General Physics 1–Honors (PHYS 101H): Final Exam Tuesday, December 13, 2022

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Overview and instructions

In this final you will apply your understanding of the topics covered in Physics 101–Honors. These topics include: kinematics and dynamics in one and two dimensions; Newton's laws of motion; conservation of energy; elastic and inelastic collisions; rotational kinematics and dynamics; gravitation; fluid statics and dynamics; simple harmonic motion and oscillations; and wave motion.

Read the following instructions carefully.

There are **ten questions**, for a total of **200 points**. **Attempt all questions**. The exam will start at 9:00 am and finish at 12:00 midday. Please write your name **on every sheet of paper you submit**. It is helpful if you include page numbers at the bottom of each page, too.

You may use:

- an electronic calculator;
- your own formula sheet, written or printed on **two sides** of letter paper.

You may **not** use:

- electronic devices (except a calculator), including phones, tablets and laptops (unless previously arranged);
- textbooks or other reference resources;
- course notes or slides.

The first five questions are multiple choice. Your answer to these multiple choice questions should be written out and submitted as part of the rest of your solutions. For example, you could write, "Problem 1: my answer is **(a)**." Do **not** circle the options on the exam itself; I will not collect the exams and you will not receive credit for your answer.

The remaining five questions require written solutions. You should show all your working and include important intermediate steps, equations, and results. You can receive partial credit for these problems, even if you don't complete the problem or provide a correct final answer. Please ensure that you highlight or emphasise your final answer (for example, by circling or underlining the final answer).

You are responsible for ensuring your solutions are legible. Present your solutions legibly and as logically as you can.

In practice, this means:

1. Try to identify what "kind" or "type" of question is being asked, for example "projectile motion", "conservation of energy", or "two dimensional collision".
2. Draw a labelled diagram.
3. Write down what quantities you know.
4. Write down the relevant equations.
5. Write down what quantities you know.
6. Write down the relevant equations.
7. When carrying out manipulations or substituting values into equations, try to write each equality on separate lines or otherwise distinguish them clearly.
8. Circle or underline your final answers to identify them clearly.

Some hints for tackling problems in general:

1. Only substitute values at the end of your calculation and try to carry out all manipulations symbolically.
2. Double check the order of magnitude of your answer.
3. Double check the units of your answer.
4. Double check the number of significant figures of your answer. Remember that I am only looking for approximately the correct number of significant digits. If quantities are given to two or three significant digits, quote your answer to two or three (not one or five). Similarly if quantities are given to eight significant digits, do not quote your answer to two.

You do not have to tackle the questions in order. Briefly read through them all and then start on one!

Short questions

Remember, your answer to these multiple choice questions should be written out and submitted as part of the rest of your solutions.

Question 1 **15pts**

When you stand at rest on a floor, you exert a downward normal force on the floor. Does this force cause the Earth to accelerate in the downward direction?

(a) Yes, but the Earth is very massive, so you don't notice the motion.

(b) Yes, but you accelerate along with the Earth, so you don't notice the motion.

(c) No, because the normal force is a fictitious (pseudo) force.

(d) No, because you are also pulling on the earth gravitationally.

(e) No, because there is also friction at your feet.

Question 2 **15pts**

Clifford likes to drop his ball in the river and watch the ball float downstream before swimming after it. The river flows at a constant rate of $u = 1$ m/s, and Clifford watches the ball for 3 s before he starts swimming. Assuming that Clifford can swim with a uniform acceleration of 1.5 m/s^2, how long does it take for Clifford to catch up with his ball? Assume that both the ball and Clifford travel in a straight line downstream, and that both start their motion from rest.

(a) 1.4 s (b) 2.8 s (c) 3.4 s (d) 5.6 s (e) 6.8 s

Question 3 **15pts**

A race car passes a stationary fan watching the race from a point in the middle of a straightaway. The race car takes 2 s to travel 110 m along the straightaway, and emits sound at a constant frequency of 600 Hz. Assuming that the speed of sound is 330 m/s, what frequency does the fan hear as the car approaches?

(a) 428 Hz (b) 514 Hz (c) 600 Hz (d) 720 Hz (e) 840 Hz

Question 4 **15pts**

A boat carrying a large boulder is floating on a lake. The boulder is thrown overboard and sinks. The water level in the lake (with respect to the shore):

(a) drops, (b) rises, (c) stays the same.

Question 5 **15pts**

Gliese 667Cc is an exoplanet (a planet outside our solar system) orbiting a red dwarf about 22 light-years from Earth, and is about 4.5 times as massive as the Earth. What is the acceleration due to gravity on Gliese 667Cc, relative to the acceleration due to gravity on Earth g? The radius of Gliese 667Cc is approximately 1.5 times larger than the Earth's radius, 6.37×10^3 km.

(a) $g/4$ (b) $g/3$ (c) $3g/2$ (d) $2g$ (e) $3g$

Longer questions

Remember, present your solutions legibly and as logically as you can. Highlight your final answer by underlining or circling it.

Question 6 **25pts**

A uniform ladder leans against a smooth (frictionless) wall. The ladder has length 4 m and mass 10 kg. The base of the ladder is at rest on a rough horizontal floor, and the coefficient of static friction between the floor and the ladder is 0.5.

(a) Show that the largest angle that the ladder can lean, with respect to the floor, and remain in equilibrium is 45°.

(b) A person, of mass 65 kg, now climbs a distance of 3 m up the ladder, with the ladder leaning at 45° to the floor. A second person puts their foot against the base of the ladder and provides a force directed towards the wall to keep the ladder in place. What force must the person provide at the base of the ladder to ensure that the ladder does not slip?

Question 7 **25pts**

A balloon is filled with helium until the whole balloon occupies a volume of 2 litres (there are 1000 litres in 1 m^3). The balloon is tied down with a string of negligible mass. In the following, you can neglect the volume of the rubber of the balloon itself.

(a) Assuming that the density of air is 1.3 kg/m^3, find the bouyant force on the balloon.

(b) Assuming that the mass of the rubber in the balloon is 1 g, and the balloon floats in equilibrium at the end of the string, what is the tension in the string? The density of helium is 0.16 kg/m^3.

(c) What is the upward acceleration of the balloon, if the string is untied and the balloon released?

Question 8 **25pts**

A sphere of mass m can move across a horizontal, frictionless surface. The sphere is attached to a spring. At time $t = 0$ the sphere is pulled aside from the equilibrium position, $x = 0$, to a distance d in the positive direction and released from rest.

(a) What is the (angular) frequency with which the spring–mass system oscillates after being released?

(b) What is the period of oscillation of the mass?

(c) Describe qualitatively (in words) what would happen to the motion of the ball, after it is released, if it instead moves across a surface with friction. Include in your description what will happen to the frequency, period, and amplitude of the oscillatory motion in the presence of friction.

(d) The full solution for underdamped oscillatory motion (oscillatory motion in the presence of friction) is

$$x(t) = Ae^{-bt/(2m)} \cos(\omega t + \phi).$$

Here b is a coefficient that characterises the size of the frictional force. Show that if this frictional force is very small (which means that $b/2m$ is very small), the resulting motion is approximately the same as simple harmonic motion without damping.

Question 9 **25pts**

A large open tank, of height 10.0 m, is used to collect water for irrigation. The water can drain through a horizontal hose of diameter 5.0 cm at the base of the tank. The tank sits on a pedestal 3.5 m high. You can assume the density of water is $\rho = 1000$ kg/m^3 and atmospheric pressure is $P_{\text{atm}} = 1.01 \times 10^5$ Pa.

(a) Find the water pressure at the base of the tank.

(b) Assuming that the tank is so large that the water level at the top of the tank does not drop as water leaves through the hose, what is the velocity of water as it exits the tank through the hose?

(c) Find the horizontal distance the water travels before it hits the ground. Neglect friction and air resistance.

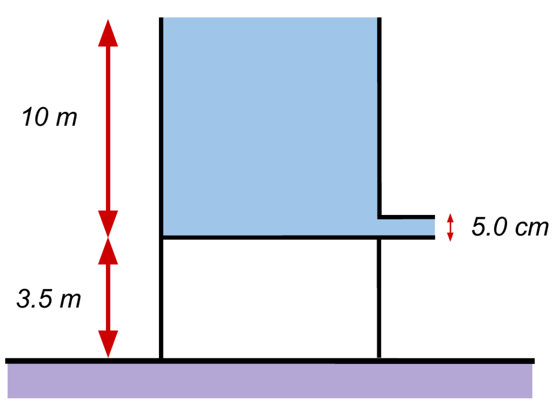

Figure 1: Diagram for Question 9.

Question 10 **25pts**

A uniform rod of mass $M = 0.3\,\text{kg}$ and length $L = 1.0\,\text{m}$ can rotate about a hinge at its left end. A sticky ball of plasticine, of mass $m = 10.0\,\text{g}$, moving with speed $v = 3.0\,\text{m/s}$, strikes the rod at an angle $\theta = 90°$ and at a distance $d = \frac{2}{3}L$ from the point of rotation. The rod is initially at rest, and the ball sticks to the rod after the collision. The arrangement of the rod and the ball before the collision is shown in figure 2.

Hint: In the following, it may be helpful to know that the moment of inertia of a uniform rod of mass m and length ℓ about one end is $\frac{m\ell^2}{3}$.

(a) What kind of collision is this? And what is conserved in this collision?

(b) What is the magnitude of the initial angular momentum of the ball, right before the collision, relative to the pivot point of the rod?

(c) What is the total moment of inertia, with respect to the hinge, of the rod-ball-system after the collision?

(d) What is the angular speed of the system immediately after the collision?

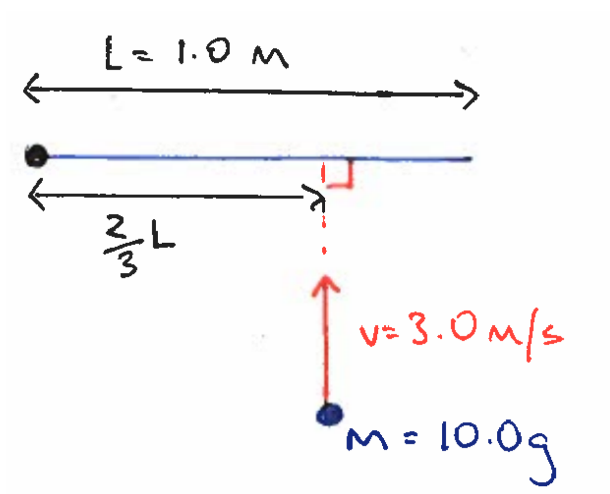

Figure 2: Diagram for Question 10.