PHYS 1410 6.0: PHYSICAL SCIENCE (Fall 2011)

Class test #1 **Oct 5, 1:30 p.m. – 2:20 p.m. = 50 min**

NAME: STUDENT NR:

Formulae at the end and calculators = only aid; total = 19 points (18 points = 100 %)
Note on units: You don't have to write out the units in intermediate steps as long as you are working consistently in the SI system. Give your final answers in SI units (where appropriate).

1. (0.5 point) Give an example for an action-reaction pair that fulfills Newton's third law.

2. (0.5 point) Alice throws a snowball horizontally from the top of a roof; Bob throws a snowball straight down. Once in flight, the acceleration of snowball B is ... the acceleration of snowball A.

   ◦ greater than
   ◦ less than
   ◦ equal to

3. (6 points) Consider the following examples and provide sketches of their $x(t)$ and $v_x(t)$ graphs, where $x(t)$ characterizes the horizontal motion:

   (a) A runner at the beginning of a race, starting from rest to top speed.

   (b) A runner, slowing from top speed to a stop at the end of a race.

   (c) A ball thrown at the optimum launch angle of 45°.

4. (4 points) For the motion of an object one finds (through observation) the position-time law

   $$x(t) = A \sin \omega t$$

   where A and ω are positive constants.

   (a) What are the SI units of A and ω?

   (b) Calculate velocity and acceleration of the object.

   (c) Show that the magnitude of the force F_x that accelerates the object is proportional to the displacement.

5. (7 points + 1 bonus point) A ball is thrown vertically from the ground of planet F at $t = 0$ s. It reaches its maximum height at $t = 2$ s and is at a height of 10 m at $t = 3$ s.

   (a) Use Newton's second law to determine acceleration, velocity, and position of the ball as functions of time. Derive or prove the equations you provide.

   (b) At what time does the ball hit the ground? Give reasons for your answer.

   (c) Determine the initial speed v_0 and g on planet F.

   (d) Now assume that the ball is thrown at an launch angle of 20° with respect to the horizontal axis with the same initial speed. Calculate its range Δx.
   Hint: the range is given by the equation

$$\Delta x = v_{0,x} t_{\text{ground}} \quad \text{with } t_{\text{ground}} = \frac{2v_{0,y}}{g}$$

   (e) (bonus) At which angle do you have to throw the ball from the ground of the Earth to obtain the same range?

Note that air drag can be neglected in this problem. If the numbers you obtain in part (c) are wrong, you can still earn full marks in parts (d) and (e) if you provide correct (final) equations. Even without those equations you can earn partial marks for qualitative reasoning.

FORMULAE

$$\frac{d}{dt}t^n = nt^{n-1}\ ;\ \frac{d}{dt}\sin t = \cos t\ ;\ \frac{d}{dt}\cos t = -\sin t\ ;\ \frac{d}{dt}\exp t = \exp t$$

$$\frac{d}{dt}\left(f(t)+g(t)\right) = \frac{df}{dt} + \frac{dg}{dt}\ ; \qquad \frac{d}{dt}(\alpha f(t)) = \alpha\frac{df}{dt} \quad \text{for any } \alpha \in \Re$$

$$\text{product rule}: \ \frac{d}{dt}(fg) = \frac{df}{dt}g + f\frac{dg}{dt}\ ; \qquad \text{chain rule}: \ \frac{d}{dt}[f(x(t))] = \frac{df}{dx}\frac{dx}{dt}$$

$\frac{d}{dt}\vec{r}(t) = \vec{v}(t)$; $\frac{d}{dt}\vec{v}(t) = \vec{a}(t)$; $m\vec{a} = \vec{F}_{\text{net}}$; $F_{\text{grav}} = mg$; on Earth: $g = 9.8$ m/s^2