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Pre-Exam I,
Physics 117-Spring 2003, Fri. 3/7/2003

General Instructions

- There are a total of five problems in this exam. All problems carry equal weights. Each part of each problem carries equal weights.
- Do all the five problems by writing on the exam book (continue to work on the back of each page if you run out of room).
- Write your name (in capital letters) on every page of the exam.
- Purely numerical answers will not be accepted. Explain with symbols or words your line of reasoning. Corrected formulae counts more than corrected numbers.

What you can do

- You may look at your text book in taking the exam
- Use a calculator

What you can't do

- Speak with nearby colleagues
- Use any wireless device during the exam

Hints to do well

- Read carefully the problem before to compute. Before to start you must have clear in your mind what you need to arrive to the answer.
- Do problems with symbols first (introduce them if you have to). Only put in numbers at the end.
- Check your answers for dimensional correctness.
- If you are not absolutely sure about a problem, please write down what you understand so that partial credit can be given.

Honor Pledge: Please sign at the end of the statement below confirming that you will abide by the University of Maryland Honor Pledge

"I pledge on my honor that I have not given or received any unauthorized assistance on this assignment/examination."

Signature:_______________________________

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Exercise 1

A ball is thrown horizontally with a horizontal speed u from a height of 500 m. The ball drops on the ground at a horizontal distance of 100 m.
Take g=10 m/s^2 and ignore air resistance.

Q-1.1: *How long takes the ball to touch the ground?*

$$v_{horiz} = u = \text{const}$$
$$v_{vert} = gt$$
$$d_{vert} = \frac{1}{2}gt^2 \Rightarrow t = \sqrt{\frac{2d_{vert}}{g}} = \sqrt{\frac{1000m}{10m/s^2}} = 10s$$

Q-1.2: *What is* u*?*

$$u = \frac{d_{horiz}}{t} = \frac{100m}{10s} = 10\frac{m}{s}$$

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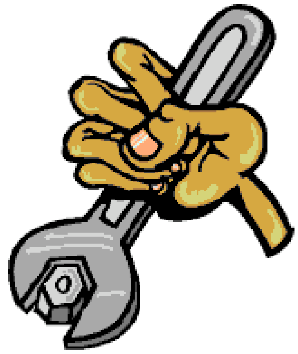
Exercise 2



To tighten a bolt, you push with a force of 80 N at the end of a wrench handle that is 0.25 m from the axis of the bolt.

Q-2.1: *What torque are you exerting?*

$$\tau_1 = F_1 \cdot R_1 = 80N \cdot \frac{25}{100} m = 20\ N \cdot m$$

Q-2.2: *If you move your hand inward to be only 0.10 m from the bolt, what force do you have to exert to achieve the same torque?*

$$\tau_2 = F_2 \cdot R_2$$

$$\text{If}\quad \tau_2 = \tau_1 \Rightarrow \quad F_2 \cdot R_2 = \tau_1 \Rightarrow \quad F_2 = \frac{\tau_1}{R_2} = \frac{20\ Nm}{0.1\ m} = 200\ N$$

Q-2.3: *If the wrench has a rotational inertia I=0.2 Kg·m^2 and your torque makes it rotate on a full circle in 4 s, what is the angular momentum of the wrench?*

$$L = I\omega$$

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{4s} = \frac{\pi}{2} s^{-1}$$

$$L = 0.2\ Kg \cdot m^2 \cdot \frac{\pi}{2} s^{-1} \approx 0.31\ \frac{Kg \cdot m^2}{s}$$

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Exercise 3

Q-3.1: *Write the general formula for the acceleration that a body will acquire due to the gravitational field of the Earth. Describe in words how it varies above, below and on the surface of the Earth.*

$$F_{gravity} = \frac{GM_{Earth}m}{R^2} \qquad R = \text{distance of the object from the center of the Earth}$$

$$a = \frac{F}{m} \Leftarrow \text{Newton's second law} \quad \Rightarrow \quad a_{gravity} = \frac{GM_{Earth}}{R^2}$$

$a_{gravity}$ decreases at growing distance (and incrases at smaller distances) with the square of the radius, in the special case in which the object is on the surface of the Earth ($R = R_{Earth}$) one gets

$$a_{gravity} = \frac{GM_{Earth}}{R^2_{Earth}} \equiv g \approx 10\frac{m}{s^2}$$

Q-3.2: *A satellite is sent to the height of* $h=0.1\cdot R_{Earth}$ *above the surface of the Earth. What is the acceleration due to gravity of the satellite?*
(Assume $g=10m/s^2$. Note: You do not need G, M_{Earth}, or R_{Earth})

$$a_{gravity} = \frac{GM_{Earth}}{R^2_{sat}} = \frac{GM_{Earth}}{(R_{Earth}+h)^2} = \frac{GM_{Earth}}{(R_{Earth}+0.1\cdot R_{Earth})^2} = \frac{GM_{Earth}}{R^2_{Earth}}\frac{1}{(1.1)^2} = \frac{g}{1.21} \approx 8.2\ \frac{m}{s^2}$$

Q-3.3: *If the satellite orbit is approximately circular, what is its revolution time around the Earth?*

Only the force of gravity acts on the satellite. Hence the centripetal acceleration necessary for a circular orbit is provided by the gravitational acceleration

$$a_{sat} = \frac{v^2}{R} = a_{grav} \qquad \text{so} \qquad v = \sqrt{a_{grav}R_{sat}} = \sqrt{a_{sat}\cdot 1.1R_{Earth}}$$

We can get the period from its relation with the speed along the path

$$v = \frac{2\pi R_{sat}}{T} \quad \Rightarrow \quad T = \frac{2\pi R_{sat}}{v} = \frac{2\pi(1.1\cdot R_{Earth})}{\sqrt{a_{grav}\cdot 1.1\cdot R_{Earth}}}$$

(Here one need to use $R_{Earth} \approx 6400Km = 64\cdot 10^5 m$ to get the numerical result)

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Exercise 4

A 100 Kg lead ball is initially at rest inside a cannon. The cannon, when it fires, takes 0.05 seconds to eject the ball with a speed of 200 m/s.

Q-4.1: *What is the change in momentum of the ball?*

$$\Delta p = p_{final} - p_{initial} = m\mathrm{v}_\mathrm{f} - m\mathrm{v}_\mathrm{i} = m\mathrm{v}_\mathrm{f} - 0 = 100\ \ Kg \cdot 200\ \ \frac{m}{s} = 2{,}0000\ \ Kg\frac{m}{s}$$

Q-4.2: *What is the change in kinetic energy of the ball?*

$$\Delta KE = KE_{final} - KE_{initial} = \frac{1}{2}m\mathrm{v}_\mathrm{f}^2 - \frac{1}{2}m\mathrm{v}_\mathrm{i}^2 = \frac{1}{2}m\mathrm{v}_\mathrm{f}^2 - 0 = \frac{1}{2}100\ \ Kg \cdot \left(200\ \ \frac{m}{s}\right)^2 = 2 \cdot 10^6\ \ Kg\frac{m}{s}$$

Q-4.2: *What is the force applied by the cannon during the shot?*

Knowing Δp and ΔKE one can think to use one of the following formula

$F \cdot \Delta t = \Delta p \quad \Rightarrow$ The change in momentum is equal to the Impulse (=Force times the time over which it is applied)

$F \cdot \Delta l = \Delta KE \quad \Rightarrow$ The change in the KE is equal to the work done (=Force times the length over which it is applied)

In this case we know $\Delta t = 0.05\ \ s$ but we ignore Δl (length of the cannon). So we must use the first formula

$$F \cdot \Delta t = \Delta p = 2{,}0000\ \ Kg\frac{m}{s}$$

so $$F = \frac{\Delta p}{\Delta t} = 4 \cdot 10^5\ \ \ N$$

Exercise 5

A 1200 Kg frictionless cart travels on a roller coaster as described in the picture

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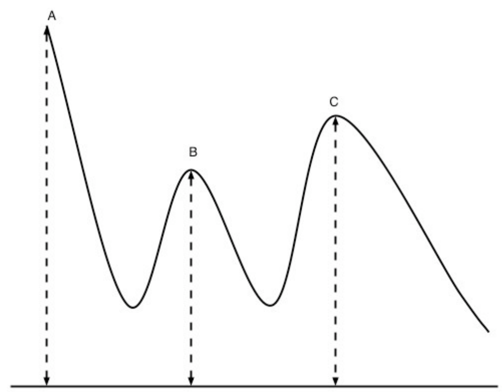

The roller coaster starts at rest from a height of 20 m.

The basic concept to be used in order to solve this kind of problem is
the conservation of the mechanical energy

$$ME = GPE + KE = mgh + \frac{1}{2}m\text{v}^2$$

The conservation of *ME* is correct given the lack (or negligibility) of friction (see text).

Q-5.1: *What is its kinetic energy when it goes over the hill B that is 12 m high?*

Using that $\text{v}_A^2 = 0$ (cart at rest) and the conservation of the mechanical energy,
we can write that at point B

$$mgh_B + \frac{1}{2}m\text{v}_B^2 = mgh_A \quad \Rightarrow \quad \frac{1}{2}m\text{v}_B^2 \equiv KE_B = mg(h_A - h_B) = 1200Kg \cdot 10\frac{m}{s^2} \cdot 8m = 96000\ J$$

Q-5.2: *What is the altitude of point C if the speed of the cart there is v_C=10 m/s ?*

Using that $\text{v}_A^2 = 0$ (cart at rest) and the conservation of the mechanical energy,
we can write that at point C

$$mgh_C + \frac{1}{2}m\text{v}_C^2 = mgh_A \quad \Rightarrow \quad gh_C = -\frac{1}{2}\text{v}_C^2 + gh_A \quad \Rightarrow \quad h_C = h_A - \frac{1}{2}\frac{\text{v}_C^2}{g}$$

$$h_C = 20m - \frac{1}{2}\frac{100\ \ m^2/s^2}{10\ \ m/s^2} = 20m - 5m = 15m$$