PHY 111 – Take-Home Quiz

Gravitation, Work & Energy, Momentum & Collisions

Name: ________________________________ **Date:** ______________

Rules for this take-home quiz:

- This is to be completed **without use of the internet or any AI tool** of any kind.
- You *may* use your textbook and your own course notes.
- You may work together with another student in class, but when it comes time to write up solutions, this needs to be done independently.
- Write **legibly**. Illegible work cannot be graded.
- For every problem, in addition to your final answer, include a short discussion (a few sentences) of *how you are thinking about the problem* – what principle(s) apply, why you set it up the way you did, and any assumptions you are making. A correct number with no reasoning will receive little credit; clear reasoning with a minor arithmetic slip will receive most of the credit.
- Show all work: define variables, write the governing equation(s) before substituting numbers, and box your final answer with correct units. Where a diagram is requested, it must be **drawn by hand** with your own labels – not just described in words.
- Your solutions for each question should be preceded by this printout of each question; i.e. use each page of this handout to separate your solutions for each question. Staple your final work together.
- You handwritten solutions will be collected at the beginning of class on Tuesday, 23 June 2026. Late submissions will not be accepted.

Problem 1 – Weight vs. Mass

A student has a mass of 68.0 kg measured on a scale in her bathroom on Earth.

(a) Explain, in your own words, the physical difference between an object's *mass* and its *weight*. Why does one of these change when she travels to the Moon, while the other does not?

(b) Compute her weight on the surface of the Earth.

(c) The surface gravitational acceleration on the Moon is roughly 1/6 that of Earth's. Compute her mass and her weight while standing on the Moon's surface.

Problem 2 – Local g on a Mountain

The acceleration due to gravity at the surface of a planet (or moon) of mass M and radius R is given by Newton's law of gravitation applied at the surface:

$$g = \frac{GM}{R^2}.$$

(a) Starting from Newton's law of universal gravitation, $F = \dfrac{GMm}{r^2}$, derive the expression above for g at a planet's surface. Be explicit about what you are setting equal to what, and why.

(b) Mount Washington in New Hampshire has a summit elevation of about 1.91 km above sea level. Using $R_E = 6.371 \times 10^6$ m and $M_E = 5.972 \times 10^{24}$ kg, compute g at sea level and g at the summit of Mount Washington. (Treat the mountain's own mass as negligible, and assume the Earth is a uniform sphere.)

(c) By what percentage does g change between sea level and the summit? Is this consistent with the assumption, often made in introductory problems, that g is constant near Earth's surface? Explain briefly.

Problem 3 – Work and the Dot Product

A crate is dragged 12.0 m across a horizontal floor by a rope that makes an angle of 30.0° above the horizontal. The tension in the rope is 85.0 N, and a constant friction force of 40.0 N opposes the motion of the crate.

(a) **Draw a free-body diagram of the crate by hand** in the space below. Label every force acting on the crate (tension, friction, weight, normal force) with your own symbol for each (e.g. $\vec{T}$, $\vec{f}$, $\vec{W}$, $\vec{N}$), and label the angle the rope makes with the horizontal. Then, in a sentence or two, refer back to your diagram by the symbols you chose and state which forces have a component along the direction of motion and which do not.

(b) Write the work done by the tension force as a dot product, $W = \vec{F} \cdot \vec{d}$, and explain in words why only the component of force *along* the displacement contributes to the work – that is, explain physically why the dot product (rather than, say, the full magnitude of $\vec{F}$ times the magnitude of $\vec{d}$) is the right tool here.

(c) Compute the work done by the tension on the crate.

(d) Compute the work done by friction on the crate.

(e) Compute the net work done on the crate by all horizontal forces, and state what the work–energy theorem then tells you about the crate's change in kinetic energy.

Problem 4 – Energy Conservation with a Non-Conservative Force

A 2.00 kg block starts from rest at the top of a frictionless curved ramp at height $h = 3.00$ m above the floor, slides down, and then continues across a rough horizontal floor where the coefficient of kinetic friction is $\mu_k = 0.250$.

(a) Using conservation of energy on the frictionless part of the ramp, find the block's speed at the bottom of the ramp.

(b) Set up the energy conservation equation for the *entire* trip (ramp + floor), including the work done by friction as a non-conservative force, i.e.

$$K_i + U_i = K_f + U_f + |W_{nc}|$$

Explain in your own words what W_{nc} represents physically and why it must be included once friction acts.

(c) Find how far the block slides along the rough floor before coming to rest.

Problem 5 – Impulse and Momentum

A 0.145 kg baseball is thrown toward a batter, arriving with a horizontal velocity of 38.0 m/s. The batter hits it straight back, and it leaves the bat with a horizontal velocity of 45.0 m/s in the opposite direction. The bat is in contact with the ball for 1.30 ms.

(a) Carefully define a positive direction, then write the ball's initial and final velocities (with correct signs) in your chosen coordinate system.

(b) Compute the impulse delivered to the ball by the bat.

(c) Compute the average force exerted by the bat on the ball during the collision.

(d) Explain, using Newton's third law and the impulse–momentum theorem, why the force the *ball* exerts on the *bat* has the same magnitude as the force you just found, even though the ball is much lighter than the bat.

Problem 6 – Perfectly Inelastic Collision in 1D

A 1500 kg car traveling east at 20.0 m/s collides head-on with a stationary 1200 kg car and the two vehicles lock together (a perfectly inelastic collision).

(a) **Draw two sketches by hand**: one showing the two cars *just before* the collision, and one showing the wreckage *just after*. On the "before" sketch, label each car's mass and velocity using your own symbols (e.g. m_1, v_{1i}, m_2, v_{2i}) and draw an arrow indicating each velocity's direction; on the "after" sketch, label the combined mass and the single final velocity v_f with its direction. Choose and state your positive direction directly on the diagram.

(b) Using conservation of momentum and the symbols from your sketch, find the common velocity of the wreckage immediately after the collision.

(c) Compute the total kinetic energy of the system just before and just after the collision.

(d) Where did the "missing" kinetic energy go? Explain physically why momentum is conserved in this collision while kinetic energy is not.

Problem 7 – Elastic Collision in 1D

A 0.50 kg cart moving at 3.00 m/s to the right on a frictionless track undergoes a head-on *elastic* collision with a stationary 1.50 kg cart.

(a) Write down the two conservation statements (momentum and kinetic energy) that define an elastic collision, in terms of the two unknown final velocities v_{1f} and v_{2f}.

(b) Solve for v_{1f} and v_{2f}, using the momentum conservation equation above and the elastic collision result we derived in class wherein

$$v_{1i} - v_{2i} = -(v_{1f} - v_{2f}).$$

Show your algebra neatly and methodically!

(c) Check your answer by verifying explicitly that both momentum *and* kinetic energy are conserved using your numerical results.

Problem 8 – Center of Mass

Three point masses lie along the x-axis: $m_1 = 2.0$ kg at $x_1 = 0$ m, $m_2 = 3.0$ kg at $x_2 = 1.5$ m, and $m_3 = 5.0$ kg at $x_3 = 4.0$ m.

(a) Write the general formula for the center of mass of a system of point particles, and explain in words what this quantity represents physically (e.g., in terms of how the system would behave if treated as a single particle).

(b) Compute the location of the center of mass, x_{cm}, for this system.

(c) Suppose no external horizontal forces act on this three-mass system, and the masses are connected by springs so they can push and pull on one another internally. If the masses are released and allowed to interact, what happens to x_{cm} over time? Justify your answer using Newton's laws (not just by quoting the result).

End of quiz. Please check that all 8 problems are complete and that your reasoning discussion is included for each question.