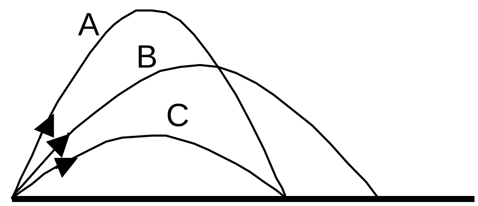
Questions from April 2000 Physics 111.6 Final Examination

A1. The figure shows the position versus time graph for a mouse running along a straight narrow tunnel. For the time interval shown, the mouse has

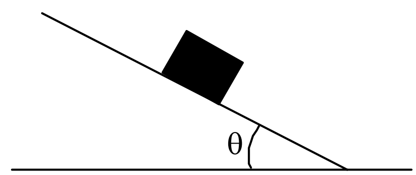
(A) constant non-zero acceleration.
(B) constant non-zero velocity.
(C) a velocity that changes linearly with time.
(D) zero velocity.
(E) a constantly changing acceleration.

A2. The diagram shows the trajectory of three artillery shells. Each was fired with the same initial speed. Which shell was in the air for the longest time? (Ignore air friction.)



(A) Shell A.
(B) Shell B.
(C) Shell C.
(D) Shells A and C were in the air for equal time, which was longer than for shell B.
(E) The three shells were in the air for the same time.

A3. A box, of mass m, is at rest on a ramp inclined at an angle θ to the horizontal as shown. The static friction force on the box is



(A) $mg\sin\theta$ directed up the ramp and parallel to the ramp.
(B) $mg\sin\theta$ directed horizontally to the left.
(C) $mg\cos\theta$ directed up the ramp and parallel to the ramp.
(D) $mg\cos\theta$ directed normal to the ramp.
(E) zero, since the box is stationary.

A4. A toy airplane is travelling in a horizontal circle at a constant speed at the end of a tether wire. The magnitude of the tension in the wire in this situation is F. The wire is played out until it is twice its original length <u>and</u> the plane is made to fly at twice its original speed. The tension in the wire is now

(A) $\frac{1}{4}F$
(B) $\frac{1}{2}F$
(C) F
(D) $2F$
(E) $4F$

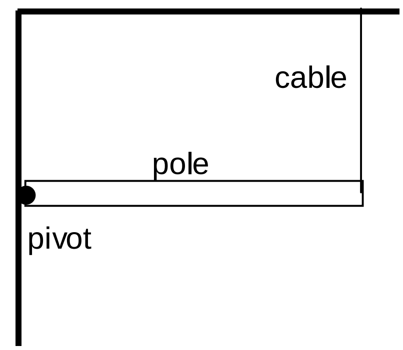
A5. A mass M, which is attached to a linear spring, executes simple harmonic motion with a period T. If the mass is replaced with a mass $2M$, the new period would be

(A) $2T$
(B) $3T$
(C) $4T$
(D) $\sqrt{2}\,T$
(E) $\frac{T}{\sqrt{2}}$

A6. A mass m is released from rest from a height h above the ground. Ignore any frictional effects. Which one of the following statements is correct?

(A) The speed of the mass when it strikes the ground is directly proportional to h.
(B) The speed of the mass when it strikes the ground is inversely proportional to h.
(C) The speed of the mass when it strikes the ground is directly proportional to m.
(D) The kinetic energy of the mass when it strikes the ground is directly proportional to h.
(E) The kinetic energy of the mass when it strikes the ground is inversely proportional to m.

A7. A uniform pole is attached to a vertical wall by a frictionless pivot. The pole is held horizontal by a vertical cable attached to the ceiling as shown. Considering torques on the pole about the axis of the pivot, which one of the following statements is correct?



(A) The magnitude of the torque due to the tension in the cable is equal to the magnitude of the torque due to the weight of the pole.
(B) The magnitude of the torque due to the tension in the cable is greater than the magnitude of the torque due to the weight of the pole.
(C) The magnitude of the torque due to the tension in the cable is less than the magnitude of the torque due to the weight of the pole.
(D) The tension in the cable is equal to the weight of the pole.
(E) The tension in the cable is greater than the weight of the pole.

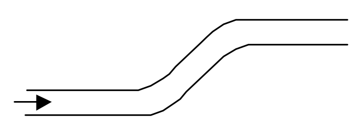
A8. An electron initially moving horizontally north enters a region where the electric field is constant and is directed vertically upward. Which of the following statements correctly describes the electron's trajectory in the region of uniform electric field?

(A) The electron follows a downward-curved path similar to that of a ball thrown horizontally.
(B) The electron follows an upward-curved path.
(C) The electron is deflected horizontally to the east on a circular arc.
(D) The electron is deflected horizontally to the west on a circular arc.
(E) The electron is deflected horizontally to the south on a circular arc.

A9. After being accelerated from rest through a potential difference of 40 kV, the kinetic energy of a proton is

(A) 40 kC (B) 40 kV (C) 40 keV (D) 40 kJ (E) 40 kW

A10. A non-viscous, incompressible fluid initially moves through a horizontal section of pipe with steady flow. The cross-sectional area of the pipe is constant. If the pipe undergoes an increase in elevation,



(A) the speed of the fluid increases and the pressure of the fluid decreases.
(B) the speed of the fluid increases and the pressure of the fluid increases.
(C) the speed of the fluid decreases and the pressure of the fluid decreases.
(D) the speed of the fluid decreases and the pressure of the fluid increases.
(E) the speed of the fluid remains constant and the pressure of the fluid decreases.

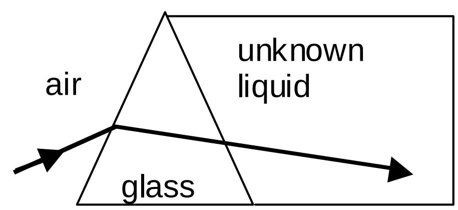
A11. A police car siren produces sound of frequency 955 Hz. A police car, with siren on, is chasing a speeding car towards a roadblock. The police car and the speeding car have the same velocity. An officer is standing at the roadblock. Which of the following statements is correct?

(A) A person in the speeding car hears a siren frequency of 955 Hz, and the officer standing at the roadblock hears a siren frequency less than 955 Hz.
(B) A person in the speeding car hears a siren frequency of 955 Hz, and the officer standing at the roadblock hears a siren frequency greater than 955 Hz.
(C) A person in the speeding car hears a siren frequency less than 955 Hz, and the officer standing at the roadblock hears a siren frequency of 955 Hz.
(D) A person in the speeding car hears a siren frequency greater than 955 Hz, and the officer standing at the roadblock hears a siren frequency of 955 Hz.
(E) A person in the speeding car hears a siren frequency less than 955 Hz, and the officer standing at the roadblock hears a siren frequency greater than 955 Hz.

A12. When a copper wire is connected across the terminals of an ideal battery, it draws a current *I*. If that wire is replaced by another copper wire of twice the length and twice the radius, the current drawn from the battery will now be

(A) ¼ *I*
(B) ½ *I*
(C) *I*
(D) 2 *I*
(E) 4 *I*

A13. A ray of green light travels through air and is refracted as it enters a glass prism as shown in the diagram. An unknown liquid is in contact with the right side of the prism. The light follows the path shown. Which one of the following statements is true?



(A) The frequency of the light inside the prism is different from the frequency in the air or in the unknown liquid.
(B) The index of refraction of the glass is smaller than that of the air.
(C) The index of refraction of the unknown liquid is the same as that of the glass.
(D) The speed of light is larger in the unknown liquid than in the glass.
(E) The index of refraction of the unknown liquid is the same as that of the air.

A14. A particle, moving through a certain region of space, experiences a non-zero magnetic force. Which of the following is possible?

(A) No magnetic field exists in that region.
(B) A magnetic field exists in this region and the particle's velocity vector is parallel to the magnetic field vector.
(C) A magnetic field exists in this region and the particle is moving at right angles to the magnetic field.
(D) The particle is electrically neutral.
(E) A magnetic field exists in this region and the particle is moving in the direction opposite to the magnetic field vector.

A15. The following statements describe differences between a camera and the human eye. Which statement is correct?

(A) The camera forms an inverted image; the eye does not.
(B) The camera always forms a real image; the eye does not.
(C) The camera always has a fixed image distance; the eye does not.
(D) The camera always has a fixed focal length; the eye does not.
(E) A camera cannot focus on objects at infinity, but the eye can.

A16. In a Young's double-slit experiment using light of wavelength λ, the first bright fringe adjacent to the central maximum occurs where the path difference from the two slits is

(A) 0 (B) $\lambda/4$ (C) $\lambda/2$ (D) λ (E) 2λ

A17. The observation that a low-pressure gas, when excited in a high-voltage discharge tube, emits only certain discrete wavelengths of light, led to an important advance in our understanding of nature. Which of the following best describes this advance?

(A) The electron charge is the smallest quantum of charge found in nature.
(B) Light has a particle-like nature as well as a wave nature.
(C) Energy and mass are equivalent.
(D) Short wavelength photons have more energy than long wavelength photons.
(E) Electron energy levels in atoms have discrete and well-defined energy values, rather than a continuum of possible values.

A18. Which of the following statements about the strong nuclear force is **false**?

(A) It has a short range.
(B) It is smaller in magnitude than the gravitational and electromagnetic forces.
(C) It is always attractive and never repulsive.
(D) It acts between all nucleons.
(E) Without it, the nucleus would not exist.

A19. Identify the unknown nucleus X in the following reaction:

$$^{27}_{13}\mathrm{Al} + \alpha \rightarrow X + n$$

(A) $^{30}_{14}\mathrm{Si}$ (B) $^{27}_{15}\mathrm{P}$ (C) $^{28}_{13}\mathrm{Al}$ (D) $^{27}_{14}\mathrm{Si}$ (E) $^{30}_{15}\mathrm{P}$

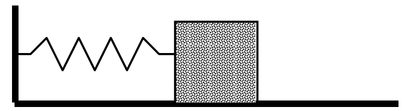
A20. The process in which a nucleus splits into two roughly equal parts with the release of some energy is called

(A) Fusion.
(B) Fission.
(C) α–decay.
(D) β–decay.
(E) γ–decay.

B1. An elevator is suspended from a vertical cable. When the elevator is accelerating downward at $7.30\ \mathrm{m/s^2}$, the tension in the cable is 6.56×10^3 N. Calculate the mass of the elevator.

B2. A satellite, "*Martian Orbiter I*", is in a circular orbit around Mars. The speed of the satellite is 3.08×10^3 m/s. The mass of Mars is 6.42×10^{23} kg. Calculate the radius of the satellite's orbit.

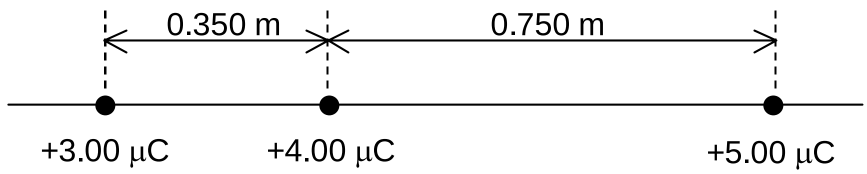
B3. A mass of 0.550 kg on a frictionless horizontal surface is attached to an ideal spring. The mass is displaced 0.0400 m from its equilibrium position and released. Its speed as it passes the equilibrium position is 0.240 m/s. Calculate the spring constant.



B4.

B5. A beach ball, with a mass of 0.124 kg, is held fully submerged in water by pushing down on it with a force of 7.00 N. Calculate the buoyant force on the beach ball when it is fully submerged.

B6. Three point charges are arranged on a line as shown. Calculate the magnitude of the net electric force on the +4.00 μC charge.



B7. An 8.50 Ω resistor and a 13.0 Ω resistor are wired in parallel and are connected to an ideal 12.0 V battery. Calculate the total current supplied by the battery.

B8. Photosynthesis is the process by which chlorophyll in plants absorbs sunlight and converts carbon dioxide (CO_2) into carbohydrates. In a typical reaction, nine photons are needed to convert one molecule of CO_2 into carbohydrate and oxygen. Assuming the light has wavelength 670 nm (this is the wavelength at which chlorophyll absorbs most strongly), how much energy is absorbed in a typical reaction? (Express your answer in eV.)

B9. The critical angle for total internal reflection at a diamond-air interface is 24.4°. Calculate the index of refraction of diamond.

B10. The isotope ${}^{14}_{6}C$ has a half-life of 5730 years (1.81×10^{11} s). If a sample contains 1.00×10^{22} carbon-14 nuclei, what is its activity (in Bq)?

B11. The work function of lead is 4.14 eV. Photons of wavelength 216 nm are incident on a lead surface. Calculate the maximum kinetic energy of the electrons emitted from the lead surface. (Express your answer in eV.)

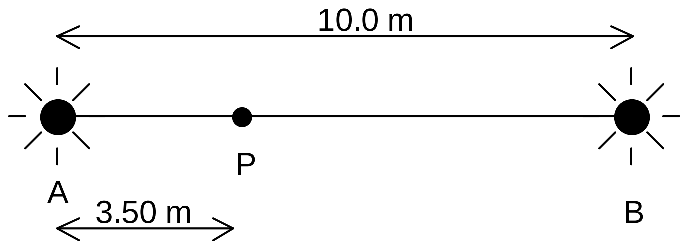
C1. A speeding automobile, with a speed of 30.0 m/s, strikes the rear of a parked automobile. After impact the two vehicles remain locked together as they skid along a horizontal stretch of pavement with all their wheels locked (i.e. sliding not rolling). The mass of the speeding automobile is 2200 kg and that of the parked automobile is 1400 kg.

(a) Calculate the speed of the two automobiles immediately after the impact.

(b) The coefficient of kinetic friction between the tires and the pavement is 0.950. Calculate the magnitude of the kinetic friction force on the skidding vehicles.

(c) Calculate the distance that the vehicles skid before coming to rest.

C2. Two audio speakers, A and B, are 10.0 m apart. Both speakers emit sound waves with the same frequency and are in phase. Assume the sound from each speaker is emitted uniformly in all directions. An observer at point P, located on a line between the two speakers, is 3.50 m from speaker A. The speed of sound in air is 343 m/s.



(a) If the observer is to hear no sound at point P, calculate the lowest (non-zero) frequency of the sound waves that can be emitted by each speaker.

(b) Assume that only speaker A is activated, emitting sound with a power of 100 W. Calculate the sound intensity level (in dB) heard by the observer at P.

(c) Speaker B is now mounted on a cart so that it moves away from the observer at P with a speed of 4.00 m/s along the line connecting the two speakers. Both speakers now emit sound waves with a frequency of 650.00 Hz. Calculate the beat frequency heard by the observer.

C3. One of the fusion reactions which may be used in commercial power stations in the future combines two deuterium nuclei ($^{2}_{1}H$) to form a tritium nucleus ($^{3}_{1}H$) and a proton:

$$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{1}H + p$$

The atomic masses are: $m(^{2}_{1}H) = 2.014102\ u$

$m(^{3}_{1}H) = 3.016050\ u$

The deuterium nuclei can be obtained from normal sea water. There are 6.02×10^{23} water molecules in 18.0 g of sea water, and there are two hydrogen atoms in each water molecule. The fraction of hydrogen nuclei which are in the form of deuterium is 1.50×10^{-4}.

(a) Calculate the number of deuterium nuclei in a 1.00-kg sample of sea water.

(b) Calculate the energy released in one fusion reaction (in MeV).

(c) Calculate the ratio of the energy released in the fusion of 1.00 kg of sea water to that released in the combustion of 1.00 kg of gasoline (which is 5.00×10^{7} J).