PHYS 1420 (Fall 2019) - Midterm Exam (A)

Name: Sols

Student Number:

Instructions:

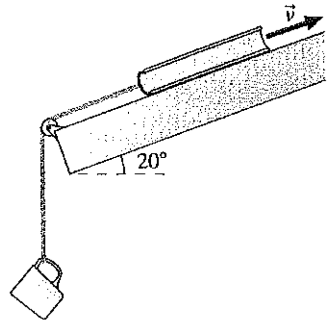
- **Read all instructions carefully.**
- Clearly write your name and student number above **BEFORE** you start the exam. Also, have your student ID out and on your desk (you may be asked for an invigilator to see it before/during/after the exam).
- Once the test begins, the instructor and invigilators will not be able to answer questions. You will need to interpret things as best you can and answer accordingly.
- Show all work clearly in order to get full credit. Points can be taken off if it is not clear to see how you arrived at your answer (even if the final answer is correct).
- Calculators can be used for this exam. Use of phones/tablets/computers/smart watches/etc... is not permitted.
- Sketch all relevant graphs and explain all relevant mathematics. Circle/box your final answers.
- Please keep your written answers brief; be clear and to the point.
- Feel free to use scratch paper (some is included at the back, feel free to detach it). You will not be graded upon what is on the scratch paper, though you must turn it in with your exam.
- You are allowed a formula sheet (8.5x11 in) to bring with you. It must be a single hard copy sheet of paper (though you can write on front and back). **You must turn such in with your exam.**
- This test has 3 problems (plus an extra credit problem) and is worth 100 points. It is your responsibility to make sure that you have done all the problems!
- Make sure to turn your test in as requested at the end of the exam period. Failure to do such can lead to a failing grade.

1. *(30 points)*
For the following questions, circle the appropriate choice for True or False. **No explanation in necessary.**

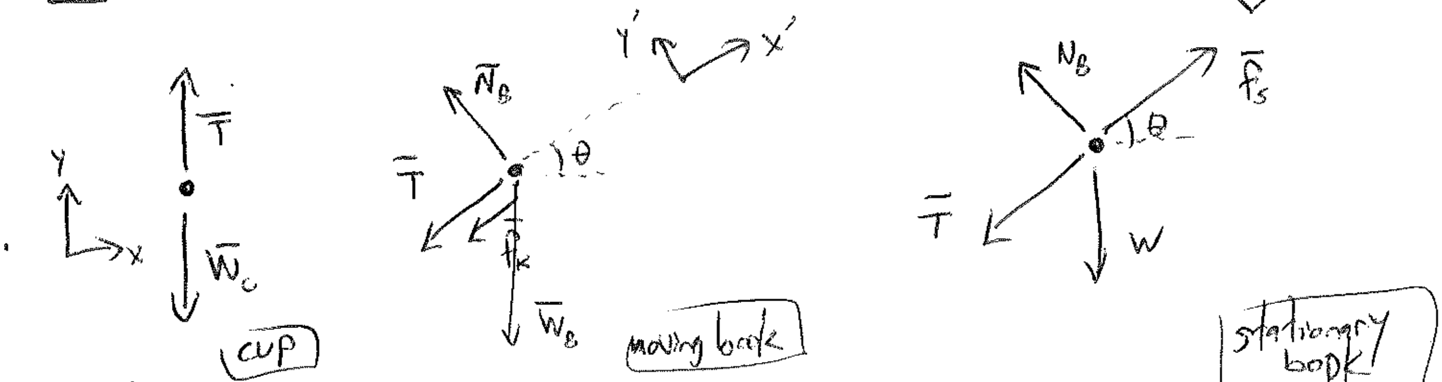
- *True* or *False* – Speed and velocity are the same thing.
- *True* or *False* – Centripetal acceleration (a) is related to the square of the angular velocity.
- *True* or *False* – Parabolas are related to cubic functions.
- *True* or *False* – Einstein's theory of general relativity is an approximation of Newton's law of gravity.
- *True* or *False* – If a plane flying at constant velocity drops a package, it will be directly over the package when it hits the ground.
- *True* or *False* – Velocity is the integral of displacement with respect to time.
- *True* or *False* – Newton's 2nd law is $\mathbf{F} = \frac{d\mathbf{p}}{dt}$ where p is momentum.
- *True* or *False* – If the rate of change of a function is proportional to itself, then the function is exponential.
- *True* or *False* – For uniform circular motion, the acceleration vectors all point in the same direction.
- *True* or *False* – A feather and a rock both move towards Earth with the same acceleration.
- *True* or *False* – A ball dropped versus throw up both move towards Earth with the same acceleration.
- *True* or *False* – Arc length is $r\theta^2$, where r is the radius and θ is the angle extended.
- *True* or *False* – The basic idea underlying rocket thrust is a. reduction of mass and b. conservation of momentum.
- *True* or *False* – *Stiction* refers to the friction of sliding bodies.
- *True* or *False* – Kinetic friction tends to be greater than static friction.
- *True* or *False* – A falling cylinder would always feel a smaller drag force than a sphere.
- *True* or *False* – A cylinder falling "end down" and another falling "side down" will have the same drag coefficients.
- *True* or *False* – Work is the energy transferred between systems via a continuous force.
- *True* or *False* – Conservation on energy indicates that energy does not change.
- *True* or *False* – A change in energy is always negative.
- *True* or *False* – For a thrown ball, it is possible to have the velocity and acceleration vectors to point in the same direction at the instant the ball is thrown.

- *True* or *False* – Uniform motion can effectively be described as "unchanging change".
- *True* or *False* – The product of two vectors is always a scalar.
- *True* or *False* – Work has the same units as energy.
- *True* or *False* – When compressing a spring, the work done on the spring is positive.
- *True* or *False* – Integrals can arise from Riemann sums when the rectangles get infinitesimally large.
- *True* or *False* – A falling object experiencing drag will asymptotically approach terminal velocity.
- *True* or *False* – The First Law of Thermodynamics embodies the distinction between "good" versus "bad" energy.
- *True* or *False* – Rolling friction tends to be larger than kinetic or static friction, thus giving tires their "grip".
- *True* or *False* – Drag forces can only be proportional to velocity or its square.

2. (*35 points*)
A 1.0 kg physics book in is connected by a string to a 500 g coffee cup (see figure below). The book is given a push up the slope and released with a speed $v = 3.0$ m/s. The coefficients of friction are $\mu_S = 0.50$ and $\mu_K = 0.20$.



[10] a. Draw the appropriate free-body diagram.



[15] b. Determine how far does the book slides.

Known: $m_c = 0.5$ kg $\quad m_B = 1.0$ kg $\quad V_0 = 3.0$ m/s $\quad \mu_s = 0.50,\ \mu_k = 0.20$

☐ Book will slide upwards w/ some const. acceleration (call it a_1). Assume book is initially at x_0' $(=0)$ and comes to rest at x_1'. Then

$$V_{fx'}^2 = V_{0x'}^2 + 2a_1(x_1' - x_0') = 0 = 3.0^2 + 2a_1(x_1')$$

$$\rightarrow \boxed{a_1 x_1' = -4.5\ m^2/s^2} \quad (\text{Note: We are trying to determine } x_1')$$

☐ We can determine a_1 by considering all forces acting on the book:

$$(\Sigma F_B)_{y'} = N_B - W_B\cos(20) = 0 \rightarrow N_B = (1.0)(9.8)\cos(20) = 9.2\,N$$

(cont)

$(\Sigma F_B)_{x'} = \boxed{T + f_k + W_B \sin(20) = -m_B a_1}$ (Note: $f_k = \mu_k N_B$)

negative since book slows along y'

☐ Also consider the forces acting on the cup:

$(\Sigma F_c)_y = \boxed{T - W_c = m_c a_1}$ (since cup and book must have same acceleration!)

☐ We can add the two eqns. together to yield: $a_1(m_c + m_B) = -g[m_c + m_B \sin(20)] - \mu_k N_B$

$\rightsquigarrow a_1(1.0 + 0.5) = -(9.8)[0.5 + 1.0 \cdot \sin(20)] - (0.20)(9.21) \rightarrow a_1 = -6.7\ m/s^2$

☐ Back to earlier: $x_1' = \frac{-4.5}{a_1} = \frac{-4.5}{-6.7} \simeq 0.7\ m \implies \boxed{x_1' \simeq 0.7\ m}$

10 c. At the highest point, does the book stick to the slope, or does it slide back down?

☐ Max value of static friction is

$(f_s)_{max} = \mu_s N_B = (0.50)(9.21) = 4.6\ N$

☐ Now we consider whether the force (f_s) needed to keep the book in place is larger or smaller than $(f_s)_{max}$:

- When cup is at rest, $T = W_c = m_c g$
- Then the total forces acting along x' for the book are:

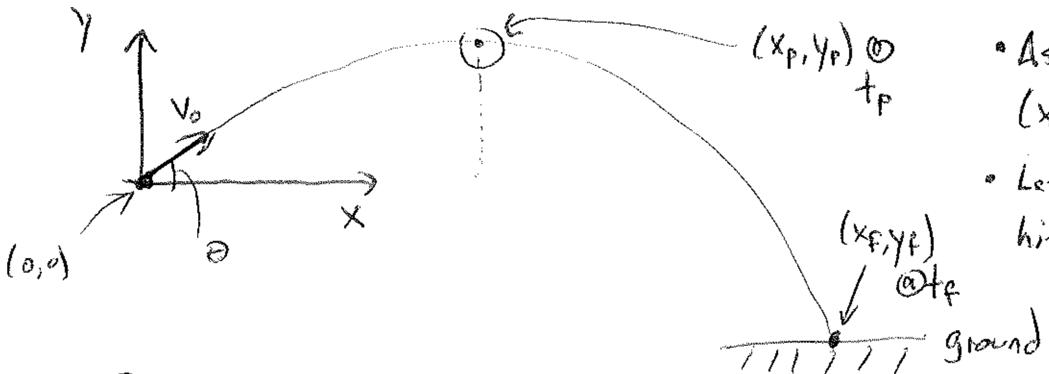
$(\Sigma F_B)_{x'} = f_s - T - W_B \sin(20) = f_s - m_c g - m_B \sin(20) = 0$

$\rightsquigarrow f_s = (m_c + m_B \sin 20) g \simeq 8.3\ N$

$\implies$ Since $f_s > (f_s)_{max}$, the book will **slide down**

3. (*35 points*)
A projectile is fired with an initial speed of 30 m/s at an angle of 60° above the horizontal. The object hits the ground 7.5 s later.

[10] a. Sketch the relevant diagram, indicating the main quantities of interest.



- Assume projectile fired at $(x_0, y_0) = (0,0)$
- Let t_f (= 7.5 s) be the time it hits ground at y_f
  - Let (x_p, y_p) be the "peak" values

[15] b. How much higher or lower is the launch point relative to the point where the projectile hits the ground?

[1] Note: y_f could be positive or negative (that is what we need to find out!)

[1] Known: $V_0 = 30\ m/s$, $a_x = 0$, $a_y = -9.8\ m/s^2$, $t_0 = 0$, $x_0 = 0$, $y_0 = 0$, $t_f = 7.5\ s$

[1] Then $y_f = y_0 + V_{0y}(t_f - t_0) + \frac{1}{2}a_y(t_f - t_0)^2$

$= 0 + 30 \cdot \sin(60)(7.5 - 0) + \frac{1}{2}(-9.8)(7.5-0)^2 \simeq -80.8\ m$

$\Rightarrow$ Thus launch point is $\simeq 81\ m$ above landing site

[10] c. To what maximum height above the launch point does the projectile rise?

[4] Similar to before, except that at peak [i.e. @ (x_p, y_p)], $V_{py} = 0$

$V_{py}^2 = V_{0y}^2 + 2a_y(y_p - y_0) = 0 = [30\sin(60°)]^2 + 2(-9.8)(y_p - 0)$

$\Rightarrow y_p \simeq 34\ m$

Extra Credit (10 Points):

You are a member of the CSI-T (Crime Scene Investigation – Toronto) team. You get a call that a body has been found in an apartment. You head immediately over to the crime scene and arrive at 3:02 AM. As per your training, one of the first things you do is measure the body temperature and find it to be 69.4° F. You notice the apartment has had its air conditioner (AC) blasting, and that it appears it has been on for a long time (presumably since before the murder). You measure the ambient temperature and find it to be 65.0°. You then proceed to look for other clues. Fifty nine minutes after you arrived (and measured the body temperature), you measure the body temperature again and find it to be 67.68° F (ambient is still at 65.0°). You announce to your partner that you have deduced the approximate time of death.

[*Hint: Normal (healthy) body temperature is* 98.6° *F*]

a. Briefly explain how you could estimate the time of death from the information provided above.

☐ Newton's Law of cooling: $\frac{dT}{dt} = \alpha (T_0 - T) \rightarrow T(t) = T_0 + Ce^{-\alpha t}$

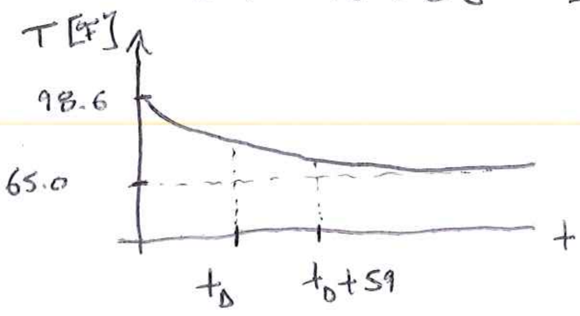
☐ We should have enough pieces to deduce how much time has passed since death (Note: $\alpha > 0$)

b. What was the approximate time of death?

☐ Let $t=0$ be the time of death and measures were made at t_D and $t_D + 59$ min. ($[t] = \text{min}$)

☐ $T(0) = 98.6 = T_0 + Ce^{-\alpha \cdot 0} = T_0 + C = 65.0 + C \rightarrow C = 33.6\,°F$

$T(\infty) = T_0 + Ce^{-\infty} = T_0 \rightarrow T_0 = 65.0\,°C$ (ambient temp)



$T(t_D) = 69.4 = 65 + 33.6 \cdot e^{-\alpha t_D}$

$\rightarrow \alpha t_D = -\ln\left(\frac{4.4}{33.6}\right) = 2.03$

$T(t_D + 59) = 67.68 = 65 + 33.6 \cdot e^{-\alpha(t_D + 59)}$

$\rightsquigarrow \alpha(t_D + 59) = -\ln\left(\frac{2.68}{33.6}\right) = 2.53$

☐ Two equations, two unknowns: $\rightsquigarrow \alpha = \frac{2.03}{t_D}$

$\alpha(t_D + 59) = \frac{2.03}{t_D}(t_D + 59) = 2.53 \rightarrow t_D = 239$ min $= 3$ hrs. 59 min

$\Rightarrow$ Body found @ 3:02 AM means death occurred @ **11:03 PM**