PHYS 115 Midterm Exam #2 – Alternative Version – Solutions

Description

This set of 1 statement of commitment to academic integrity and 9 questions is the second midterm exam for PHYS 115 Fall 2021 at the University of Saskatchewan.

1/3 of the exam mark is based on the answers for the 6 multiple-choice questions submitted through WebAssign. All 6 multiple-choice questions are weighted equally.

2/3 of the exam mark is based on the answers (submitted through WebAssign) and solutions (submitted through Canvas) for the 3 word problems. All 3 word problems are weighted equally.

Instructions

Answers for **all** questions need to be submitted in WebAssign.

For each of questions 8, 9, and 10, in addition to submitting your answers in WebAssign, write the complete solution, **including a diagram**, using the problem-solving method discussed in class.

Your solutions must use the same symbols as are used on the formulae sheet.

Formulas not on the Formulae Sheet must be derived.

Keep extra decimal places throughout your calculations, and then round-off your final answer to three significant figures.

Submit your answer to each question in WebAssign.

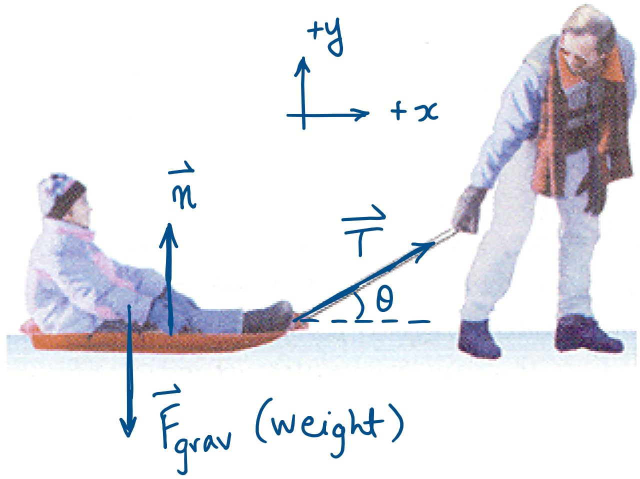
When you have finished the entire exam, scan your written work for questions 8 through 10 and submit a single multi-page PDF file using the link in the Canvas site for your section.

Your WebAssign submission is due no later than 90 minutes after the questions become available and your Canvas submission is due no later than 120 minutes after the questions become available.

1. UofS-P115-P117-Honour [4820285]
On my honour, I pledge that I will not give or receive aid during this assessment. I understand that I am expected to complete this assessment with no communication with other persons and no resource material other than the PHYS 115/117 Formulae sheet. I recognize that it is my responsibility to uphold academic integrity and I agree to follow the rules of this assessment and the guidelines laid forth in the policies of the University of Saskatchewan. Furthermore, I fully understand that disciplinary action may be taken against me if I am discovered to have communicated with another person or to have used an internet resource.
Yes, I understand and agree.

2. P115-2021-MT2-ALT-A1 [5126951]
A child on a toboggan is being pulled to the right along the horizontal ground as shown in the figure below. Which one of the following statements is true concerning the magnitude of the normal force exerted by the ground on the toboggan?

- greater than the total weight of the child and toboggan
- possibly greater or less than the total weight of the child and toboggan, depending on the coefficient of friction between the toboggan and the ground
- possibly greater or less than the total weight of the child and toboggan, depending on the magnitude of the weight compared to the tension in the rope
- equal to the total weight of the child and toboggan



Note that the net force in the vertical direction is zero.

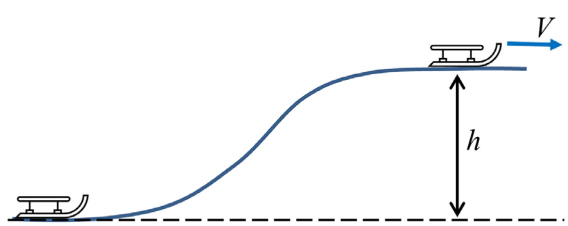
$\therefore \sum F_y = 0$

$\therefore +n + T\sin\theta - F_{grav} = 0$

$\therefore n = F_{grav} - T\sin\theta$

$\therefore n < F_{grav}$

3. P115-2021-MT2-ALT-A2 [5128447]
A parent pulls a child's sled, which has mass *m*, up a snowy hill. We can ignore friction between the sled and the snow. When the sled is at the bottom it is stationary. When it reaches the top, at a height *h* above the bottom, the sled is moving with speed *V*. Which one of the following statements is correct for the work done on the sled by the parent?



The only non-conservative forces acting on the sled are the force due to the parent and the normal force, n.

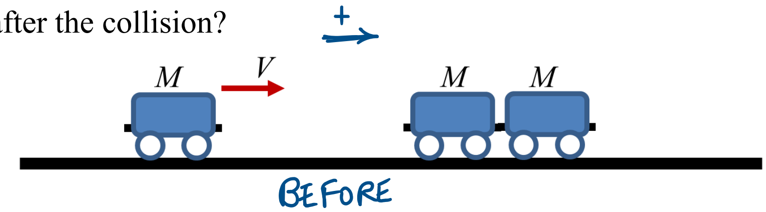
$W_n = 0$ ($\vec{n} \perp$ to displacement)

$\frac{1}{2}mV^2 - mgh$ $\quad$ $\frac{1}{2}mV^2 + mgh$ $\quad$ $\frac{1}{2}mV^2$ $\quad$ mgh $\quad$ $mgh - \frac{1}{2}mV^2$

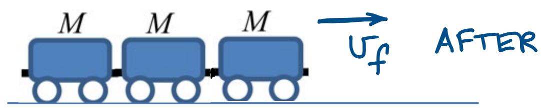
$$W_{nc} = (KE_f + PE_f) - (KE_i + PE_i) \Rightarrow W_{parent} = \left(\tfrac{1}{2}mV^2 + mgh\right) - (0+0)$$

$$W_{parent} = \tfrac{1}{2}mV^2 + mgh$$

4. P115-2021-MT2-ALT-A3 [5128448]
A train car is moving with speed V toward a pair of train cars that are stationary and coupled together as shown. All three train cars have the same mass M. After the collision all three cars are coupled together and move as one. Ignore friction in the motion of the cars along the track. The initial kinetic energy of the moving train car is $KE_i = \frac{1}{2}MV^2$. What is the sum of the kinetic energies of the three train cars, KE_f, after the collision?



Ignoring friction, $\Sigma \vec{F}_{ext} = 0$
∴ momentum is conserved.



$KE_f = \frac{1}{6}KE_i$ $KE_f = KE_i$ $KE_f = \frac{1}{3}KE_i$ $KE_f = \frac{1}{9}KE_i$ $KE_f = \frac{1}{2}KE_i$

$$\vec{P}_{tot_f} = \vec{P}_{tot_i} \Rightarrow (3M)v_f = MV \Rightarrow v_f = \frac{1}{3}V$$

$$KE_f = \frac{1}{2}(3M)\left(\frac{1}{3}V\right)^2 = \frac{1}{2}(3M)\left(\frac{1}{9}V^2\right) = \frac{1}{3}\left(\frac{1}{2}MV^2\right) = \boxed{\frac{1}{3}KE_i}$$

5. P115-2021-MT2-ALT-A4 [5128452]
A bullet with a mass of 2.04 g moves at a speed of 1.50×10^3 m/s. A racquetball of mass 85.9 g has the same momentum as the bullet. Which one of the following statements is true?

- The ball has the greater speed and the smaller kinetic energy, compared to the bullet.
- The bullet has the greater speed and the smaller kinetic energy, compared to the ball.
- The ball and the bullet have the same speed and they have the same kinetic energy.
- The ball has the greater speed and the greater kinetic energy, compared to the bullet.

Note that $KE = \frac{1}{2}mv^2 = \frac{1}{2}\frac{m^2v^2}{m} = \frac{1}{2}\frac{p^2}{m} = \frac{p^2}{2m}$

$m_{bullet} = 2.04\,g$ $m_{ball} = 85.9\,g$
$v_{bullet} = 1.50 \times 10^3\,m/s$ $v_{ball} = ?$

Given $p_{bullet} = p_{ball}$
$m_{bullet}v_{bullet} = m_{ball}v_{ball}$
Since $m_{bullet} < m_{ball}$, $\boxed{v_{bullet} > v_{ball}}$

Since $KE = \frac{p^2}{2m}$ and $p_{bullet} = p_{ball} = p$, $KE_{bullet} = \frac{p^2}{2m_{bullet}}$ and $KE_{ball} = \frac{p^2}{2m_{ball}}$

Since $m_{bullet} < m_{ball}$, $\boxed{KE_{bullet} > KE_{ball}}$

6. P115-2021-MT2-ALT-A5 [5128459]

A large rotating flywheel uniformly increases in angular speed from rest with angular acceleration α_1 over a given time interval, achieving an angular speed ω_1. The same flywheel again starts from rest and accelerates uniformly in the same time interval, but now the angular acceleration is $\alpha_2 = 2\alpha_1$. Which one of the following statements is true regarding the new final angular speed ω_2?

It is quadruple the value of ω_1.

It is 1.44 times the value of ω_1.

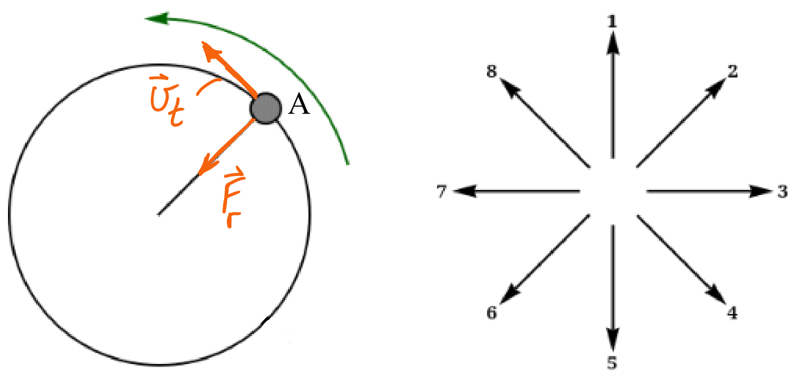
It is the same as ω_1.

Same time interval. $\omega = \omega_0 + \alpha t$ $\omega_1 = 0 + \alpha_1 t = \alpha_1 t$

$\omega_2 = 0 + \alpha_2 t = \alpha_2 t = (2\alpha_1)t = 2(\alpha_1 t) = 2\omega_1$

7. P115-2021-MT2-ALT-A6 [5128439]

An object tied to the end of a string is moving in a circle at constant speed on a horizontal frictionless surface, as shown in the diagram.



(a) Which one of the arrows shows the direction of the centripetal force acting on the object when it is at location A? 6

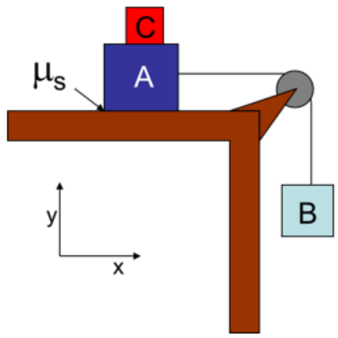
(b) If the string breaks when the object is at location A, which one of the arrows shows the direction in which the object will move? 8

(a) The centripetal force is directed radially inward. ∴ In the direction of arrow 6 when the object is at A.

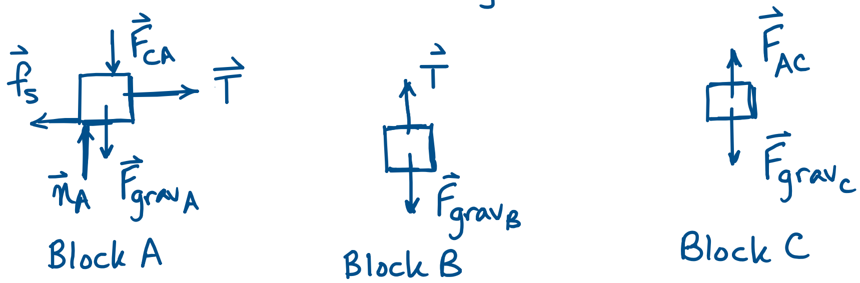
(b) It will move in the direction of the tangential velocity at A, the direction of arrow 8.

8. P115-2021-MT2-ALT-B1 [5128440]

A set of blocks is connected to a pulley as shown in the diagram below. The pulley is ideal (massless and frictionless) and the rope is massless.



Consider the forces acting on each of the blocks:



Given the following values, calculate the minimum required mass of block C such that block A does not slide on the table top. To receive full marks, you must include a diagram showing the physical situation and your choice of coordinate system. $m_A = 5.81$ kg; $m_B = 3.04$ kg; $\mu_s = 0.211$ ANS: $m_C = 8.6\ kg$

Note that the minimum required mass of block C will correspond to the static frictional force on block A being $f_{s,max}$. Recall $f_{s,max} = \mu_s n$

Also, if block A does not slide, then none of the blocks will move.

$\therefore \sum \vec{F} = 0$ for each block.

Block B: $\sum \vec{F} = 0 \Rightarrow T - F_{grav_B} = 0 \Rightarrow T = m_B g$ ①

Block C: $\sum \vec{F} = 0 \Rightarrow F_{AC} - F_{grav_C} = 0 \Rightarrow F_{AC} = m_C g$

$\vec{F}_{AC}$ is the contact force of block A on block C.

Block A: $\sum F_x = 0 \Rightarrow T - f_{s,max} = 0 \Rightarrow T = f_{s,max}$ ②

$\sum F_y = 0 \Rightarrow n_A - F_{CA} - F_{grav_A} = 0$

$n_A = m_A g + m_C g$ ③

$\vec{F}_{CA}$ is the contact force of block C on block A.

Note that $|\vec{F}_{AC}| = |\vec{F}_{CA}| = m_C g$

Substituting ① into ②: $m_B g = f_{s,max} \Rightarrow m_B g = \mu_s n_A$

Substituting from ③: $m_B g = \mu_s (m_A g + m_C g) \Rightarrow m_B = \mu_s m_A + \mu_s m_C$

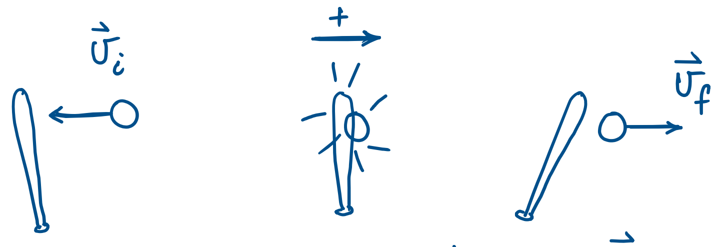
$$\therefore m_C = \frac{m_B}{\mu_s} - m_A = \frac{3.04\ kg}{0.211} - 5.81\ kg = \boxed{8.60\ kg}$$

9. P115-2021-MT2-ALT-B2 [5128441]

Just before being struck by a bat, a ball is moving with a speed of 32.8 m/s. The mass of the ball is 0.107 kg. After being struck by the bat, the ball is moving with a speed of 46.4 m/s in the exact opposite direction to its original velocity. To receive full marks, you must include a diagram showing the physical situation and your choice of coordinate system.

(a) What magnitude of impulse did the bat impart on the ball? *8.47 kg.m/s*

(b) If the time that the ball was in contact with the bat was 0.231 s, what was the magnitude of the average acceleration of the ball during that time period? *343 m/s²*



(a) From the Impulse-Momentum Theorem, $\vec{I} = \Delta\vec{p} = m\vec{v}_f - m\vec{v}_i$

$\therefore |\vec{I}| = m|\vec{v}_f - \vec{v}_i| = (0.107\text{ kg})|(+46.4\text{ m/s}) - (-32.8\text{ m/s})| = \boxed{8.47\text{ kg}\cdot\text{m/s}}$

$(8.474\text{ kg}\cdot\text{m/s})$

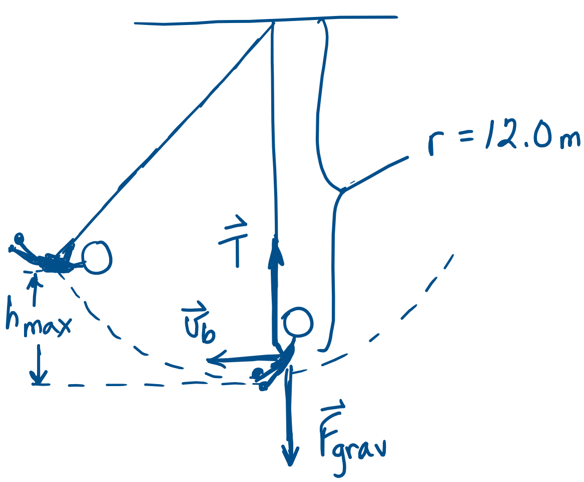
(b) $|\vec{I}| = |\vec{F}_{av}|\Delta t = |m\vec{a}_{av}|\Delta t \Rightarrow |\vec{a}_{av}| = \dfrac{|\vec{I}|}{m\Delta t} = \dfrac{8.474\text{ kg}\cdot\text{m/s}}{(0.107\text{ kg})(0.231\text{ s})} = \boxed{343\text{ m/s}^2}$

10. P115-2021-MT2-ALT-B3 [5128443]

An actor playing Tarzan is filming a scene where he swings across a river on a vine. The crew must use a vine with enough strength so that it doesn't break while he is swinging. The actor's mass is 84.0 kg, the vine is 12.0 m long, and the speed of the actor at the bottom of the swing has been determined to be 7.20 m/s. To receive full marks, you must include a diagram showing the physical situation.

(a) Calculate the minimum tension force (in N) the vine must be able to support without breaking. *1190 N*

(b) If the actor continues to swing on the vine until reaching the highest point of the trajectory, calculate the value of this maximum height above the bottom of the swing. *2.64 m/s*



(a) Note that the actor is in circular motion as he swings on the vine. Applying Newton for Circular Motion at the bottom of the swing:

$$\Sigma F_r = ma_c$$

$$T - F_{grav} = \frac{mv_b^2}{r}$$

$$T = \frac{mv_b^2}{r} + mg = m\left(\frac{v_b^2}{r} + g\right)$$

$$T = 84.0\,\text{kg}\left(\frac{(7.20\,\text{m/s})^2}{12.0\,\text{m}} + 9.80\,\text{m/s}^2\right) = \boxed{1.19 \times 10^3\,\text{N}}$$

(b) At max. height, $v = 0$. Applying Cons. of Mechanical Energy:

$$W_{nc} = (KE_f + PE_f) - (KE_i + PE_i) \Rightarrow 0 = (0 + PE_f) - (KE_i + 0)$$

$$\therefore PE_f = KE_i \Rightarrow mgh_{max} = \frac{1}{2}mv_b^2 \Rightarrow h_{max} = \frac{v_b^2}{2g} = \frac{(7.20\,\text{m/s})^2}{2(9.80\,\text{m/s}^2)} = \boxed{2.64\text{ m}}$$