec{v}_i| = 24.2\ \text{m/s}}$

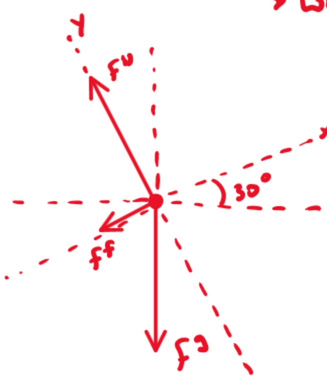
10. (10 points) A skier is traveling at 25 m/s when they begin going up a hill that makes an angle of 30° with respect to the horizontal. The coefficient of kinetic friction between their skis and the slope is 0.10 and we are interested in how far they travel up the hill.

How far up the slope (**d**) do they travel before coming to rest?



forces → kinematics or work/energy

2 dimensions (1 stage, 1 object)



Y

$F^N + F^g_y = m\cancel{a_y}^{0}$

$F^N = -F^g_y$

$F^N = -(-mg\cos\theta)$

$F^N = mg\cos\theta$

$F^f = \mu F^N$

$= \mu mg\cos\theta$

$W^{ext} = \Delta E$

$\Rightarrow \quad E_i + W^{ext} = E_f$

$\Rightarrow \quad KE_i + W^{f,k} = U^g_f$

$\Rightarrow \quad \frac{1}{2} m v_i^2 + |F^f|(d)\underbrace{\cos(180^\circ)}_{-1} = mg\, y_f$

$\sin\theta = \frac{y_f}{d}$

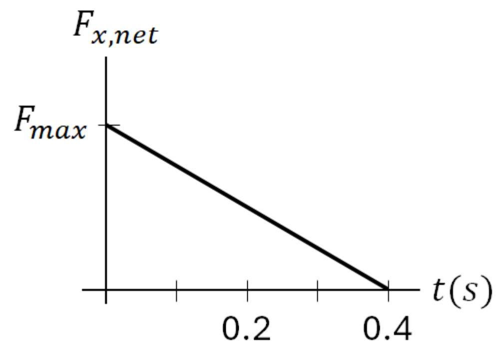
$y_f = d\sin\theta$

$\frac{1}{2}\cancel{m} v_i^2 - \mu \cancel{m} g d = \cancel{m} g d \sin\theta$

$\frac{1}{2} v_i^2 = \mu g d + g d \sin\theta$

$d = \frac{\frac{1}{2} v_i^2}{\mu g + g\sin\theta} = 53.1\ m$

11. (10 points) Two bumper hover boats are involved in a fun collision. Each has a mass of 100 kg. Just before the collision the velocity of the red boat is 8 m/s in the positive x-direction and the velocity of the blue boat is 3 m/s in the positive x-direction. Immediately after the collision, the velocity of the red boat is 5 m/s in the positive x-direction. After the collision, the blue boat's engine cuts out and it slides to rest due to the drag force from the water (assume no other horizontal forces are involved). The magnitude of the drag force experienced by the blue boat after the collision is shown in the graph given here.



What is the maximum drag force (F_{max}) experienced by the blue bumper boat after the collision?

Collision + sliding ⇒ two stages

Collision: conservation of mom.

Sliding: know F, Δt ⇒ impulse (or forces + kinematics)

two objects in 1st stage (1 in second)

one-dimension (yay!)

1st stage

$\Sigma F^{ext} \Delta t = 0 = \Delta p$

$\Rightarrow \vec{p}_i = \vec{p}_f$

$\Rightarrow p_{rix} + p_{bix} = p_{rfx} + p_{bfx}$

$\Rightarrow \cancel{(100\,kg)}(+8\,m/s) + \cancel{(100\,kg)}(+3\,m/s) = \cancel{(100\,kg)}(+5\,m/s) + \cancel{(100\,kg)}\,v_{fbx}$

$\Rightarrow 8 + 3 = 5 + v_{fbx}$

$v_{fbx} = 6\,m/s$

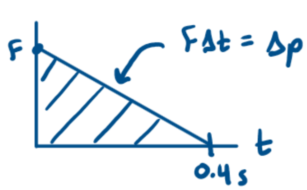
Connection between stages is $v_{1fbx} = v_{2ibx}$

2nd stage

$v_{ib} = 6\,m/s$

$v_{fb} = 0\,m/s$

graph ⇒



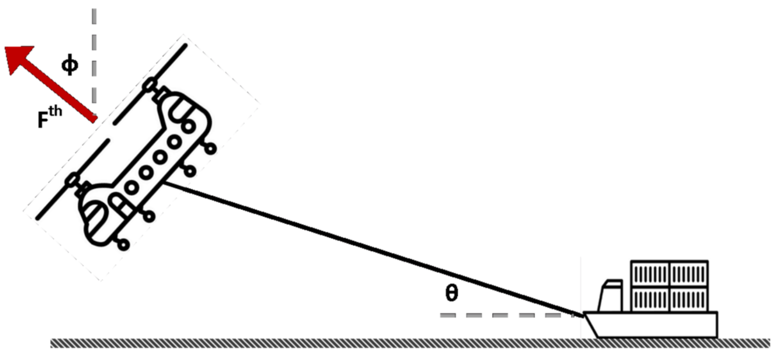
$\left(\frac{1}{2} F_{max} \Delta t\right) = \Delta p = m \Delta v = m(v_f - v_i)$

$\frac{1}{2} F_{max}(0.4\,s) = (100\,kg)(0\,m/s - 6\,m/s)$

$\boxed{F_{max} = 3000\,N}$

12. (12 points) In 1982 a Columbia 107 helicopter towed a hover barge over 50 miles across flat broken ice in Prudhoe Bay, Alaska. To achieve this feat, the helicopter had to tilt forward so that it's rotors provided thrust not straight upward, but rather at an angle of 55° with respect to the vertical. This resulted in the cable connecting the helicopter and the barge making an angle of 20° with respect to the horizontal. The helicopter had a mass of 10,000 kg and the barge was 70% the mass of the helicopter. Assume the helicopter maintained a constant speed and that the coefficient kinetic friction between the barge and the ice was 0.15.

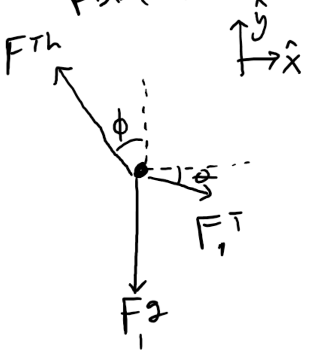
(a) Draw FBD of both the helicopter and the barge separately.
(b) Identify Newton's 3rd law forces pairs between the helicopter and the barge
(c) Find the tension in the cable.
(d) Find the thrust from the rotors acting on the helicopter.



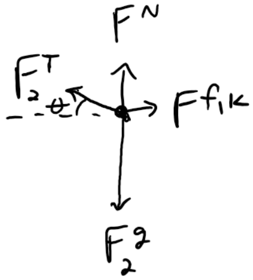
not F.P.'s but equal magnitudes

$$|\vec{F}^T_1| = |\vec{F}^T_2| \equiv F^T$$

FBD(1)



FBD(2)



$$M_2 = 0.7M_1 = 7{,}000\,kg$$

② $\sum F_x \Rightarrow F^{fik} - F^T\cos\theta = m_2 \cancel{a_x}^{0}$

$\sum F_y \Rightarrow F^N + F^T\sin\theta - m_2 g = m_2 \cancel{a_y}^{0} \Rightarrow F^N = m_2 g - F^T\sin\theta$

$$\mu_K(m_2 g - F^T\sin\theta) - F^T\cos\theta = 0$$

$$F^T = \frac{\mu_K m_2 g}{(\mu_K\sin\theta + \cos\theta)} =$$

$$\mu_K m_2 g - \mu_K F^T\sin\theta - F^T\cos\theta = 0$$

$$F^T(\mu_K\sin\theta + \cos\theta) = \mu_K m_2 g$$