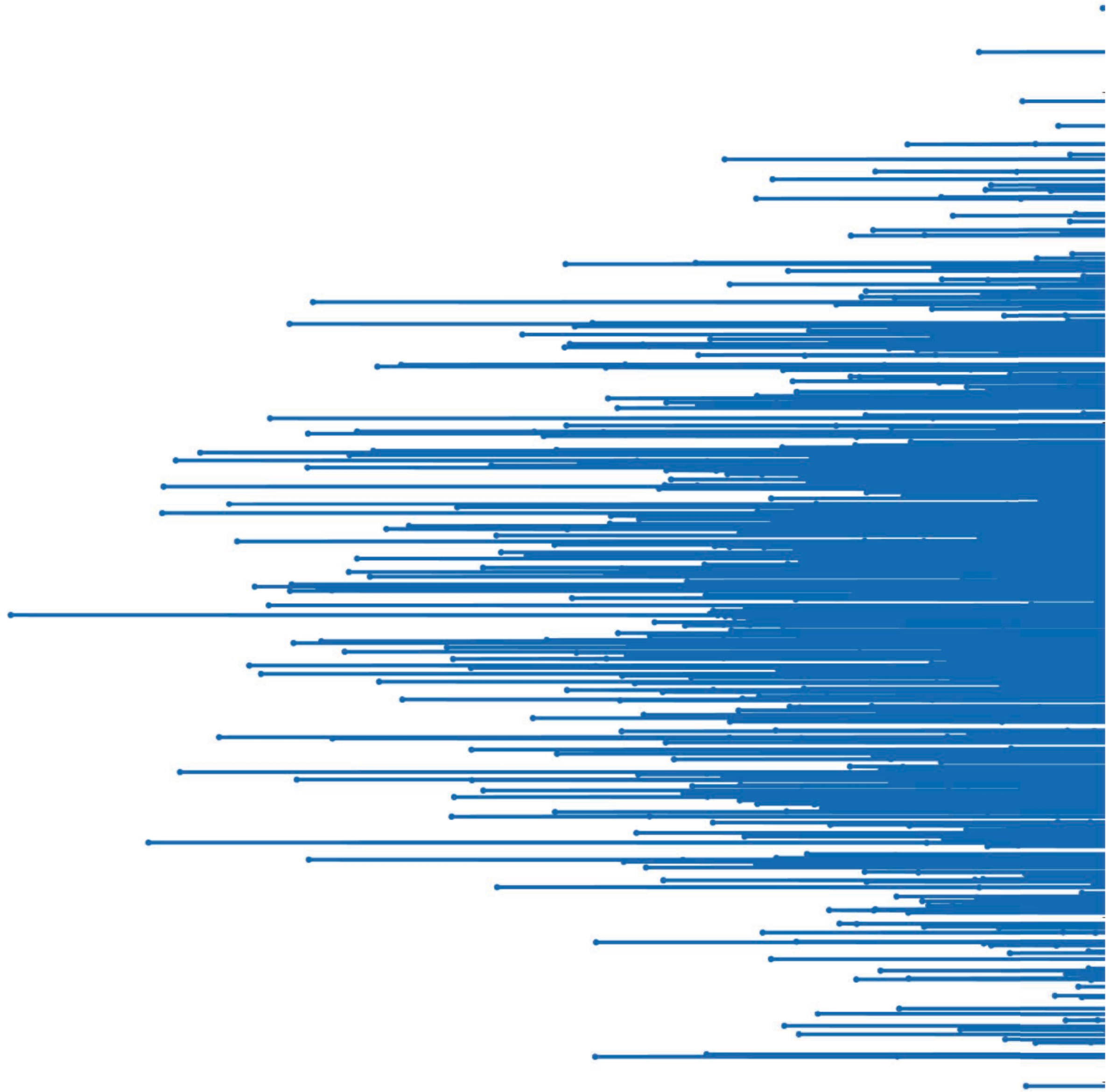
PHYS 2010 (W20)
Classical Mechanics



HW1

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Ref. (re images):
Knudsen & Hjorth (2000), Kesten & Tauck (2012)

Problem 1

A variable $n(t)$ is described by a first-order linear differential equation with constant coefficients

$$\tau \frac{dn(t)}{dt} + n(t) = n_\infty$$

where τ and n_∞ are constants. Let $n(0) = n_0$.

a) For $t \geq 0$, determine an expression for $n(t)$ in terms of τ, n_∞, and n_0.

b) Plot $n(t)$ versus t for the following two cases and explain the difference between the two plots:
   - i) $n_0 = 0, \quad n_\infty = 10, \quad \tau = 1,$
   - ii) $n_0 = 0, \quad n_\infty = 10, \quad \tau = 10,$

c) Plot $n(t)$ versus t for the following two cases and explain the difference between the two plots:
   - iii) $n_0 = 10, \quad n_\infty = 0, \quad \tau = 1,$
   - iv) $n_0 = 10, \quad n_\infty = 10, \quad \tau = 1,$

d) Plot $n(t)$ versus t for the following two cases and explain the difference between the two plots:
   - v) $n_0 = 10, \quad n_\infty = 0, \quad \tau = 1,$
   - vi) $n_0 = -10, \quad n_\infty = 10, \quad \tau = 1.$

Problem 2

An airplane flying upward at 35.3 m/s and an angle of 30.0° relative to the horizontal releases a ball when it is 255 m above the ground. Calculate (a) the time of it takes the ball to hit the ground, (b) the maximum height of the ball, and (c) the horizontal distance the ball travels from the release point to the ground. (Neglect any effects due to air resistance.)

Problem 3

You observe two cars traveling in the same direction on a long, straight section of Highway 5. The red car is moving at a constant v_R equal to 34 m/s and the blue car is moving at constant v_B equal to 28 m/s. At the moment you first see them, the blue car is 24 m ahead of the red car. (a) How long after you first see the cars does the red car catch up to the blue car? (b) How far did the red car travel between when you first saw it and when it caught up to the blue car? (c) Suppose the red car started to accelerate at a rate of a equal to $\frac{4}{3}$ m/s^2 just at the moment you saw the cars. How long after that would the red car catch up to the blue car?

Problem 4

A naval destroyer is testing five clocks. Exactly at noon, as determined by the WWV time signal, on the successive days of a week the clocks read as follows:

Clock	Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.
A	12:36:40	12:36:56	12:37:12	12:37:27	12:37:44	12:37:59	12:38:14
B	11:59:59	12:00:02	11:59:57	12:00:07	12:00:02	11:59:56	12:00:03
C	15:50:45	15:51:43	15:52:41	15:53:39	15:54:37	15:55:35	15:56:33
D	12:03:59	12:02:52	12:01:45	12:00:38	11:59:31	11:58:24	11:57:17
E	12:03:59	12:02:49	12:01:54	12:01:52	12:01:32	12:01:22	12:01:12

How would you arrange these five clocks in the order of their relative value as good timekeepers? Justify your choice.

Problem 5

Calculate the speed of an artificial earth satellite, assuming that it is traveling at an altitude h of 140 miles above the surface of the earth

Problem 6

Given the two vectors $\mathbf{A} = 2\mathbf{i} + \mathbf{j} - \mathbf{k}$, $\mathbf{B} = \mathbf{i} - \mathbf{j} + 2\mathbf{k}$, find $\mathbf{A} \times \mathbf{B}$.

Find a unit vector normal to the plane containing the two vectors **A** and **B** above.

Problem 7

Given the three vectors $\mathbf{A} = \mathbf{i}$, $\mathbf{B} = \mathbf{i} - \mathbf{j}$, and $\mathbf{C} = \mathbf{k}$, find $\mathbf{A} \cdot (\mathbf{B} \times \mathbf{C})$.

Find $\mathbf{A} \times (\mathbf{B} \times \mathbf{C})$ above.

Problem 8

An orbiting space station is observed to remain always vertically above the same point on Earth.

a. Where on Earth is the observer? Why?

b. Estimate the radius of orbit. Make sure to clearly note any assumptions made.

Problem 9

A bucket is left out in the rain. Will the speed at which the bucket is filled with water be altered if a wind starts to blow?

Bonus

A load of mass m begins to slip without friction down the inclined face of a wedge lying on a horizontal plane surface; there is no friction either between wedge and plane. The mass of the wedge is M, the angle of inclination of the wedge's top surface with the horizontal is α. Find the acceleration of the load and of the wedge relative to the plane, the force exerted by the load on the wedge and by the wedge on the plane.