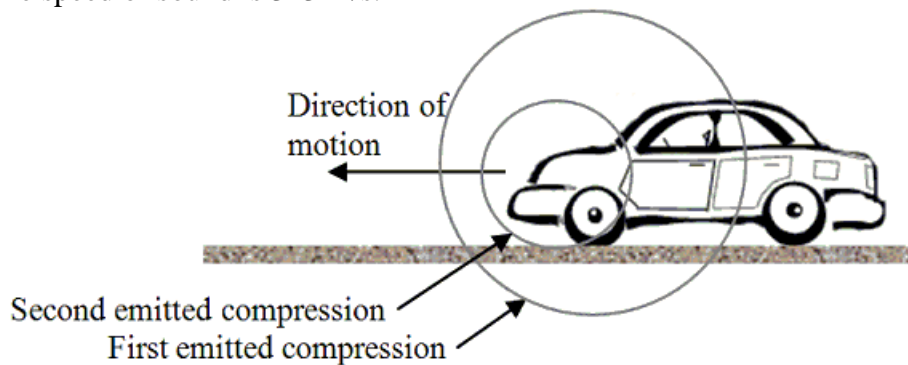


1. The activity of carbon-14 in a sample of charcoal from an archaeological site is 0.07 Bq. Determine the approximate age (in years) of the sample. The half-life of carbon-14 is 5730 years, and the activity of C-14 from live organism is 0.23 Bq.
- A) 9800
B) 12500
C) 14500
D) 16500
E) 18500
2. How many neutrons will remain in the nucleus C-14 nucleus after emits a photon?
- A) 15
B) 13
C) 14
D) 12
E) None of these
3. The car in the drawing is moving to the left at 35 m/s. The car's horn continuously emits a 220 Hz sound. The figure also shows the first two regions of compression of the emitted sound waves. The speed of sound is 343 m/s.



- What is the approximate frequency heard by an observer in front of the car, racing toward it to the right at 50 m/s?
- A) 108 Hz
B) 176 Hz
C) 200 Hz
D) 281 Hz
E) None of these

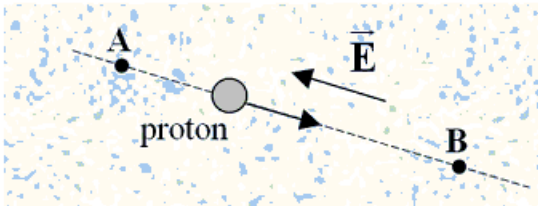
4. The mass of a uniform 400-m long cylindrical metal rod is 1508 kg. The radius of the circular cross-section of the rod is 0.02 m. The Young's modulus of this metal is $2.1 \times 10^{10} \text{ N/m}^2$. If both ends of this rod are clamped, what is the lowest frequency (in Hz) of vibration that will create a standing wave along the rod?
- A) 6.5
 - B) 5.7
 - C) 3.3
 - D) 8.5
 - E) None of these
5. What is the third-lowest possible frequency of vibration in a 3.2 m pipe closed at one end, open at the other? The speed of sound is 343 m/s.
- A) 89
 - B) 134
 - C) 154
 - D) 178
 - E) None of these
6. A guitar string produces four beats/s when sounded with a 250 Hz tuning fork and three beats per second when sounded with a 257 Hz tuning fork. What is the vibrational frequency of the string?
- A) 240 Hz
 - B) 266 Hz
 - C) 258 Hz
 - D) 262 Hz
 - E) None of these
7. A string with a linear density of 0.035 kg/m and a mass of 0.014 kg is clamped at both ends. Under approximately what tension in the string will it have a fundamental frequency (lowest frequency) of 220 Hz?
- A) 270 N
 - B) 650 N
 - C) 450 N
 - D) 1080 N
 - E) None of these

8. A proton ($q = 1.6 \times 10^{-19} \text{ C}$) is located at $x = 0$ on the x -axis. What is the magnitude of the electric potential difference (in volts) due to this proton between the points $x = 2 \text{ nm}$ and $x = 1 \text{ nm}$? (Note: $1 \text{ nm} = 1 \times 10^{-9} \text{ m}$)
- A) 0.56
 B) 1.24
 C) 0.72
 D) 3.41
 E) None of these

9. A positive point charge $q_1 = 3e$ is a distance a from a negative point charge $q_2 = -5e$, where e is the charge on a proton. How far from q_1 may a third point charge be placed without that charge experiencing a net electric force? Give your answer as a multiple of the distance a . Note: the quadratic formula will be needed here:

$$x = [-b + (b^2 - 4ac)^{1/2}] / 2a$$

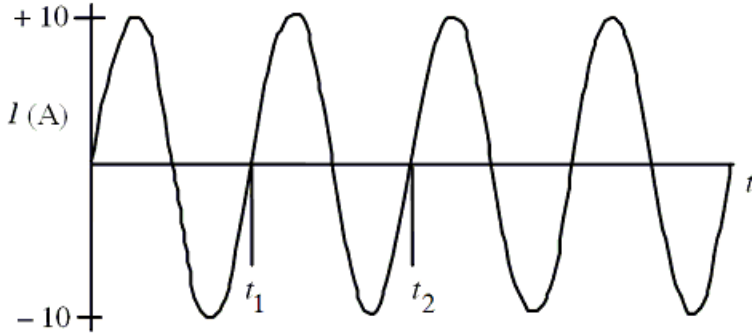
- A) 1.35 a
 B) 2.02 a
 C) 3.44 a
 D) 4.11 a
 E) None of these
10. An electric charged is pushed by a 1250 N force from A to B, against the electric field, as shown in the picture. If the distance from point A to point B is 0.50 m, what is the change in the charge's electric potential energy, in joules?



- A) 625
 B) 875
 C) 985
 D) 420
 E) None of these
11. If the magnitude of the electric field in the previous problem is 600 N/C , how much work is required to move a $+150 \mu\text{C}$ point charge from **P** to **Q**?
- A) 0.011 J
 B) 0.045 J
 C) 75.00 J
 D) 140.50 J
 E) None of these

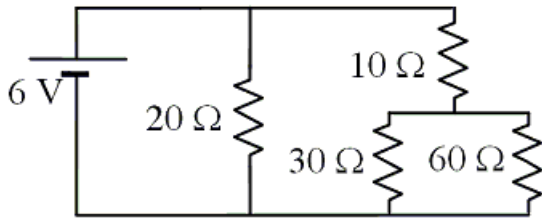
12. A 4-A current is maintained in a simple circuit with a total resistance of $2\ \Omega$. If the cost of electrical energy is \$0.12 per kilowatt-hour, about how much (in dollars) would it cost to maintain the current in this circuit for five months?
- A) 9
 B) 14
 C) 18
 D) 33
 E) None of these

13. The figure shows variation of the current in amperes through the heating element with time in an iron when it is plugged into a standard 120 V, 60 Hz outlet.



What is the total resistance (in ohms) in this circuit?

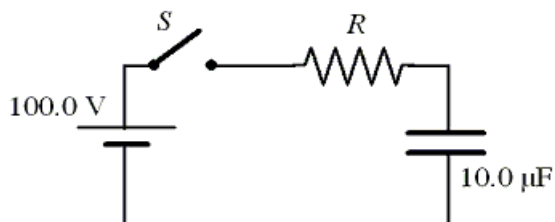
- A) 16.97
 B) 12.00
 C) 14.14
 D) 2.00
 E) None of these
14. Four resistors and a 6-V battery are arranged as shown in the circuit diagram.



Determine the current through the 20-ohm resistor.

- A) 0.30 A
 B) 0.10 A
 C) 0.50 A
 D) 0.20 A
 E) None of these

15. The figure shows a simple RC circuit consisting of a 100-V battery in series with a 10.0- μF capacitor and a resistor. Initially, the switch S is open and the capacitor is uncharged.



Two seconds after the switch is closed, the capacitor's charge is 500 micro-coulombs. What is the resistance of the resistor, in kilo-ohms?

- A) 865
 - B) 567
 - C) 435
 - D) 289
 - E) None of these
16. A proton is fired eastward along the Earth's equator. In which direction will it be deflected?
- A) upward
 - B) downward
 - C) northward
 - D) southward
 - E) None of these
17. A ray of light propagates through glass ($n = 1.51$), and exits into a liquid. If the critical angle for total internal reflection is 65.2° , determine the index of refraction of the liquid.
- A) 1.08
 - B) 1.21
 - C) 1.37
 - D) 1.28
 - E) None of these
18. Which one of the following statements is *not* a characteristic of a plane mirror?
- A) The image is real.
 - B) The magnification is +1.
 - C) The image is always upright.
 - D) The image is reversed right to left.
 - E) The image and object distances are equal in magnitude.

19. The focal point of a concave mirror is 4.0 m in front of the mirror. A woman stands 2.0 m in front of the mirror. What is the distance (in m) between the woman and her image?
- A) 2
 - B) 3
 - C) 4
 - D) 6
 - E) None of these
20. What must be the capacitance (in nano-farads) of an LC radio receiver circuit whose inductance is 0.33 micro-henry if it is tuned to an AM radio station emitting radio waves at a frequency of 2.00×10^6 Hz?
- A) 8.9
 - B) 11.8
 - C) 14.6
 - D) 19.2
 - E) None of these
21. A circular conducting loop of radius 7.0 cm contains 30 turns of wire and is positioned such that a uniform 1.40 T magnetic field makes an angle of 60° with respect to the line that is normal to the plane of the loop. What will be the average induced voltage (emf) in the loop if the magnetic field increases to 3.40 T in 0.15 s?
- A) 0.42 V
 - B) 0.75 V
 - C) 0.87 V
 - D) 6.16 V
 - E) None of these
22. A straight metal rod is dropped toward the ground at the equator. The rod is aligned along the east-west directions, parallel to the equator. Soon after the rod is dropped, what is the direction of the force on the rod exerted by the Earth's magnetic field?
- A) northward
 - B) southward
 - C) upward
 - D) downward
 - E) none of these
23. Light propagates from soda lime glass ($n = 1.518$) into Pyrex glass ($n = 1.473$). Determine the smallest angle of incidence onto the Pyrex glass that will cause all of the light to be reflected back into the soda lime glass.
- A) 13.99°
 - B) 76.01°
 - C) 52.48°
 - D) 65.22°
 - E) None of these

24. An object with a height of 6.0 cm is placed in front of a concave lens. The focal point of the lens is 18 cm from the lens. The resulting upright image has a height of 2.0 cm. How far is the object from the lens?
- A) 7.5 cm
 - B) 6.0 cm
 - C) 36 cm
 - D) 17 cm
 - E) None of these
25. A transparent polymer having an index of refraction of 1.45 is to be used to coat a glass plate with a thin film. The index of refraction of the glass is 1.60. What is the approximate minimum thickness (in nm) of film that will cause maximum reflection for light of wavelength 700 nm incident normally from the air onto the film?
- A) 219
 - B) 651
 - C) 632
 - D) 304
 - E) None of these
26. A rocket is designed to self-destruct soon after an explosive onboard is armed. The rocket is launched from Earth and accelerated to an unknown final speed. After reaching a final speed of $0.99c$, a clock onboard the rocket determines that the explosive detonates 3.50 seconds after it is armed. How many seconds after arming will observers on Earth say the explosion occurs?
- A) 12.33
 - B) 3.12
 - C) 4.55
 - D) 24.81
 - E) None of these
27. A nucleus having a mass of $3.97464500 \times 10^{-25}$ kg decays via gamma emission to a nucleus having a mass of $3.97464317 \times 10^{-25}$ kg. What is the wavelength of the gamma photon emitted, in nano-meters (nm)?
- A) 1.75
 - B) 20.54
 - C) 0.01
 - D) 4.03
 - E) None of these
28. A measurement of the speed of a proton ($m = 1.67 \times 10^{-27}$ kg) is determined to be between 4.99 m/s and 5.01 m/s, i.e., $v = 5.00 \pm 0.01$ m/s. What is the approximate least-possible uncertainty in the proton's location, in nanometers (nm), according to the Heisenberg Uncertainty principle? (Note: $h = 6.63 \times 10^{-34}$ J-s)
- A) 120 nm
 - B) 830 nm
 - C) 1340 nm
 - D) 3160 nm
 - E) None of these

29. What frequency of light (in hertz) will cause electrons in the ground state ($n=1$) of hydrogen atoms to be excited to the $n=2$ level?
- A) 1.12×10^{14}
 - B) 8.97×10^{14}
 - C) 2.46×10^{15}
 - D) 5.82×10^{15}
 - E) None of these
30. What is the change in the decibel level when the sound intensity changes from $4 \times 10^{-9} \text{ W/m}^2$ to $1.7 \times 10^{-8} \text{ W/m}^2$?
- A) 6.06
 - B) 6.18
 - C) 6.28
 - D) 7.23
 - E) None of these
31. Light of what minimum frequency incident on a metal surface will cause some electrons to be emitted from the metal with a speed of about $1.19 \times 10^6 \text{ m/s}$, given that the work function for the metal is 5.0 eV?
- A) $7.3 \times 10^{14} \text{ Hz}$
 - B) $1.2 \times 10^{15} \text{ Hz}$
 - C) $3.8 \times 10^{17} \text{ Hz}$
 - D) $2.2 \times 10^{15} \text{ Hz}$
 - E) None of these
32. How many protons remain in the nucleus that is left when $^{145}_{61}\text{Pm}$ decays by emitting first a beta particle, then an alpha particle?
- A) 59
 - B) 60
 - C) 61
 - D) 58
 - E) None of these
33. What is the frequency (in Hz) of the 0.059-MeV gamma-ray photon emitted by $^{31}_{14}\text{Si}$?
- Note: 1 MeV = one million eV.
- A) 1.4×10^{-19}
 - B) 1.7×10^{-17}
 - C) 2.1×10^{-14}
 - D) 4.8×10^{-15}
 - E) None of these