# PHY 101 In-class Exam II

## Monday, October 30, 2:15-3:35PM

Please be sure to show your work where it is requested. If no work is shown where it is requested, you will not receive any points. Also, partial credit will be given where appropriate, so *show me your physics thoughts.*

Please answer the following multiple choice questions. Circle only one answer per question.

(1) As a hiker descends (goes down) a hill, the work done by gravity on the hiker is
A. positive and depends on the path taken.
B. negative and depends on the path taken.
C. positive and independent of the path taken.
D. negative and independent of the path taken.

(2) A heavy object and a light object are dropped at the same time from rest in a *vacuum.* The heavier object reaches the ground
A. sooner than the lighter object.
B. later than the lighter object.
C. at the same time as the lighter object.
D. almost immediately.

(3) To be dimensionally consistent, distance (length), velocity (length/time), and acceleration (length/time$^2$) must be related as follows:
A. Distance=velocity/acceleration
B. Distance=velocity$^2$/acceleration
C. Distance=velocity $\times$ acceleration
D. Distance=velocity$^2$ $\times$ acceleration

(4) After getting on 81 N to head to Canada, a car accelerates from 30 mi/hr to 60 mi/hr. Its kinetic energy
A. increases by a factor of $\sqrt{3}$.
B. decreases by a factor of 4.
C. increases by a factor of 2.
D. increases by a factor of 4.

(5) Which pair of quantities can be expressed in the same units?
A. Young's modulus and stress
B. Young's modulus and strain
C. stress and strain
D. ultimate strength and strain

(6) Hydraulic lifts are useful because of
A. Coulomb's law.
B. Avogadro's law.
C. Pascal's principle.
D. gravitational potential energy.

(7) A mass is suspended vertically from a spring so it is at rest at the equilibrium position. The mass is pulled straight down to an extension $y$ and released so that it oscillates about the

equilibrium position. The speed of the mass is greatest when the mass is
A. at its maximum upward travel.
B. at the equilibrium point.
C. at its maximum lower travel.
D. somewhere between the equilibrium point and maximum extension.

(8) A vertical spring system with a bob having mass M is set into motion with amplitude A. When the bob is pulled instead to move with amplitude 2A, the following can be concluded:
A. The period is unaffected.
B. The period is twice as large as before.
C. The period is 0.7 times as large as before.
D. The period is half as large as before.

(9) A proton is moving in an electric field. The direction of the acceleration of the proton is
A. perpendicular to the direction of the electric field.
B. perpendicular to the direction the proton is moving.
C. in the direction of the electric field.
D. opposite the direction of the electric field.

(10) Which of these statements comparing electric and gravitational forces is correct?
A. The direction of the electric force exerted by one point particle on another is always the same as the direction of the gravitational force exerted by that particle on the other.
B. The electric and gravitational forces exerted by two particles on each other are inversely proportional to the separation of the particles.
C. The electric force exerted by one planet on another is typically stronger than the gravitational force exerted by that same planet on the other.
D. none of the above.

(11) A tiny charged pellet of massmis suspended at rest by the electric field between two horizontal, charged metallic plates. The lower plate has a positive charge and the upper plate has a negative charge. Which statement in the answers here is not true?
A. The electric field between the plates points vertically upward.
B. The magnitude of the electric force on the pellet is equal to $mg$.
C. If the magnitude of charge on the plates is increased, the pellet begins to move upward.
D. The pellet is negatively charged.

(12) A rock is thrown straight down towards the surface of the Earth. Which one of the following statements describes the energy transformation of the rock as it falls? Neglect air resistance.
A. The total energy of the rock increases.
B. The kinetic energy increases and the potential energy decreases.
C. Both the kinetic energy and the potential energy of the rock remain the same.
D. The kinetic energy decreases and the potential energy increases.

Now respond to the following short answer questions. Please answer THREE out of FOUR for questions (13)-(16). CLEARLY indicate which ones you would like to be graded on the front sheet of the exam.

(13) In the design of a roller coaster, is it possible for any hill of the ride to be higher than the first one? If so, how? What principle/law is at work here?

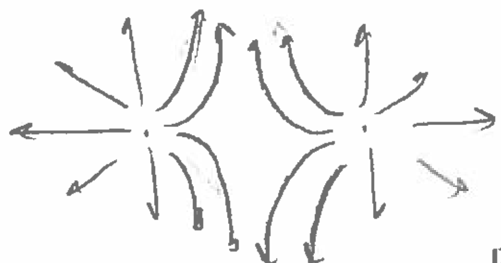
As long as there is no additional motors involved, by the conservation of energy, it is not possible for any hill of the ride to be higher than the first hill.

(14) Recall your pendulum lab. The pendulum is a small bob (ball) of mass $m$ suspended by a string of length $l$ from a fixed point. Does the period of the pendulum depend on *both* $m$ and $l$? What other parameters does the period of the pendulum depend on? And recall the demo we did in class with a pendulum and inserting a second "pivot point". Why did the amplitude of the pendulum not change when the second pivot point was inserted?

$T_{pendulum} = 2\pi\sqrt{\frac{l}{g}}$ → only depends on $l$ not $m$.
depends on $g$

The amplitude did not change because the energy did not change. The reference pt. for the gravitational potential energy is the lowest pt. of the pendulum.

(15) Draw the electric field lines for two protons at distance $d$ apart from each other.



E field lines cannot cross

(16) Helvetica and Arial are at a water theme park. There are two water slides with straight slopes that start at the same height and end at the same height. Slide A has a more gradual slope than slide B. Helvetica says he likes slide B better because you reach a faster speed, and he notes that he got to the bottom level in less time on slide B as measured with his stop watch. Arial, on the other hand, says you reach the same speed with either slide. Who is correct and why? What principle/law is at work here? Both slides have negligible friction.

Using conservation of energy, Arial is correct that you will reach the same speed at the end of either slide --- the path does not matter - only the initial and final points.

Now answer THREE of the following FOUR quantitative questions (17)-(20). Please clearly indicate which ones you would like to be graded on the front sheet of the exam. You are welcome to approximate $g$ as 10 $m/s^2$ to obtain numbers. See how close you come to reaching a number without the use of a calculator.

(17) Consider a child on a swing. Neglect friction and air resistance.
(a) What are the contributions to the energy at the highest point and at the lowest point of the child's trajectory? You can use words and/or equations with variables but no numbers are needed.

HP → GPE

LP → K, KE

(b) If the maximum speed of the child on the swing is 2 m/s how high above the lowest point in the trajectory is the child's highest point?

$$\frac{1}{2}mv^2 = mgh$$

$$\frac{v^2}{2g} = h = \frac{(2\ m/s)^2}{2(10\ m/s^2)} = \frac{2}{10}\ m = .2\ m$$

(c) If the child's height above the ground is 0.6 m at the lowest point in the trajectory, what is the child's highest point as measured from the ground (as opposed to from the lowest point in the trajectory)?

$$y = .2\ m + .6\ m = .8\ m$$

(d) If friction and/or air resistance were included in this calculation, what equation would you use as a starting point?

$$W_{nc} = \Delta U + \Delta K$$

(18) Some claim that mountain climbers suffer from headaches due not only to a lack of oxygen in the brain, but also to the expansion of the cranium. Find the fractional change of the cranium's volume ($\frac{\Delta V}{V}$) due to a reduction in pressure from 100 kPa at sea level to 30 kPa up in the Himalayas. The cranium bulk modulus is 2 GPa.

$$\Delta P = -B\frac{\Delta V}{V}$$

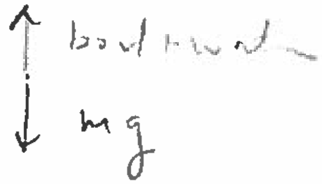
$$-\frac{\Delta P}{B} = \frac{\Delta V}{V} = -\frac{(30\times10^3 - 100\times10^3)\ Pa}{2\times10^9\ Pa} = \frac{70\times10^3}{2\times10^9}$$

$$= 35\times10^{-6}$$

$$= 3.5\times10^{-5}$$

(19) A small rowboat has a mass of 100 kg. When a 100 kg person gets into the boat, the boat floats 5.0 cm lower in the water. If the boat is then pushed slightly deeper in the water, it will bob up and down with simple harmonic motion (neglecting any friction).

(a) Treating the boat+water as a spring, draw the forces on the person.




(b) Since the boat floats 5.0 cm lower in the water with the person, what is the spring constant of the boat+water? The person is in equilibrium at this point.

$$m_p g - k y = 0$$

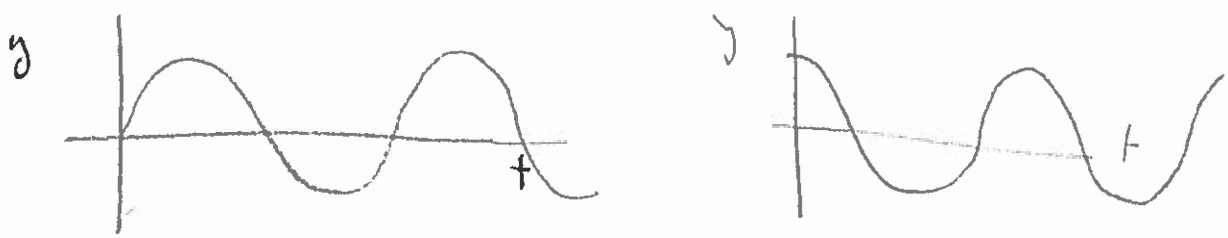
$$\frac{m_p g}{y} = k \qquad \frac{(100\,\text{kg})(10\,\text{m/s}^2)}{.05\,\text{m}} = 2\times10^4\,\frac{N}{m}$$

(c) What will the period of oscillation be for the boat as it bobs around its equilibrium position? Since the boat will oscillate on its own as well (if pushed down further than its own equilibrium position in the water), consider both the mass of the boat and the person in this part of the calculation.

$$T = 2\pi\sqrt{\frac{m_{tot}}{K}} = 6\left(\frac{100\,\text{kg} + 100\,\text{kg}}{2\times10^4\,N/m}\right)^{1/2}$$

$$= 6\left(\frac{200\,\text{kg}}{2\times10^4\,N/m}\right)^{1/2} = 6\,(.015)^{1/2} = .6\,\text{s}$$

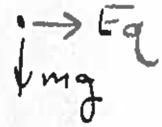
(d) Graph the height of the person as a function of time as the person oscillates up and down (gently) in the boat.




(20) A cathode ray tube (CRT) is used to accelerate electrons in some televisions, computer monitors, oscilloscopes, and x-ray tubes. Electrons from a heated filament pass through a hole in the cathode (a negatively charged plate); they are then accelerated by an electric field between the cathode and the anode (a positively charged plate). See the figure below of the side view. Suppose an electron passes through the hole in the cathode at a velocity of $1.0\times10^5$ m/s toward

the anode. The electric field is uniform between the anode and cathode and has a magnitude of $1.0 \times 10^3$ N/C. The direction of the electric field goes from the postive to the negative plate (to the left). Approximate the charge of the electron as $2.0 \times 10^{-19}$ C and its mass as $10 \times 10^{-31}$ kg.

(a) Draw the forces on the electron as it moves between the two plates?




(b) Now neglecting the force of gravity on the electron, what is its acceleration in the $y$ direction and in the $x$ direction? Please specify a sign if the acceleration in either direction is nonzero. Are they both constant?

$-16 + 30$

$a_y = 0$

to right

$m_e a_x = E|q|$

$a_x = \frac{(1 \times 10^3 \, N/C)(2 \times 10^{-19} \, C)}{10 \times 10^{-31} \, kg} = 2 \times 10^{14} \, m/s^2$

(c) Given its initial velocity of the electron in the $x$-direction as it enters the field between the two plates, if the anode and cathode are separated by 0.1 mm, what is the final velocity of the electron as it emerges from the anode?

$v_f^2 = v_i^2 + 2 a_x d$

$v_f = \sqrt{(1 \times 10^5 \, m/s)^2 + 2(2 \times 10^{14} \, m/s^2)(1 \times 10^{-4} \, m)}$

(d) If both plates were rotated by 90 degrees, how would the calculations in (b) and (c) change qualitatively speaking?

$a_y > 0$

like projectile motion

$v_f = \sqrt{1 \times 10^{10} \, m^2/s^2 + 4 \times 10^{10} \, m^2/s^2}$

$= \sqrt{5 \times 10^{10} \, \frac{m^2}{s^2}}$

$= \sqrt{5} \times 10^5 \, \frac{m}{s}$