Homework No. 06 (Fall 2024)

PHYS 205A-002: UNIVERSITY PHYSICS

School of Physics and Applied Physics, Southern Illinois University–Carbondale

Due date: Monday, 2024 Sep 23, 2:00 PM, on D2L

Instructions

- You are encouraged to use any of the resources to complete this homework. However, the extent to which you depend on resources while doing this homework is a measure of how much extra work you need to put in to master the associated concepts. Solutions should be the last resource.
- Links to solutions are provided. Further, links to few variations of the problem are provided that serve as practice problems.
- Describe your thought process in detail and organize it clearly. Make sure your answer has units and right number of significant digits.
- Additional problems, with hyperlinks to exams, are available in Lecture Notes.
- After completion, scan the pages as a single PDF file, and submit the file on D2L (under Assesments → Assignments). You can replace your PDF file, only the last file is graded.

Problems

1. (**10 points.**) A vinyl record on a turntable rotates at $33\frac{1}{3}$ revolutions per minute.
   (a) What is its angular speed in radians per second?
   (b) What is the linear speed of a point on the record at the needle when the needle is 15 cm from the turntable axis?
   (c) What is the linear speed of a point on the record at the needle when the needle is 7.4 cm from the turntable axis?

   [**Solution**]

2. (**10 points.**) Earth rotates about its axis once in 24 hours. Radius of Earth is 6400 km. Earth is spherical to a good approximation.
   (a) Compute the magnitude and direction of the centripetal acceleration at the equator, due to rotation of Earth.
   (b) Compute the magnitude and direction of the centripetal acceleration at the North pole, due to rotation of Earth.

(c) Compute the magnitude and direction of the centripetal acceleration at Carbondale (at a latitude of 38° N) due to rotation of Earth.

[**Solution**] Erratum: Unit of acceleration a should be $\mathrm{m/s^2}$, not $\mathrm{rad/s^2}$, everywhere.

3. (**10 points.**) The International Space Station (ISS) orbits Earth with a time period of 93 minutes at an altitude of 420 km. Radius of Earth is 6400 km.

   (a) Compute the frequency of ISS. Or, how many times does the ISS orbit Earth in a day?

   (b) Compute the angular frequency of ISS.

   (c) Compute the orbital speed of ISS.

   (d) Compute the centripetal acceleration of ISS. How will a crew member perceive this acceleration? Compare this number to the acceleration due to gravity on the surface of Earth ($g = 9.8\,\mathrm{m/s^2}$).

   [**Solution**]

4. (**10 points.**) A ball swings counterclockwise in a vertical circle at the end of a rope 1.00 m long. When the ball is 40.0° past the lowest point on its way up, its total acceleration is

$$(-20.\,\hat{\mathbf{i}} + 15\,\hat{\mathbf{j}})\,\frac{\mathrm{m}}{\mathrm{s^2}}. \tag{1}$$

   For that instant determine the following.

   (a) Sketch a vector diagram showing the components of its acceleration, both the $\hat{\mathbf{i}}$-$\hat{\mathbf{j}}$ basis and in the $\hat{\mathbf{r}}$-$\hat{\boldsymbol{\phi}}$ basis.

   (b) Determine the angle between the acceleration vector and the radial direction at the instant.

   (c) Show that the acceleration in the $\hat{\mathbf{r}}$-$\hat{\boldsymbol{\phi}}$ basis at the instant is

$$(-24\,\hat{\mathbf{r}} - 5.6\,\hat{\boldsymbol{\phi}})\,\frac{\mathrm{m}}{\mathrm{s^2}}. \tag{2}$$

   Then, read out the magnitude of its radial acceleration,

   (d) Determine the magnitude of the velocity of the ball.

   [**Solution**]