General Physics I: Term Exam (114–1)

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	$\mu_0 = (\epsilon_0 c^2)^{-1}$	$= \pi\times4.0\times10^{-7}\,\mathrm{N/A^2}$
Coulomb constant	$k_e = (4\pi\epsilon_0)^{-1}$	$= 9.0\times10^{9}\,\mathrm{N\cdot m^2/C^2}$
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 $\vec{x}$	$\vec{B}(\vec{x})$	magnetic field (magnetic flux density) at $\vec{x}$
$V(\vec{x})$	electrostatic potential at $\vec{x}$	$\vec{F}_{XY}$	force exerted by X on Y

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

Answer **[Part A]**, **[Part B]**, and **[Part C]**, and <u>either **[Part D]** or **[Part E]**</u>. If you have done them with sufficient confidence, try **[Part F]**, a challenge from Sho.

[Part A] Small Problems (13 points)

(1) When two tones are played simultaneously, 8 beats are observed over a period of 4 seconds. We know one of the tones has a frequency of 444 Hz. Discuss the frequency of the other tone.

(2) Fill in the blanks with appropriate words or mathematical expressions.

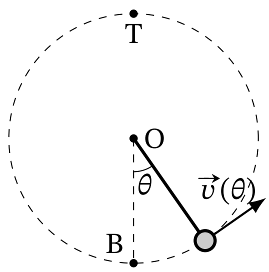
- P-waves in earthquakes are $\boxed{\textbf{(a)}}$ waves, which means the displacement is $\boxed{\textbf{(b)}}$ to the direction of wave propagation. In contrast, slower S-waves are $\boxed{\textbf{(c)}}$ waves.
- Consider a wave $\phi(x,t) = A\sin(kx+\omega t)$. Its period is $T = \boxed{\textbf{(d)}}$, wavelength is $\lambda = \boxed{\textbf{(e)}}$, and propagating velocity is $\boxed{\textbf{(f)}}$. The point at $x = a$ undergoes the motion $\phi_a(t) = A\sin(ka+\omega t)$, whose $\boxed{\textbf{(g)}}$ is A, period is $\boxed{\textbf{(h)}}$, and maximum speed is $\boxed{\textbf{(i)}}$.

(3) A 20.0-kg cannonball is fired from a cannon with speed 1.00×10^3 m/s at an angle 60.0° with the horizontal. Find the kinetic energy and momentum of the cannonball at its highest point.

(4) A car with a mass m accelerates from 0 to a speed v in a time interval of Δt. A newer car with a mass M accelerates from 0 to $2v$ in the same time period. Assuming the energy from the engine appears only as kinetic energy of the cars, compare the power of the two cars.

(5) Write, as a mathematical expression, the definition of work done by a varying force $\vec{F}$ on a particle as the particle moves from Point Ⓐ to Point Ⓑ.

[Part B] Vertical Circular Motion (15 points)



A small ball of mass m is attached to a light inextensible cord of length R and moves counterclockwise in a *vertical* circle about a fixed pivot O. We label the lowest point as Point B (bottom), and the highest point of the circle as Point T (top). Let θ be the angle of the cord from $\overrightarrow{\mathrm{OB}}$, measured counterclockwise. Namely, the ball is to the right of O for $0 < \theta < \pi$ and to the left for $\pi < 0 < 2\pi$. Neglect air resistance throughout this problem.

First, neglect friction at the pivot. Consider one half cycle of the motion, from the bottom (Point B) to the top position (Point T), during which the ball travels a distance πR along the circular path. Because the ball is fast enough, the cord remains taut throughout this motion. Let $v(\theta)$ and $T(\theta)$ denote the speed of the ball and the tension in the cord at angle θ, respectively, with $0 \le \theta \le \pi$.

(1) **Starting from the definition of work** (see your answer to Problem (5) in Part A), calculate the work done by <u>**(1)** gravity</u> and <u>**(2)** the tension in the cord</u> during this motion from Point B to T.

(2) Express $v(\theta)$ in terms of g, m, R, θ, and v_{bot}, where v_{bot} is the speed of the ball at Point B.

(3) Express $T(\theta)$ in terms of g, m, R, θ, and $v(\theta)$.

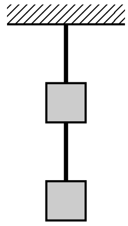
(4) Determine the minimum value of v_{bot} for the ball to reach Point T.

Next, include friction at the pivot. Assume the negative work done by friction is proportional to the traveled distance $R\Delta\theta$, and thus proportional to the traveled angle $\Delta\theta$, so that $W_{\text{friction}} = -\varepsilon\,\Delta\theta$.

(5) Suppose the ball passes the bottom position, Point B, with speed v_0. Discuss how many times the ball passes Point T after that. [Hint: First, find the condition for the ball to reach Point T.]

[The exam questions continue on the next page.]

[Part C] One-dimentional Motion (13 points)



As in the figure on the right, two cubes are hanging in series from the ceiling by two strings. Both blocks have a mass m and an edge length d. Both strings are with a length L. The distance between the bottom of the lower block and the floor is H. Neglect air resistance and assume the cubes are rigid, i.e., hard enough not to deform, and the strings are massless and inextensible.

An agent gently cuts the upper string, causing both blocks to fall freely under gravity. The lower block then hits the floor, which we call the first collision. It is an elastic collision, i.e., it bounces without any loss of kinetic energy. Next, the lower block hits the upper cube. This second collision is perfectly inelastic, after which they stick together and move as a single body. Finally, as the third collision, the combined block hits the floor.

(1) Determine the tensions of both strings just before the upper string is cut.

(2) Find the speed of the lower block just before the first collision.

(3) When do the first collision and the second collision happen?

(4) Find the impulse exerted by the floor on the lower block during the first collision.

(5) Find the velocity of the combined block just after the second collision.

Answer either **[Part D]** or **[Part E]**. **DO NOT SOLVE BOTH OF THEM.**
Specify clearly which part you answer.

[Part D] Learning at University (9 points)

(1) The following passage explains this course and the textbook used in it. Fill in the blanks with appropriate words. In some blanks, the first letter is provided.

> This course began with calculus and vector arithmetic. Motion and forces were the main topic before the midterm. After the exam, we studied **(a)** w________, **(b)** e________, and linear **(c)** m__________. The last two weeks before the term exam was devoted to **(d)** o______________ and waves.
> These topics are included in Chapters 1–9 and 15–17 of the textbook, *Physics for Scientists and Engineers* (11th edition). Each chapter contains several “ **(e)** Quiz” and “ **(f)** prevention” to ascertain students’ understanding. Important words are shown in boldface and in **(g)** color. The textbook has many examples and, at the end of each chapter, we can find a summary and many problems. Their solutions are given in the end of the book, but only for **(h)**.

(2) Almost all first-year students encounter learning challenges due to the differences in the learning environment compared to high school. How about you? Write one difficulty you encountered, and describe what you did to overcome, or tried to resolve, the difficulty.

[Part E] Logical Explanation (9 points)

(1) Prove $\dfrac{\mathrm{d}}{\mathrm{d}x}\sqrt{x} = \dfrac{1}{2\sqrt{x}}$ using the definition of derivative.

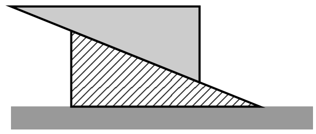
(2) Prove a perfectly inelastic collision is an inelastic collision.

[The exam questions continue on the next page.]

An extra problem is 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 F] Extra Challenge Problem (unlimited points)

Two blocks are placed on the floor as in the figure, showing the cross-sectional view of the system. The blocks have the same size and shape, a triangular prism with a right-triangular cross section, and thus the top surface of the upper block is horizontal (parallel to the floor). They are made of different materials and each has a uniform mass density, so they have different masses. Both were fixed and at rest, but all the fixings are released simultaneously. The upper block slides down and reaches the floor, during which the top surface stays horizontal. Discuss physics.



[Hint: If too difficult, simplify the problem by assuming some surfaces are frictionless.]

[This is the end of the exam questions.]