General Physics I: Midterm Exam (115–1)

100 minutes, full mark = 50

It is **strictly forbidden** to use your notebooks/memos/books.
It is **strictly forbidden** to **have/wear/use** any electric devices, even in your pockets.
It is **strictly forbidden** to discuss with other students.

Administrative Remarks

- Use full-sized sheets for your answers. Smaller sheets are for calculation, not to submit.
- Write your name and student ID on the answer sheet. Put your student ID on the desk.
- Allowed on your desk: student ID card (required), pens/pencils, correction tools (eraser etc.), rulers, and drinks. **Other items must be stored in your bags.**
- You cannot wear watches nor electronic devices. **You cannot have them even in your pockets.**
- **After 13:10, the following actions are considered cheating. You may immediately lose your credit.**
  - If non-allowed items (pen cases, foods, poaches, etc.) are found on desks.
  - If you have textbooks, mobile phones, tablets, or PC, if they are not stored in your bags, or if you use them. They must be in your bags even after you submit your answer sheets.
- Breaks are not allowed in principle. After 14:00, you may leave after submission. In case of health problems or other issues, call the TA or lecturer.
- *Any form of academic dishonesty, including chats, additions/corrections after the period, and using your phones, will be treated by NSYSU "Academic Regulations."*

Scientific Remarks

- Show your calculations or thought process for **partial mark**!
- Use English, where mistakes are tolerated. Meanwhile, scientific mistakes are not tolerated.
  - Provide appropriate **units** properly.
  - Clearly distinguish **vectors** (by writing $\vec{E}$, $\vec{x}$ or $\mathbb{E}$, $\mathbb{x}$) from scalars (E, x).
- If you find any errors or issues in the questions, explain them on your answer sheet, make necessary adjustments on the question, and answer accordingly.
- You may use the following symbols and values without definition/declaration.

standard acceleration of gravity	g	$= 9.8\,\mathrm{m/s^2}$
Newtonian constant of gravitation	G	$= 6.7\times10^{-11}\,\mathrm{N\cdot m^2/kg^2}$
elementary charge	e (or $\lvert e\rvert$)	$= 1.6\times10^{-19}\,\mathrm{C}$
permittivity of free space	ϵ_0	$= 8.9\times10^{-12}\,\mathrm{C^2\,N^{-1}\,m^{-2}}$
permeability of free space	$\mu_0 = \left(\epsilon_0 c^2\right)^{-1}$	$= \pi\times4.0\times10^{-7}\,\mathrm{N/A^2}$
Coulomb constant	$k_e = \left(4\pi\epsilon_0\right)^{-1}$	$= 9.0\times10^{9}\,\mathrm{N\cdot m^2/C^2}$
speed of light in vacuum	c	$= 3.0\times10^{8}\,\mathrm{m/s}$
Avogadro's number	N_A	$= 6.0\times10^{23}/\mathrm{mol}$
masses of protons and electrons	m_p, m_e	$= 1.7\times10^{-27}\,\mathrm{kg}, 9.1\times10^{-31}\,\mathrm{kg}$

Unit vectors in the direction of the axes $(\vec{e_x}, \vec{e_y}, \vec{e_z})$ or $(\hat{e_x}, \hat{e_y}, \hat{e_z})$ or $(\hat{\imath}, \hat{\jmath}, \hat{k})$

$\vec{E}(\vec{x})$ electric field at $\vec{x}$ $\quad$ $\vec{B}(\vec{x})$ magnetic field (magnetic flux density) at $\vec{x}$
$V(\vec{x})$ electrostatic potential at $\vec{x}$ $\quad$ $\vec{F}_{XY}$ force exerted by X on Y

$\sqrt{2}\approx1.414$ $\quad$ $\sqrt{3}\approx1.732$ $\quad$ $\sqrt{5}\approx2.236$ $\quad$ $\sqrt{7}\approx2.646$ $\quad$ $\pi\approx3.142$ $\quad$ $\mathrm{e}\approx2.718$

Answer **[Part 1]**–**[Part 4]** and either **[Part 5]** or **[Part 6]**. Also, try **[Part 7]** if you have extra time.
However, if you are not a first-year student, you cannot choose **[Part 6]**.

[Part 1] Mini Test Review (10 points)

- Calculate the following expressions.

(A) $\dfrac{\mathrm{d}}{\mathrm{d}x}x^{5/3}$ **(B)** $\dfrac{\mathrm{d}}{\mathrm{d}x}\sqrt{x}\cos x$ **(C)** $\dfrac{\mathrm{d}}{\mathrm{d}\theta}\dfrac{\cos^2\theta}{\sin\theta}$ **(D)** $\dfrac{\mathrm{d}}{\mathrm{d}x}\tan x^2$

- Consider a triangle OAB. We define $\vec{a} = \overrightarrow{\mathrm{OA}}$, $\vec{b} = \overrightarrow{\mathrm{OB}}$, and $\theta = \angle\mathrm{AOB}$, so the angle between $\vec{a}$ and $\vec{b}$ is θ. We know $|\vec{a}| = 2\sqrt{6}$, $|\vec{b}| = \sqrt{3}$, and $\vec{a}\cdot\vec{b} = 6$.

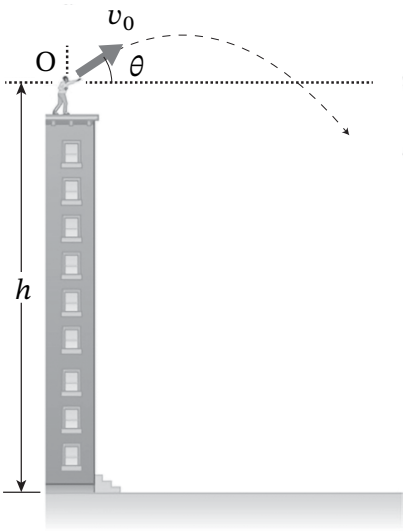
(E) Calculate θ and answer it in radians.

(F) Calculate $|\vec{v}|$ and $|\overrightarrow{\mathrm{AB}}|$, where $\vec{v} = (\vec{a} + \vec{b})/2$.

(G) A vector $\vec{w} = k\vec{a} + (1-k)\vec{b}$ is perpendicular to $\overrightarrow{\mathrm{AB}}$. Find the real number k.

[Part 2] Two-dimensional Motion (11 points)

At time $t = 0$, a kid throws a stone from the top of a building upward at an angle θ to the horizontal with an initial speed v_0. The height from which the stone is thrown is h above the ground. It reaches its highest point at time $t = t_1$ and reaches the ground at $t = t_2$. Air resistance is negligible, and the magnitude of the gravitational acceleration is g.



(A) Find t_1 and t_2.

(B) Find the height of the stone at time $t = t_1$ measured from the ground.

(C) Find the speed of the stone at time $t = t_1$ and $t = t_2$.

[Part 3] Uniform Circular Motion (8 points)

A girl swings a ball, which is connected to the end of a rope, in a horizontal circle. The ball has a mass of 0.20 kg and the rope has a negligible mass. She is able to rotate the ball at the rate of 2.0 rev/s when the length of the rope is 0.50 m.

(A) Identify all the forces exerted on the ball. **No need** to describe their magnitude and direction.

(B) Find the period of the ball's motion.

(C) Find the speed, angular speed, and the magnitude of the centripetal acceleration of the ball.

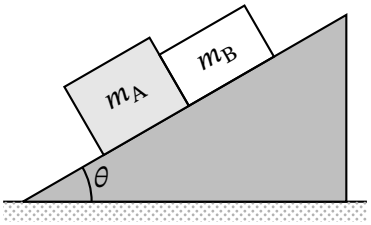
(D) Find the magnitude of the net force on the ball.

[The exam questions continue on the next page.]

[Part 4] Forces (12 points)

As in the figure to the right, a wedge with an angle θ and a mass M is placed on the horizontal floor. Block A with mass m_{A} and Block B with mass m_{B} are placed on the wedge in contact with each other. The wedge is not fixed on the ground, but all the three objects are at rest.

Friction between Block B and the wedge and between Block A and Block B is negligible, while friction between Block A and the wedge is given by the coefficient μ_{k} of kinetic friction and the coefficient μ_{s} of the static friction.



(A) Identify all the forces exerted on Block A. For each of them, describe its direction **in English words** and find its magnitude.

(B) What can we say about μ_{s} and μ_{k}?

Answer either **[Part 5]** or **[Part 6]**. However, if you are not a first-year student, answer **[Part 5]**.
DO NOT SOLVE BOTH OF THEM. Specify clearly which part you answer.

[Part 5] Logical Explanation (9 points)

Consider an object in uniform circular motion with a radius R.

(A) We can choose the coordinates and time origin $t = 0$ so that the position of the object is expressed as $\vec{r}(t) = \begin{pmatrix} R\cos\omega t \\ R\sin\omega t \end{pmatrix}$ with a constant ω. Explain in detail how and why we can do this.

(B) Using this $\vec{r}(t)$, calculate the velocity and acceleration of the object *based on the definition of velocity and acceleration* and show they are perpendicular to each other.

[Part 6] Learning at University (9 points)

(A) We have had four lectures in this course so far. Summarize each lecture in 3 to 10 words. For example, you may list the main topics or write a short summary.
[Your answer should be in the form "Lecture 1: ...; Lecture 2: ...; Lecture 3: ...; Lecture 4: ...".]

(B) Think about your own department. Identify **five** major differences between studying in your department and studying in high school that may cause difficulties for you or other students.

[The exam questions continue on the next page.]

Three extra questions are given below. You may try writing something for a partial mark, because no penalty is given for incorrect answer as long as you are a student.

[Part 7] Challenge Problems (unlimited points)

(A) Look again at **[Part 1]**. The points described by $\vec{v}$ and $\vec{w}$ have special meanings for the triangle. Describe where each point is in the triangle.

(B) Revisit **[Part 3]** and, for each force exerted on the ball, find its magnitude and direction. You can use symbols instead of the numerical values; for example, m for the mass and R for the radius.

(C) In the situation given in **[Part 4]**, an agent gives Block B a gentle and brief push. Then, all the objects start to move and, even after the agent stops pushing, all the objects continue to accelerate. Discuss the physics of this situation. You may include any relevant ideas.

[This is the end of the exam questions.]