Last Name: ________________ First Name: ______________________ NetID: __________________

Discussion Section: ______ Discussion TA: ____

Instructions – ***Turn off your cell phone and put it away. Please keep your calculator on your own desk. Calculators may not be shared.***

This is a closed book exam. You have (1.5) hours to complete it.

I. *Fill in ALL the information requested on the lines above and sign the Formula Sheet.*

II. At the end of this exam, you must return this Exam Booklet complete with all pages, including the formula sheet, along with your answer sheet.

III. If you do not turn in a complete Exam Booklet, your Answer Sheet will not be graded, and you will receive the grade AB (Absent) for this exam.

1. Fill in completely (until there is no white space visible) the circle for each intended input – both on the identification side of your answer sheet and on the side on which you mark your answers. If you decide to change an answer, erase vigorously; the scanner sometimes registers incompletely erased marks as intended answers; this can adversely affect your grade. Light marks or marks extending outside the circle may be read improperly by the scanner.
2. Print your last name in the **YOUR LAST NAME** boxes on your answer sheet and print the first letter of your first name in the **FIRST NAME INI** box. Mark (as described above) the corresponding circle below each of these letters.
3. Print your NetID in the **NETWORK ID** boxes, and then mark the corresponding circle below each of the letters or numerals. Note that there are different circles for the letter "I" and the numeral "1" and for the letter "O" and the numeral "0". **Do not** mark the hyphen circle at the bottom of any of these columns.
4. You may find the version of **this Exam Booklet at the top of the page** Mark the **version** circle in the **TEST FORM** box near the middle of your answer sheet. **DO THIS NOW!**
5. Stop **now** and double-check that you have bubbled in all the information requested in 2 through 4 above and that your marks meet the criteria in 1 above. Check that you do not have more than one circle marked in any of the columns.
6. Print your UIN# in the **STUDENT NUMBER** designated spaces and mark the corresponding circles. You need not write in or mark the circles in the SECTION box.
7. On the **SECTION** line, print your **DISCUSSION SECTION**. (You need not fill in the COURSE or INSTRUCTOR lines.)
8. Sign **(DO NOT PRINT)** your name on the **STUDENT SIGNATURE** line.

CHECK NOW THAT YOU HAVE COMPLETED ALL OF THE ABOVE STEPS

Before starting work, check to make sure that your test booklet is complete. Grading policy is explained on page 2.

Academic Integrity—Giving assistance to or receiving assistance from another student or using unauthorized materials during a University Examination can be grounds for disciplinary action, up to and including dismissal from the university.

This Exam Booklet is Version A. Mark the **A** circle in the **TEST FORM** box near the middle of your answer sheet. **DO THIS NOW!**

Exam Grading Policy—

The exam is composed of three types of questions.

MC5: *multiple-choice-five-answer questions, each worth 6 points.* **Partial credit will be granted as follows.**

(a) If you mark only one answer and it is the correct answer, you earn **6** points.
(b) If you mark two answers, one of which is the correct answer, you earn **3** points.
(c) If you mark three answers, one of which is the correct answer, you earn **2** points.
(d) If you mark four answers, one of which is the correct answer, you earn **1.5** points.
(d) If you mark five answers, one of which is the correct answer, you earn **1.2** points

MC3: *multiple-choice-three-answer questions, each worth 3 points.* **Partial credit will be granted as follows.**

(a) If you mark only one answer and it is the correct answer, you earn **3** points.
(b) If you mark two answers, one of which is the correct answer, you earn **1.5** points.
(c) If you mark three answers, one of which is the correct answer, you earn **1** point.

MC2: *multiple-choice-three-answer questions, each worth 2 points.* **Partial credit will be granted as follows.**

(a) If you mark only one answer and it is the correct answer, you earn **2** points.
(b) If you mark two answers, one of which is the correct answer, you earn **1** point.

The next two questions pertain to the situation described below.

A ball thrown into the air lands 40 m away 2.4 s later. Assume the ball lands at the same height from which it was thrown.

1) Find the y component of the initial velocity v_{0y}

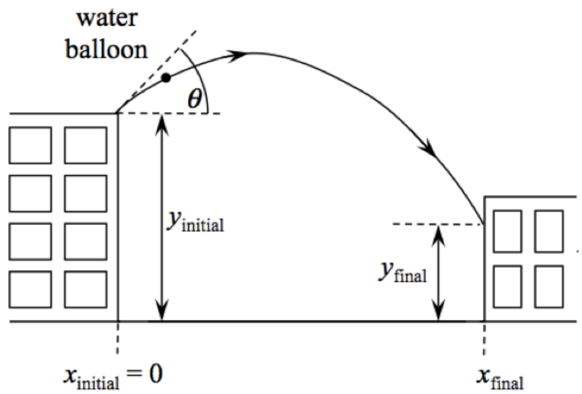
a. $v_{0y} = 41.7$ m/s
b. $v_{0y} = 11.8$ m/s
c. $v_{0y} = 23.5$ m/s
d. $v_{0y} = 16.7$ m/s
e. $v_{0y} = 47.1$ m/s

2) Find the x component of the initial velocity v_{0x}

a. $v_{0x} = 16.7$ m/s
b. $v_{0x} = 28$ m/s
c. $v_{0x} = 6.67$ m/s
d. $v_{0x} = 4.89$ m/s
e. $v_{0x} = 31.7$ m/s

The next three questions pertain to the situation described below.

Physics students construct a cannon from rubber tubing and a funnel which will launch water-filled balloons. They assemble their device on the roof of Loomis and fire a test shot, which strikes the closest wall of the Astronomy Building, as shown in the figure.



The shot is launched from initial position $(x_{initial}, y_{initial})$ = (0 m, 16 m) and strikes the Astronomy Building at time t_{final} = 2.4 s and at the final position (x_{final}, y_{final}) = (180 m, 8 m).

3) The water balloon's speed is greatest

a. When it reaches its maximum altitude.
b. When it is launched.
c. When it strikes the Astronomy Building.

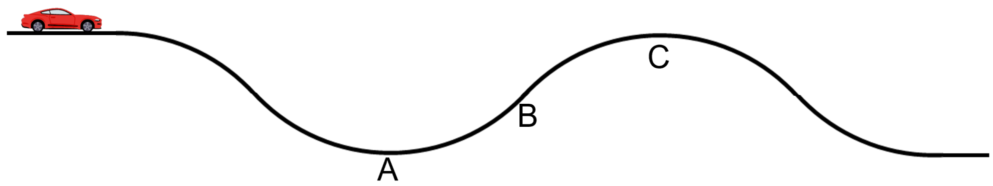
4) Which of the following best describes the magnitude of the vertical component of the water balloon's velocity during its flight towards the Astronomy Building?

a. It decreases then it increases.
b. It is constant.
c. It increases then it decreases.

5) What is the initial vertical component of the balloon's velocity, v_{0y}?

a. v_{0y} = 75 m/s
b. v_{0y} = 3.33 m/s
c. v_{0y} = 0 m/s
d. v_{0y} = 8.44 m/s
e. v_{0y} = 23.54 m/s

The next two questions pertain to the situation described below.



Your are driving along a road when you arrive at the top of an interesting hill. The bottom of the hill appears to form a semicircle with radius $R = 50$ m, and it leads up another hill whose top is also semicircular with the same radius. Your car is set to maintain a constand speed of 20 m/s. The total mass of the car including occupants is 1100 kg.

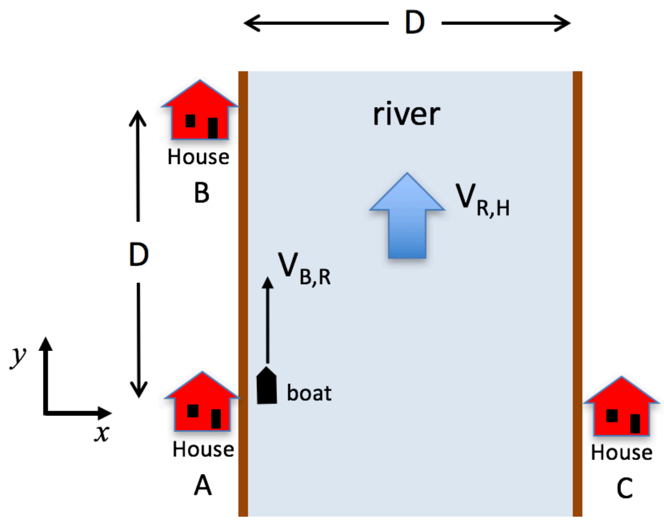
6) What is the magnitude of the acceleration of the car when it is at the bottom of the hill (point **A**)

a. $a_A = 8$ m/s^2
b. $a_A = 0$ m/s^2
c. $a_A = 18$ m/s^2

7) What is the force of the road on the car when it is at the top of the hill (point **C**) ?

a. F = 8800 N
b. F = 1.1×10^4 N
c. F = 2×10^3 N

The next three questions pertain to the situation described below.



The houses, A, B , and C, are located on a river as shown. House B is on the same side of the river as House A, and is a distance $D = 400$ m away. House C is directly across the river from House A, and is also a distance $D = 400$ m away. The river flows in the +y direction with speed $V_{R,H} = 2.6$ m/s relative to the houses. Your boat can move with maximum velocity of $V_{B,R} = 4.3$ m/s relative to the water of the river.

8) What is Δt_{AB}, the shortest time in which you can drive your boat from House A to House B ?

a. $\Delta t_{AB} = 93$ s
b. $\Delta t_{AB} = 58$ s
c. $\Delta t_{AB} = 153.8$ s
d. $\Delta t_{AB} = 235.3$ s
e. $\Delta t_{AB} = 116.8$ s

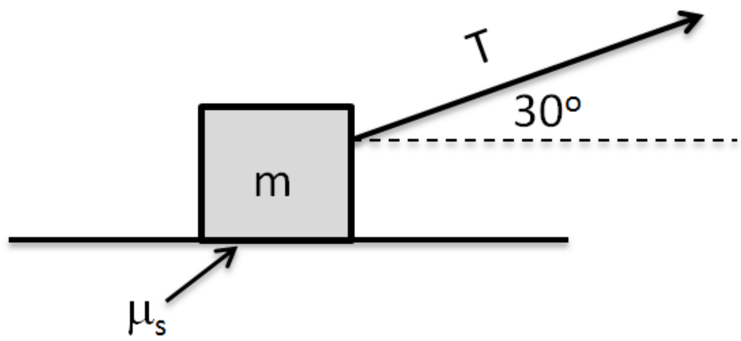
9) If you start at House A and direct your boat directly across the river, how far will you be from House C when you get to the other side of the river?

a. $y_c = 242$ m
b. $y_c = 304$ m
c. $y_c = 151$ m

10) What is Δt_{AC}, the shortest time in which you can drive your boat from House A to House C ?

a. $\Delta t_{AC} = 116.8$ s
b. $\Delta t_{AC} = 235.3$ s
c. $\Delta t_{AC} = 58$ s

The next three questions pertain to the situation described below.



A block of mass m = 1.2 kg, at rest on a level surface, is being pulled by a string having tension T = 3 N at an angle of 30^o above the horizontal, as shown in the diagram. Static friction keeps the block from moving. The coefficient of static friction between the block and the surface is $\mu_S = 0.45$.

11) The normal force acting on the block is

a. Less than the weight of the block.
b. Greater than the weight of the block.
c. Equal to the weight of the block.

12) What is the magnitude of the static frictional force on the block?

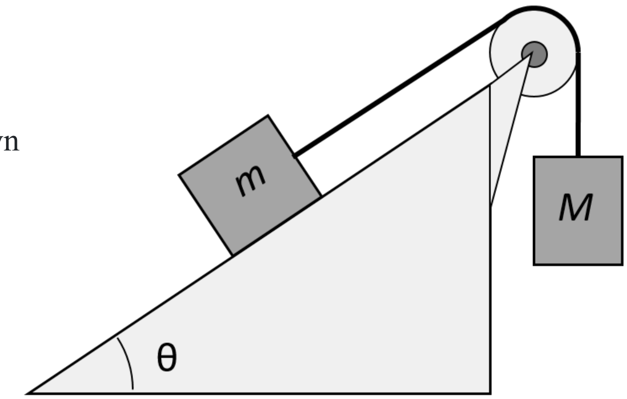
a. 5.3 N
b. 1.5 N
c. 3 N
d. 4.6 N
e. 2.6 N

13) Now assume that there is no friction, with everything else in the problem remaining the same. What is the acceleration of the block?

a. 2.5 m/s^2
b. 2.2 m/s^2
c. 1.3 m/s^2
d. 0 m/s^2
e. 7.3 m/s^2

The next three questions pertain to the situation described below.

A block of mass *m* is at rest on a frictionless inclined plane at an angle $\theta = 30°$ from the horizontal, as shown in the figure. The block *m* is connected to a second block of mass *M* by a massless string around an ideal, frictionless pulley.



14) What must the mass *M* be for the blocks to remain at rest?

a. $M = m$
b. $M = 2m$
c. $M = m/2$

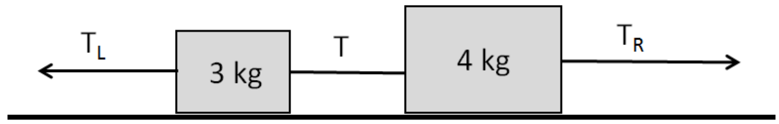
15) Now suppose that we add friction to the surface of the inclined plane, using material with coefficient of static friction $\mu_s = 0.4$ and kinetic friction $\mu_k = 0.3$. What is the maximum the mass *M* can be for the blocks to remain at rest?

a. $M_{max} = 0.15m$
b. $M_{max} = 0.5m$
c. $M_{max} = 0.65m$
d. $M_{max} = 0.85m$
e. $M_{max} = 1.65m$

16) If the block on the inclined plane had not been at rest but moving at a speed *v* initially, and we want it to maintain a constant speed, the mass *M* should be ________ compared to the previous problem.

a. the same
b. increased
c. decreased

The next three questions pertain to the situation described below.



Two blocks on a level frictionless surface have mass 3 kg and 4 kg. A string pulls the 3 kg block to the left with tension $T_L = 4.3$ N, a second string pulls the 4 kg block to the right with tension $T_R = 14.3$ N. The two blocks are connected together by a third string in the middle as shown.

17) What is the tension in the middle string, labeled T in the diagram?

a. T = 4.3 N
b. T = 8.6 N
c. T = 14.3 N
d. T = 18.6 N
e. T = 10 N

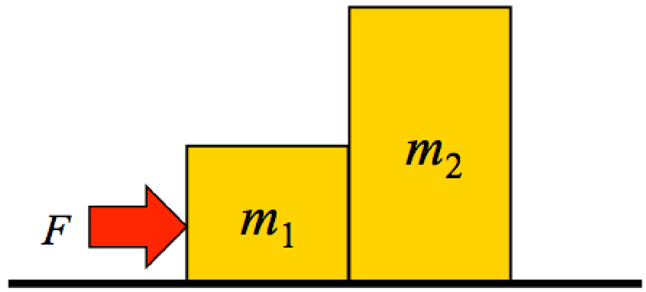
18) Suppose the mass of both blocks was doubled but T_L and T_R were kept the same. How would the tension in the middle string change?

a. T would increase.
b. T would decrease.
c. T would stay the same.

19) Suppose T_L and T_R were both set to 14.3 N. The tension in the middle string would be

a. T = 0 N
b. T = 14.3 N
c. T = 28.6 N

The next three questions pertain to the situation described below.



A box of mass m_1 = 2 kg is in contact with a heavier box of mass m_2 = 4 kg. The boxes are initially at rest on a horizontal surface, and the coefficients of kinetic and static friction between the boxes and the surface are μ_K = 0.15 and μ_S= 0.25, respectively. A horizontal force F is applied to the left of m_1 as shown in the figure.

20) How large must F be to set the boxes in motion?

a. 5.89 N
b. 8.83 N
c. 0 N
d. 2.94 N
e. 14.72 N

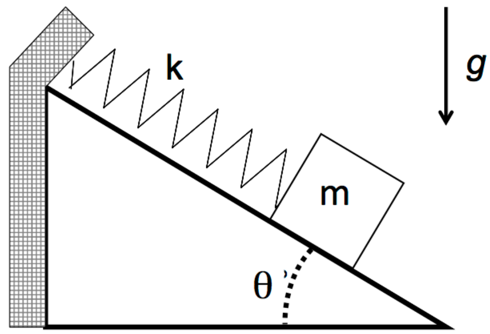
21) When F = 22.07 N, what is the acceleration of the boxes?

a. 11.04 m/s^2
b. 2.21 m/s^2
c. 3.68 m/s^2
d. 1.23 m/s^2
e. 5.52 m/s^2

22) When F = 22.07 N, what is F_{net2}/F_{net1}, the ratio of the net forces acting on m_2 and m_1?

a. $F_{net2}/F_{net1} = m_1/m_2$
b. $F_{net2}/F_{net1} = m_2/(m_1 + m_2)$
c. $F_{net2}/F_{net1} = m_2/m_1$

An ideal spring holds a stationary mass on a frictionless plane inclined by θ = 26 degrees to the horizontal. The spring constant is k = 200 N/m and the mass m is 2 kg.



23) By what distance, Δx, is the spring stretched from its equilibrium length?

a. 1.5 cm
b. 4.3 cm
c. 8.8 cm
d. 6.2 cm
e. 13.4 cm

In a lab experiment, you attach a string to the force sensor of an IOLab. The mass of the IOLab is 0.19 kg. You set the IOLab on its wheels on the surface of a horizontal table and pull the IOLab straight across the table with the string. Data from the IOLab's force sensor show that you were pulling with a constant force of 0.9 N. Data from the IOLab's wheel sensor indicates it started from rest and had a velocity of 1.3 m/s after it has travelled 39 cm.

24) What was the force of friction acting on the IOLab?

a. 0.58 N
b. 0.9 N
c. 0.49 N

This is the last question of the exam!

25) Did you check your answer sheet to ensure you

1. Entered your netid

2. Entered your exam version

3. Marked answers for all 25 questions (including this one)

a. Yes (I did all 3)
b. No (I did not enter my netid)
c. No (I did not enter my exam version)

Kinematics
$\vec{v} = \vec{v}_0 + \vec{a}t$
$\vec{r} = \vec{r}_0 + \vec{v}_0 t + \frac{1}{2}\vec{a}t^2$
$v^2 = v_0^2 + 2a\left(x - x_0\right)$
$g = 9.81\ \mathrm{m/s^2} = 32.2\ \mathrm{ft/s^2}$
$\vec{V}_{\mathrm{A,B}} = \vec{V}_{\mathrm{A,C}} + \vec{V}_{\mathrm{C,B}}$

Uniform Circular Motion
$a = v^2/r$
$v = \omega r$
$\omega = 2\pi/T = 2\pi f$

Dynamics
$\vec{F}_{\mathrm{net}} = m\vec{a} = d\vec{p}/dt$
$\vec{F}_{\mathrm{A,B}} = -\vec{F}_{\mathrm{B,A}}$
$F = mg$ (near Earth's surface)
$F_{12} = Gm_1m_2/r^2$ (in general)
$F_{\mathrm{spring}} = -k\Delta x$

Friction
$f = \mu_{\mathrm{k}}N$ (kinetic)
$f \leq \mu_{\mathrm{s}}N$ (static)

Work & Kinetic Energy
$W = \int \vec{F} \cdot d\vec{l}$
$W = \vec{F} \cdot \vec{\Delta r} = F\,\Delta r \cos\theta$ (constant force)
$W_{\mathrm{grav}} = -mg\Delta y$
$W_{\mathrm{spring}} = -k\left(x_2^2 - x_1^2\right)/2$
$K = mv^2/2$
$W_{\mathrm{net}} = \Delta K$

Potential Energy
$U_{\mathrm{grav}} = mgy$ (near Earth's surface)
$U_{\mathrm{grav}} = -GMm/r$ (in general)
$U_{\mathrm{spring}} = kx^2/2$
$\Delta E = \Delta K + \Delta U = W_{\mathrm{nc}}$

Power
$P = dW/dt$
$P = \vec{F} \cdot \vec{v}$

System of Particles
$\vec{R}_{\mathrm{CM}} = \sum m_i\vec{r}_i / \sum m_i$
$\vec{V}_{\mathrm{CM}} = \sum m_i\vec{v}_i / \sum m_i$
$\vec{A}_{\mathrm{CM}} = \sum m_i\vec{a}_i / \sum m_i$
$\vec{P} = \sum m_i\vec{v}_i$
$\sum \vec{F}_{\mathrm{ext}} = M\vec{A}_{\mathrm{CM}} = d\vec{P}/dt$

Impulse
$\vec{I} = \int \vec{F}\,dt$
$\Delta\vec{P} = \vec{F}_{\mathrm{avg}}\Delta t$

Collisions
If $\sum \vec{F}_{\mathrm{ext}} = 0$ in some direction, then $\vec{P}_{\mathrm{before}} = \vec{P}_{\mathrm{after}}$ in this direction:
$\sum m_i\vec{v}_i$ (before) $= \sum m_i\vec{v}_i$ (after)

In addition, if the collision is elastic:
- $E_{\mathrm{before}} = E_{\mathrm{after}}$
- *Rate of approach = Rate of recession*
- *The speed of an object in the Center-of-Mass reference frame is unchanged by an elastic collision.*

Rotational Kinematics
$s = R\theta,\ v = R\omega,\ a = R\alpha$
$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$
$\omega = \omega_0 + \alpha t$
$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$

Rotational Dynamics
$I = \sum_i r_i^2$
$I_{\mathrm{parallel}} = I_{\mathrm{CM}} + MD^2$
$I_{\mathrm{disk}} = I_{\mathrm{cylinder}} = \frac{1}{2}MR^2$
$I_{\mathrm{hoop}} = MR^2$
$I_{\text{solid-sphere}} = \frac{2}{5}MR^2$
$I_{\text{spherical-shell}} = \frac{2}{3}MR^2$
$I_{\text{rod-cm}} = \frac{1}{12}ML^2$
$I_{\text{rod-end}} = \frac{1}{3}ML^2$
$\tau = I\alpha$ (rotation about a fixed axis)
$\tau = \vec{r} \times \vec{F},\ |\tau| = rF\sin\phi$

Work & Energy
$K_{\mathrm{rotation}} = \frac{1}{2}I\omega^2$
$K_{\mathrm{translation}} = \frac{1}{2}MV_{\mathrm{CM}}^2$
$K_{\mathrm{total}} = K_{\mathrm{rotation}} + K_{\mathrm{translation}}$
$W = \tau\theta$

Statics
$\sum \vec{F} = 0,\ \sum \tau = 0$ (about any axis)

Angular Momentum
$\vec{L} = \vec{r} \times \vec{p}$
$L_z = I\omega_z$
$\vec{L}_{\mathrm{total}} = \vec{L}_{\mathrm{CM}} + \vec{L}^*$
$\tau_{\mathrm{ext}} = d\vec{L}/dt$
$\tau_{\mathrm{cm}} = d\vec{L}^*/dt$
$\Omega_{\mathrm{precession}} = \tau/L$

Simple Harmonic Motion
$d^2x/dt^2 = -\omega^2 x$ (differential equation for SHM)
$x(t) = A\cos(\omega t + \phi)$
$b(t) = -\omega A\sin(\omega t + \phi)$
$a(t) = -\omega^2 A\cos(\omega t + \phi)$
$\omega^2 = k/m$ (mass on spring)
$\omega^2 = g/L$ (simple pendulum)
$\omega^2 = mgR_{\mathrm{CM}}/I$ (physical pendulum)
$\omega^2 = \kappa/I$ (torsion pendulum)

General Harmonic Transverse Waves
$y(x,t) = A\cos(kx - \omega t)$
$k = 2\pi/\lambda,\ \omega = 2\pi f = 2\pi/T$
$v = \lambda f = \omega/k$

Waves on a String
$V^2 = \dfrac{F}{\mu} = \dfrac{\text{(tension)}}{\text{(mass per unit length)}}$
$\overline{P} = \frac{1}{2}\mu v\omega^2A^2$
$\dfrac{d\overline{E}}{dx} = \frac{1}{2}\mu v\omega^2A^2$
$\dfrac{d^2y}{dx^2} = \dfrac{1}{v^2}\dfrac{d^2y}{dt^2}$ (wave equation)

Fluids
$\rho = \dfrac{m}{V}$
$p = \dfrac{F}{A}$
$A_1v_1 = A_2v_2$
$p_1 + \frac{1}{2}\rho v_1^2 + \rho g_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$
$F_{\mathrm{B}} = \rho_{\mathrm{liquid}}gV_{\mathrm{liquid}}$
$F_2 = F_1\dfrac{A_2}{A_1}$

Uncertainties
$\delta = \dfrac{\sigma}{\sqrt{N}}$
$t' = \dfrac{|\mu_{\mathrm{A}} - \mu_{\mathrm{B}}|}{\sqrt{\delta_{\mathrm{A}}^2 + \delta_{\mathrm{B}}^2}}$