Quizzes (Spring 2024)

PHYS 205A-001: UNIVERSITY PHYSICS

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

Due date: At Noon before each class, on D2L

Instructions

- This document collects the quizzes for the complete semester. One question below is due on each day of lecture.
- Assessment of quizzes does not look for correctness. Instead, it expects you to be critical and creative.
- The questions are conceptual. They might be open ended, thus, it is not recommended to spend more than ten minutes on a question. You are encouraged to ponder about it though.
- After completion, scan the pages as a single PDF file, and submit the file on D2L (under Assessments → Assignments). The question number syntax Q-MMDD is derived from date.

Questions

Mathematical concepts

(**Q-0117:**) The following video,

https://youtu.be/0fKBhvDjuy0,

titled 'Powers of Ten' is a 1977 educational film describing the relative scale of the universe, by Charles and Ray Eames.

In the International System of Units (SI) the three fundamental units of measurement in mechanics are chosen to be time (second), length (meter), and mass (kilogram). If, instead, the three fundamental units of measurement in mechanics were chosen to be time (second), length (meter), and density (rho), then what would be the unit of measurement of mass in terms of second, meter, and rho.

(**Q-0119:**) What is wrong with this road sign:

Carbondale 7 mi (11.263 km)?

Motion along a straight line

(**Q-0122:**) Time always moves forward, that is, the time difference $\Delta t > 0$. In other words, time is monotonic. This is often referred to as the arrow of time. Change in position of an object, unlike time, could be positive, zero, or negative. Imagine and describe a universe where time is not monotonic.

(**Q-0124:**) When you throw a ball up in the air what is the velocity of the ball when it is reaches the highest point? (Answer: Zero.) What is the instantaneous acceleration of the ball when the ball reaches the highest point? (Hint: The instantaneous acceleration of the ball at the highest point is not zero.) Is this consistent with the definition of the instantaneous acceleration as the derivative of velocity with respect to time,

$$\mathbf{a} = \frac{d\mathbf{v}}{dt}? \tag{1}$$

(**Q-0126:**) The following BBC video captures the motion of a feather and a bowling ball when dropped together inside the world's biggest vacuum chamber.

https://www.youtube.com/watch?v=E43-CfukEgs

What would be the difference if you were to repeat this experiment on another hypothetical planet, say Mars.

Vector algebra

(**Q-0129:**) The following TED-Ed YouTube video emphasizes on the dependence of the vector components on the choice of coordinate basis vectors.

https://youtu.be/ml4NSzCQobk

Do the coordinate basis vectors, used to describe vectors, have to be orthogonal?

(**Q-0131:**) Is area a scalar or a vector? (Answer: Area is a vector.) Describe the direction associated with area.

Projectile motion

(**Q-0202:**) Uniform velocity in both horizontal and vertical direction leads to a trajectory along a straight line path. Uniform velocity in the horizontal direction and uniform acceleration in the vertical direction leads to a trajectory along a parabolic path. What would be the trajectory for uniform acceleration in both horizontal and vertical direction?

(**Q-0205:**) The following video by National Science Foundation, USA,

https://youtu.be/HB4ws7RoA3M

clarifies how the vertical and horizontal components of velocity change on the trajectory of a projectile motion.

(a) What is the vertical component of velocity at the highest point in projectile motion?

(b) What is the horizontal component of velocity at the highest point in projectile motion?

(c) What is the speed (magnitude of velocity) at the highest point in projectile motion?

(**Q-0207:**) The following video by National STEM Centre, United Kingdom,

https://youtu.be/z8S0_SHqoeY

demonstrates a counterintuitive feature in projectile motion. Next, ponder the following. In a room devoid of air a stuntman and a bullseye (target) are released from rest from the same height simultaneously. During the fall, the stuntman throws a ball horizontally towards the target. Is the ball expected to hit the target? If yes, explain. If not, why not?

Galilean relativity

(**Q-0209:**) The richness and complexity of the seemingly simple idea of relativity is nicely captured in the following 26 minute educational film, titled 'Frames of Reference', released in 1960, starring Profs. Ivey and Hume, and produced by Richard Leacock:

https://archive.org/details/frames_of_reference.

Watch the first ten minutes of the video. Then, answer the following. In 1860's Maxwell showed that speed of light in vacuum is a universal constant. How is this in direct conflict with the idea of (Galilean) relativity?

Centripetal acceleration

(**Q-0214:**) Earth rotates around its axis. So, does a flight flying against the direction of rotation take longer than a flight in the direction of rotation? Check the time of flight from New York City to Los Angeles and from Los Angeles to New York City. Explain.

(**Q-0216:**) Read about the amusement ride Gravitron at

https://en.wikipedia.org/wiki/Gravitron

Look up videos posted on social media of the ride. Briefly explain the physics of the ride.

Newton's laws of motion

(**Q-0219:**) The following video by North Carolina School of Science and Mathematics

https://youtu.be/MdrcyJN7Ie4?t=76

asks a question at time 1:16 minutes concerning spring scales. If you hang two equal masses on the two ends of a spring scale, what will the spring scale measure? What if the masses are not equal? Here are the related videos:

Part 1: https://youtu.be/gO2iwVG8OgA
Part 2: https://youtu.be/MdrcyJN7Ie4
Part 3: https://youtu.be/YTPOEKHEBXY

(**Q-0221:**) Newton's third law states that for every action there is an equal and opposite reaction. The following video by Video From Space

https://youtu.be/ZkVU-bj9bDk

demonstrates this in the International Space Station. Identify the action-reaction force pairs in the video.

(**Q-0223:**) A tank filled with water is being transported in a truck. The water level in the tank is observed to be flat while the truck is at rest. Will the water level in the tank slope forward, slope backward, or stay flat, when the truck is moving with uniform velocity along a straight road? The following video by Mr. Woodward

https://youtu.be/jakHjtvjT3Q

demonstrates this effect.

(**Q-0226:**) The Atwood machine, shown as **System 1** in Figure 1, consists of two masses m_1 and m_2 connected by a massless (inextensible) string passing over a massless frictionless pulley. A modified version of the Atwood machine, shown as **System 2** in Figure 1, consists of the same two masses m_1 and m_2 connected by a massless (inextensible) string passing over two massless frictionless pulleys. Which of the two systems leads to a larger acceleration? Why?

Newton's laws of motion: Friction, circular motion, drag

(**Q-0228:**) The following video produced by the international television program Curiosity Show

https://youtu.be/fwpZurI3oDg

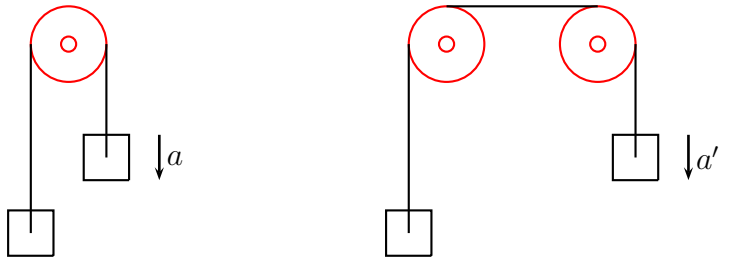

Figure 1: Atwood's machine and it's modified version.

demonstrates the effect of friction on moving cars. Since friction is necessary for motion would it be correct to conclude that friction acts in the forward direction, along the direction of velocity?

(**Q-0301:**) Consider a balloon filled with air, and another balloon filled with helium. Helium being lighter than air tends to rise up in air. While a car is taking a circular turn will a helium balloon tend to move radially inward or radially outward? The following video by Imagination Station in Toledo, Ohio,

https://youtu.be/2-UzBitLmf8

demonstrates this.

(**Q-0304:**) The following YouTube video by 3RDFlix

https://youtu.be/eGZWVwcaq0U

describes banking of roads. While taking a turn a car tends to skid outward if it goes too fast, then, do you expect it to slide inward if it goes too slow?

(**Q-0306:**) What is an inertial frame of reference? Are Newton's laws of motion applicable in non-inertial frames of reference?

Energy

(**Q-0318:**) A normal force is always pointed normal to a surface. What is the work done by the normal force acting on a block of mass sliding down an incline plane? Under what circumstances can a normal force do non-zero work? (Hint: Elevator.)

(**Q-0320:**) The following YouTube video by Interesting Engineering,

https://youtu.be/eoI98gjhx3Q,

describes the engineering behind aircraft catapult technology. Estimate the spring constant of an aircraft catapult.

(**Q-0322:**) The following YouTube video by TED-Ed,

https://youtu.be/A-QgGXbDyR0,

discusses perpetual motion machines. Why is Bhaskara's wheel not a perpetual motion machine?

Energy diagrams: Stability analysis

(**Q-0325:**) The following YouTube video by Khan Academy,

https://youtu.be/iba4gUeQN0w,

describes conservative forces. List the conservative forces you have come across.

(**Q-0327:**) A simple rigid pendulum has how many equilibrium points? Is one of them an unstable equilibrium point? After answering the question check out the following YouTube video by Steve Mould,

https://youtu.be/gMAKamGIiMc,

which behaves like a Kapitza pendulum.

(**Q-0329:**) The total energy E of a system is the sum of kinetic energy K and a potential energy U, given by

$$E = K + U, \tag{2}$$

where the potential energy as a function of distance $r > 0$ is shown in Figure 2. Determine if there is a restriction on the amount of total energy the system can have for a given type of interaction (decided by U). In particular, determine the maximum and minimum total energy the system could have? Explain.
Hint: Kinetic energy $K \geq 0$.

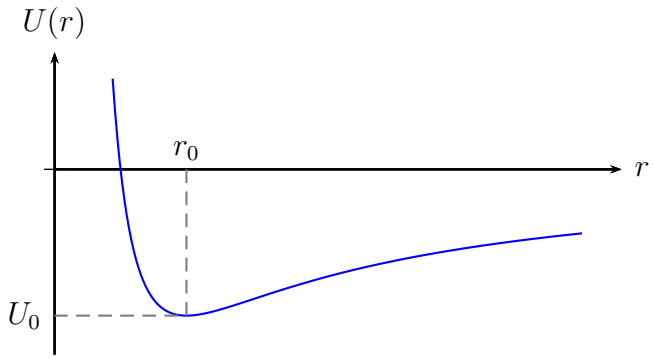

Figure 2: Potential energy $U(r)$ as a function of distance r.

Momentum

(**Q-0401:**) The following video by North Carolina School of Science and Mathematics

https://youtu.be/fdeH6Ksedwk

illustrates the idea of impulse. Similarly, argue why hail (versus water of same size) causes more damage to a surface.

(**Q-0403:**) The following video by Physics Demos

https://youtu.be/jRliH0jVilM

illustrates elastic and inelastic collisions. Give an example of (perfect) elastic collision.

(**Q-0405:**) The following YouTube video by Physics Girl

https://youtu.be/2UHS883_P60

demonstrates momentum transfer when a stack of balls is dropped. Describe the explosion of a supernova using this idea.

Center of mass

[**Not for submission**] The following video by North Carolina School of Science and Mathematics

https://youtu.be/ajTyhbvMEAg

explains how stability depends on center of mass. Give an example of an object whose center of mass is outside the object.

Rotational kinematics and dynamics

(**Q-0412:**) The following video by Khan Academy

https://youtu.be/h5BmWo5_sc8

shows that an arbitrary rotation can be described using a single vector. The direction of the vector represents the axis of rotation, and magnitude of the vector is equal to the amount of rotation about the axis. Are rotations commutative? That is, if you make two independent rotations about, say, perpendicular axes, does the order of rotations matter?

(**Q-0415:**) An object is following a circular path. Using a diagram illustrate the directions of the following vectors: angular displacement, angular velocity, angular acceleration, tangential acceleration, centripetal acceleration, Coriolis acceleration.

(**Q-0417:**) The following video by Visual Physics

https://youtu.be/WSfQwt2nmkg

describes the definition of torque. Determine the torque due to the normal force while a sphere is rolling on a surface.

(**Q-0419:**) The following video by North Carolina School of Science and Mathematics

https://youtu.be/lk_Pwu7nf1U

describes the role of rotational inertia in balancing acts. In the balancing act of the video which line represents the axis of rotation?

(**Q-0422:**) The following video by Mazda Australia

https://youtu.be/ru4JIZ-x8yo

explains the working of anti-lock braking system (ABS). Describe how the ABS could be controlled using the idea of slip ratio, $(v - \omega R)/v$, where v is the translational velocity, ω is the angular velocity, and R is the radius of the wheel.

Rotational energy and angular momentum

(**Q-0424:**) Inertia associated with translational motion is governed by mass. The rotational inertia is governed by both mass and the radial distribution of the mass about the axis of rotation. The following video by North Carolina School of Science and Mathematics illustrates how the rotational inertia affects rolling motion on an incline,

https://youtu.be/CHQOctEvtTY.

If you roll a raw egg and a hard-boiled egg (of the same mass) down an incline, which of them will reach the bottom of incline first?

(**Q-0426:**) The following video by TED-Ed

https://youtu.be/l5VgOdgptRg

describes how conservation of angular momentum is used in ballet. While spinning on your toes how does your angular velocity change when you pull your arms inward?

Gravitation

(**Q-0429:**) [Lagrange point] The following video by Spacedock

https://youtu.be/Gu4vA2ztgGM

illustrates the concept of Lagrange points. The James Webb Space Telescope (JWST), launched on 25 December 2021, is the formal successor to the Hubble Space Telescope (HST). Unlike HST, JWST does not orbit Earth. Instead it is stationed at the $L2$ Lagrange point of the Earth-Sun system. Why is the $L2$ Lagrange point a convenient location for space telescopes?

(**Q-0501:**) The following video by minutephysics

https://youtu.be/urQCmMiHKQk

evaluates how long it would take to fall through a tunnel passing through Earth. What is the gravitational potential at the center of Earth?

(**Q-0503:**) [Escape velocity] The following video by UNSW Physics

https://youtu.be/aN91GyEcB3E

explains escape velocity. Compare the orbital velocity of the International Space Station with the escape velocity of Earth.

(**Not for submission.**) [Blackhole] The following videos by Kurzgesagt–In a Nutshell

https://youtu.be/e-P5IFTqB98
https://youtu.be/yWO-cvGETRQ

explains blackhole. The radius of the event horizon of a blackhole is given by

$$R_s = \frac{2GM}{c^2}, \tag{3}$$

where c is speed of light in vacuum and M is the mass of the blackhole. For $M = 100\,kg$, a typical mass of a human, calculate the associated radius of event horizon. This is the scale to which the mass needs to compressed so that it reveals the exotic features of a blackhole.