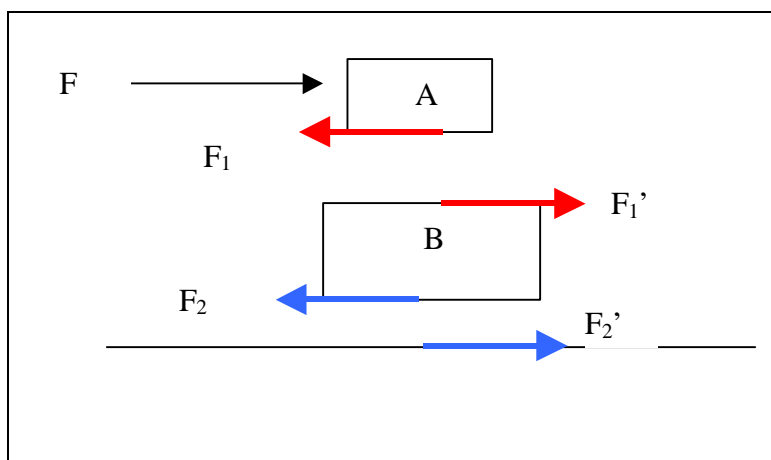


AL Physics MC Answers

Year: 2000

Questions: 1 - 45

1.



In the diagram, F_1 : frictional force acting on A by B

F_1' : frictional force acting on B by A

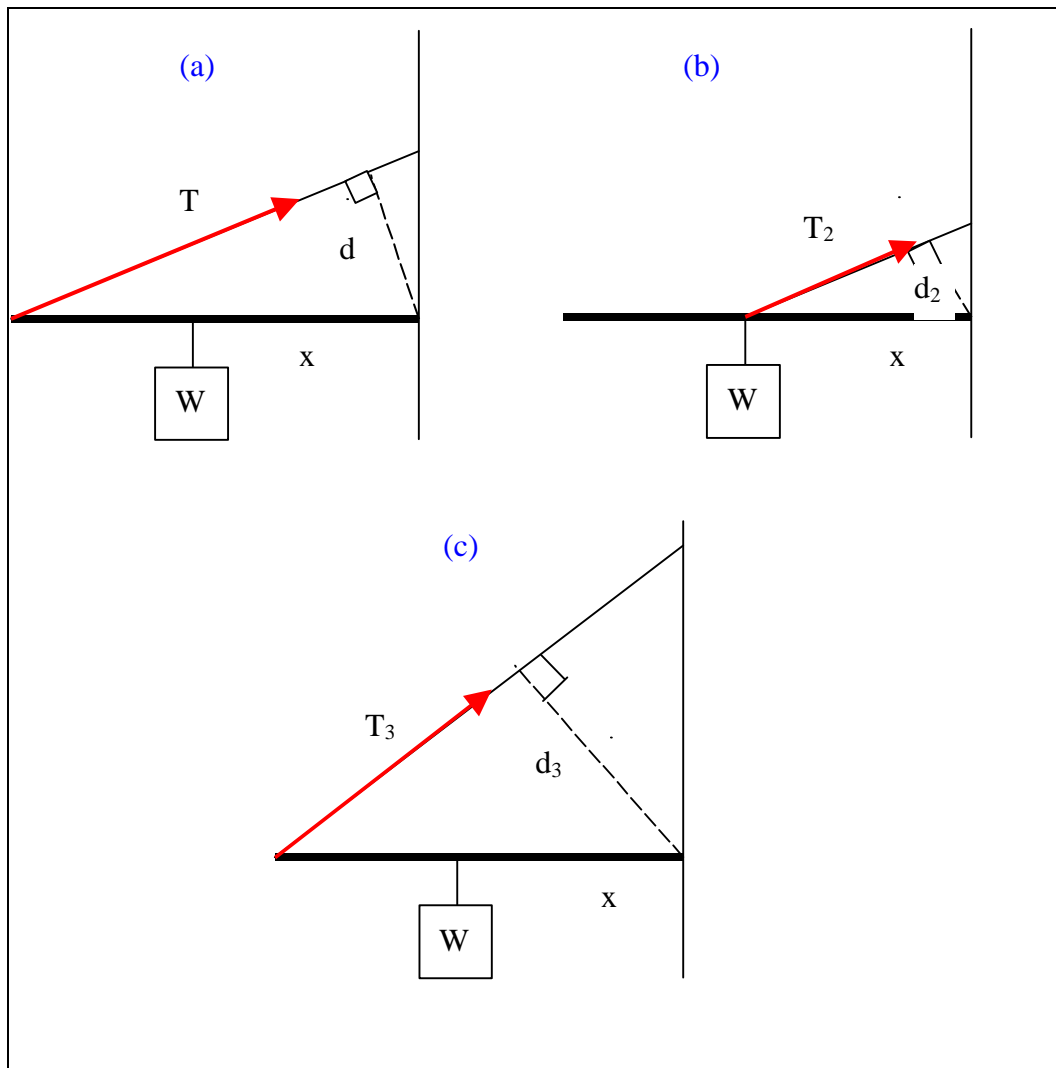
F_2 : frictional force acting on B by the table

F_2' : frictional force acting on the table by B

- (1) Incorrect. Treat the two blocks as a whole system, then the external forces acting on this system are only F and F_2 . The two blocks remains stationary, so $F = F_2$.
- (2) Correct.
- (3) Correct. Treat the two blocks as a single one, equilibrium does not depend on the point of application of F (F_2 depends on the condition of surface and the total weight. Those factors does not change, so F_2 is still equal to F)

- 2. (1) Incorrect. R is much greater than W because the ball needs a large upward acceleration to reverse its velocity in a very short time interval.
- (2) Incorrect, R is zero because the whole weight of the orbiting astronaut is used for circular motion
- (3) Correct, “moving downward with a uniform velocity” means no acceleration. $R = W$

3.



- (1) Correct. In Fig (a), $Wx = Td$. When x increases, T increases.
- (2) Correct. Compare (a) and (b), $d_2 < d$, so $T_2 > T$
- (3) Incorrect. Compare (a) and (c), $d_3 > d$, so $T_3 < T$

4. $T - mg = ma$, $a = T/m - g = 120/8 - 10 = 5 \text{ ms}^{-2}$

5. $mg\sin\theta - fr = ma$

$fr = mg\sin\theta - ma$

$fr = 0.5(10\sin15^\circ - a)$ and $fr = 0.5(10\sin20^\circ - 2a)$

Solving the above the two equation, we get $a = 0.83 \text{ ms}^{-2}$ and $fr = 0.88 \text{ N}$

6. Same force, same application time, so same momentum change.

Kinetic energy can be written as $KE = \frac{P^2}{2m}$, where P is the momentum.

If momentum is the same, $KE \propto \frac{1}{m}$. So the required ratio is 2 : 1.

7. (1) (2) Correct. In equilibrium, $mg = kx$, where x is the compression.
 (3) Incorrect. If all gravitational potential energy is converted into strain energy, then

$$mg(h + x') = \frac{1}{2} kx'^2.$$

Even if $h = 0$, $x' = 2mg/k = 2x$.

Only part of the original g.p.e. is stored in the spring after the ball comes to rest.

8. The centripetal force is provided by the horizontal component of N, so

$$N \sin \theta = mv^2/r$$

No acceleration in the vertical motion, so

$$N \cos \theta = mg$$

Remarks:

- Don't confuse with the common inclined plane: $N = mg \cos \theta$.
 Slide down an inclined plane: acceleration is downward and parallel to the plane
 Banked road: acceleration is exactly horizontal.
 Net force is required along the direction of acceleration
- Steps of analyzing circular motion
 - (a) Draw all the forces
 - (b) Locate the center of circular motion**
 - (c) Resolve the forces in (a) along the radial direction
 - (d) Net force (radial inwards) = mv^2/r
 - (e) Usually, net force along the perpendicular dir = 0 (except the simple pendulum)

9. Low-attitude satellite, $v = \sqrt{gr}$, where g is the field strength at the surface and r is the

radius of the planet. Period = $\frac{2\pi r}{v} \propto \sqrt{\frac{r}{g}} = \sqrt{\frac{r^3}{GM}}$

Same period \Rightarrow same $r^3/M \Rightarrow$ same density. [$\rho = M/(4\pi r^3)$]

10. Method I

Extension at equilibrium $x = mg/k = 0.1 \times 10/12 = 0.0833 \text{ m}$

The block is projected downwards with the speed 0.5 ms^{-1}

Initial total energy =

$$\frac{1}{2}mv^2 + \frac{1}{2}kx^2 - mgx = \frac{1}{2}(0.1)(0.5)^2 + \frac{1}{2}(12)(0.0833)^2 - 0.1 \times 10 \times 0.0833 = -0.0291J$$

(In calculating the g.p.e., h is measured from the position of natural length 0)

When the block comes to rest momentarily, all the energy is converted into strain energy and g.p.e.

$$\frac{1}{2}ky^2 - mgy = -0.0291J, \text{ where } y \text{ is the displacement of the turning point.}$$

Solving the above quadratic equation, we get $y = 0.129\text{m}$ (lower turning point) or 0.0376m (upper turning point).

Max acceleration occurs at the turning points.

If we consider the upper turning point, the net force is $mg - ky$ (because a is downward)

$$a = \frac{0.1 \times 10 - 12 \times 0.0376}{0.1} = 5.5 \text{ ms}^{-2}$$

If we consider the lower turning point, the net force is $12(0.129) - 0.1 \times 10$.

Method II

If the displacement is measured from the equilibrium point, i.e

$$F = k(\text{dis tan ce from equilibrium point}) \text{ and } E = \frac{1}{2}k(\text{dis tan ce from equilibrium point})^2,$$

then we can “forget” mg and g.p.e

$$\text{Initial energy} = \frac{1}{2}mv^2 = \frac{1}{2}(0.1)(0.5)^2 = 0.0125 \text{ J}$$

At the lowest point, all the energy is converted into strain energy, so

$$\frac{1}{2}(12)x^2 = 0.0125, \text{ so } x = 0.0456 \text{ m}$$

$$\text{Max acceleration} = kx/m = (12)(0.0456)/0.1 = 5.5 \text{ ms}^{-1}$$

Method III

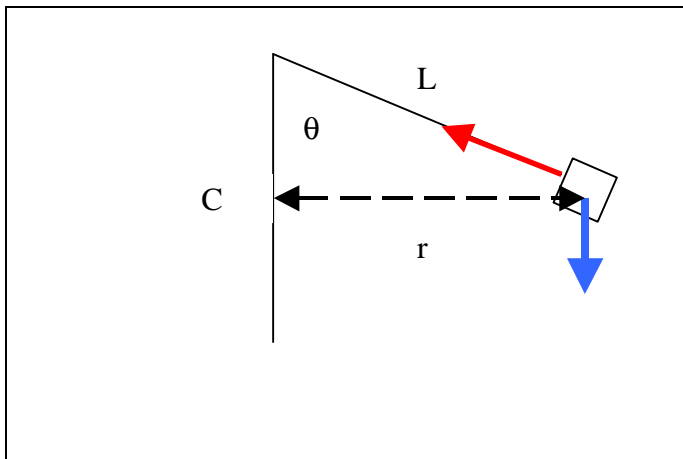
$$\text{Speed at the equilibrium } \omega A = v_{\text{max}} = 0.5 \text{ ms}^{-1}$$

$$\omega \text{ of the SHM} = \sqrt{\frac{k}{m}} = \sqrt{\frac{12}{0.1}} = 10.95 \text{ s}^{-1}$$

$$\text{Max acceleration} = \omega^2 A = 10.95 \times 0.5 = 5.5 \text{ ms}^{-1}$$

[Although Method III is the simplest, it is worthwhile to have a good understanding on the other two methods]

11.



How many forces are now acting on the bung ?	Two, tension and weight
Where is the center of circular motion ?	C
Resolve the force along the direction towards the center and the force is used as centripetal force	$T \sin \theta$ $T \sin \theta = m \omega^2 r$
Net force along the perp. dir = 0	$T \cos \theta = mg$
Equilibrium of W	$T = W$

Because of $\sin \theta = r/L$, so

$$W/m = \omega^2 L \quad \dots \dots \dots (i)$$

$$(W/m) \cos \theta = g \quad \dots \dots \dots (ii)$$

From (i) and (ii), we deduce that

(1) L is constant and ω is increased $\Rightarrow W/m$ is increases $\Rightarrow \cos \theta$ decreases $\Rightarrow \theta$ increases.

q will decrease with w \Leftrightarrow q will decrease as w increases

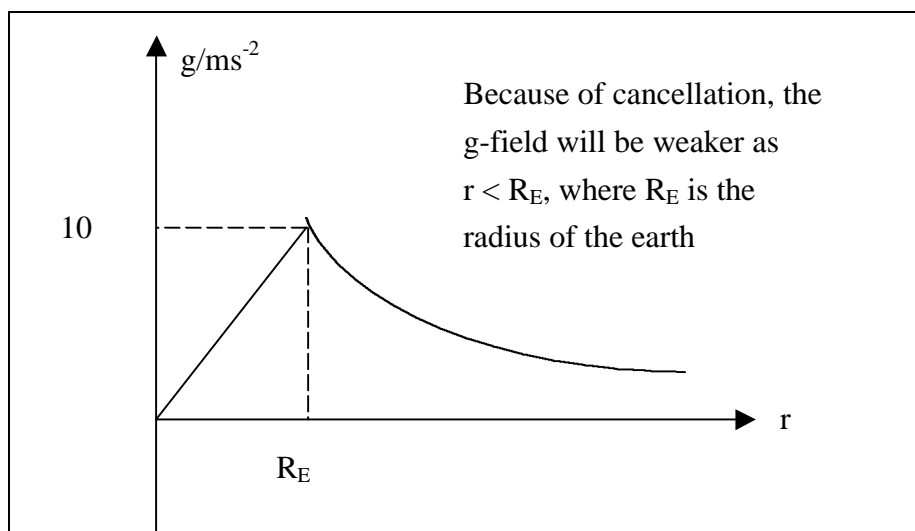
(2) θ is constant $\Rightarrow W/m$ is a constant $\Rightarrow \omega^2 L$ is constant \Rightarrow if ω increase, L will decrease.

(3) W increases $\Rightarrow \cos \theta$ decreases $\Rightarrow \theta$ increases.

(1) and (2) are incorrect, (3) is correct.

12. Period of simple pendulum $T = 2\pi \sqrt{\frac{l}{g}}$, so $g = \frac{4\pi^2 l}{T^2}$

- A. air resistance \Rightarrow longer T \Rightarrow smaller g
- B. stop watch runs slower \Rightarrow longer T
- C. longer string \Rightarrow larger g
- D. Above the sea level, g is smaller
- E. Below sea-level, g is also smaller.



-
13. (1) Correct. Max velocity $v_{\max} = \omega A$. As A is halved, v_{\max} is halved.
 (2) Incorrect Max elastic PE $\propto A^2$
 (3) Incorrect, **SHM is isochronous (period is independent of amplitude)**.
-

14. There is an external force acting on the diver, that is his own weight.
-

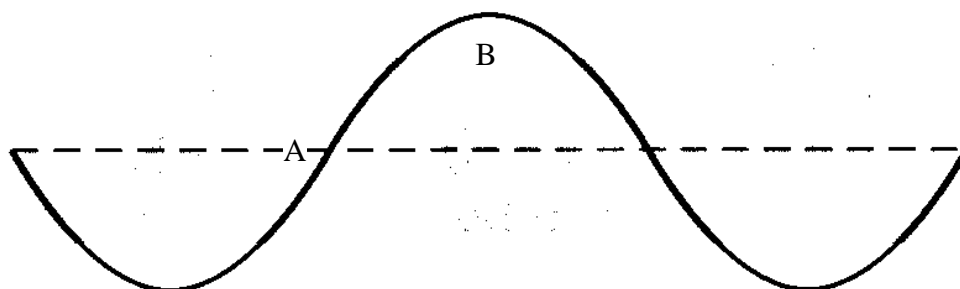
15. (1) Yes, B has the largest amplitude because its natural frequency is about the same as the frequency of the heavy bob (driving frequency).
 (2) Yes, all of them oscillate at the driving frequency (but with different amplitudes).
 (3) Yes.

When natural frequency \ll driving frequency (C), the responder and the driver are nearly in anti-phase.

When natural frequency \approx driving frequency (B), the responder is $\pi/2$ behind the driver.

When natural frequency \gg driving frequency (A), the responder and the driver are nearly in phase.

16. First of all, how does a string along which a wave is propagating store potential energy? The potential energy, of course, is not gravitational. It is the strain energy (elastic potential energy).



The dotted line represents the original string. The curve represents the string when a wave is passing. The length of the curve is longer than the dotted line. That means the string is extended. This is the reason why the string stores elastic potential energy. However, the extension is NOT uniform along the string.

String at B is not extended, so its elastic PE is the least
 Strings at A is extended the most, so its elastic PE is the largest.

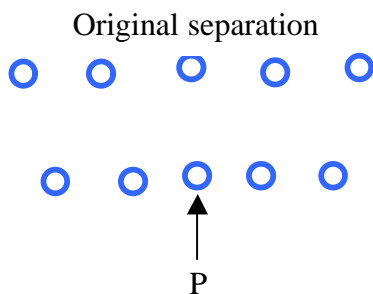
PQ is the length of a small portion of the curved string and MN is its original length. Particles only oscillate up and down. M goes to P and N goes to Q. The extension is $PQ - MN$.

Elastic PE stored in the “spring” between P and Q = $\frac{1}{2}k(PQ - MN)^2$

. The steeper the string, the longer the extension, the larger strain energy stored.

Back to the question, when the string is completely horizontal, it is not extended, so no elastic potential energy is stored in the string. At that time, particles are moving at the highest speed, so the energy is in the form of KE.

17. (1) Displacement of particles at the left of P is positive (i.e. to the right)
 Displacement of particles at the right of P is negative (i.e. to the left)
 P is a center of compression



- (2) The speed at P is the highest, so its KE is the largest (cf stationary wave)
 (3) The compression region move in the same direction as the propagation of the wave.

18. The **wavelength at the front** of the source = 1 cm

$$1 = \lambda - vT \quad (T \text{ is the period of the wave}) \quad \leftarrow \text{standard derivation}$$

$$1 = \lambda - v\lambda/20 \quad (T = \lambda/\text{speed of speed})$$

$$1 = \lambda(1 - v/20) \quad \dots \dots \dots (1)$$

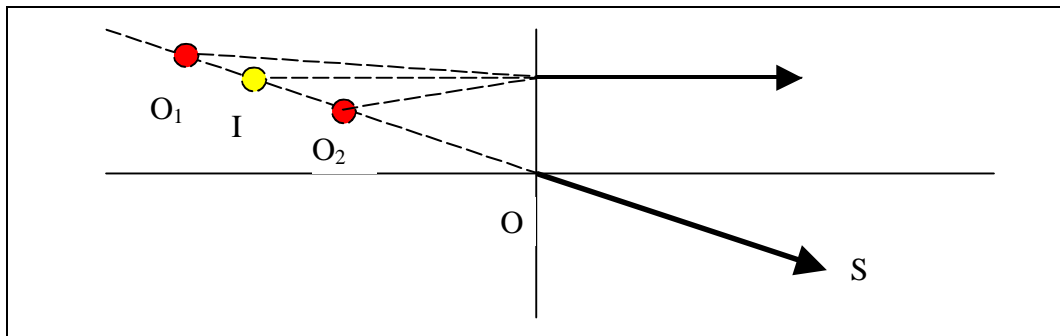
The **wavelength at the back** of the source = 3 cm

$$3 = \lambda(1 + v/20) \quad \dots \dots \dots (2)$$

Solve v from (1) and (2)

19. (1) Incorrect. White light in deficiency of yellow is not yellow
 (2) Correct. Reflections at both surface have π changes. Destructive interference occurs when $2nd = l/2$, so $d = \lambda'/4$, where $\lambda' = \lambda/n$.
 (3) Correct. Energy of incident light is always equal to the energy of transmitted light and the energy of the reflected light. No reflected light, so all energy is transmitted into the glass.

20.



- (1) Incorrect. The lens may be a concave lens or a convex lens. If the object is placed on the left of I (e.g. O_1), the lens must be concave, but if the object is placed on the right of I (e.g. O_2), the lens must be convex.
- (2) Correct. The object point must lie on the line OS because the ray of OS, before refraction, is still on the line OS.
- (3) Correct. The image must be virtual because the two real refracted rays do not intersect.

21. (1) Correct

$$\text{Potential at } +q, V_1 = \frac{1}{4\pi\epsilon_0} \left(\frac{Q}{d} + \frac{2q}{d} \right), \text{ potential at } +2q = V_2 = \frac{1}{4\pi\epsilon_0} \left(\frac{Q}{2d} + \frac{Q}{d} \right) = \frac{V_1}{2}$$

(2) Correct

WD in bringing $+q$ from infinity to its present position $= +qV_1$

WD in bringing $+2q$ from infinity to its present position $= +2qV_2 = +2q(V_1/2) = +qV_1$.

(3) Correct. If d decreases, all potentials involved will decrease.

22. Electric field points from P to R, so $V_P > V_Q > V_R$.

Electric field points towards the direction of decreasing potential

Secondly, the field is not uniform, Electric field between QR is, on average, stronger than that between PQ, so $(V_P - V_Q)/PQ < (V_Q - V_R)/QE$ or $V_P - V_Q < V_Q - V_R$

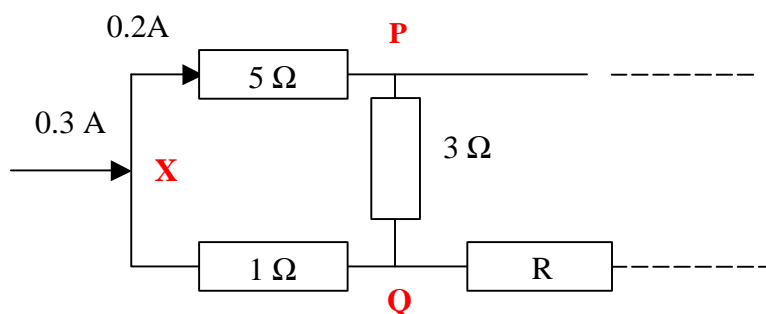
Since $V_P = 0V$, so $V_R < 2V_Q$

$$E = \left| \frac{\Delta V}{\Delta r} \right|$$

Hence,

In view of these considerations, the only choice is A.

23.



Current passing through $1\ \Omega$ resistor = $0.1\ \text{A}$

Potential drop as $0.2\ \text{A}$ passes through the $5\ \Omega$ resistor = $1\ \text{V}$

(i.e. P is lower than X by $1\ \text{V}$)

Potential drop as $0.1\ \text{A}$ passes through the $1\ \Omega$ resistor = $0.1\ \text{V}$

(i.e. Q is lower than X by $0.1\ \text{V}$)

In other words, **Q is higher than P by $0.9\ \text{V}$.**

Current passing through the $3\ \Omega$ resistor = $0.9/3 = 0.3\ \text{A}$ (Q to P)

Current passing through R = $0.3 - 0.1 = 0.2\ \text{A}$ (from right to left)

24. (1) Correct. Current is large because the total resistance is about $4\ \Omega$ only. The terminal voltage is small because the emf is divided between $4\ \Omega$ and R. Now $R \ll 4\ \Omega$, so the p.d. across R is small.

(2) Correct.

(3) Correct. It is a theorem.

Let r be the internal resistance..

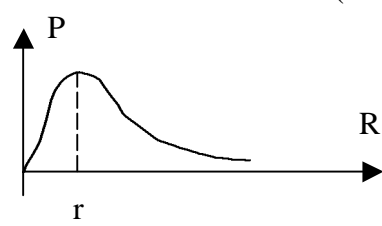
Current in the circuit $I = \frac{V}{R+r}$, power dissipated in R = $I^2R = V^2 \left[\frac{R}{(R+r)^2} \right]$

Let $\frac{1}{R+r} = x$, so $R = \frac{1}{x} - r$

$$\frac{R}{(R+r)^2} = x^2 \left(\frac{1}{x} - r \right)$$

$$= x - rx^2$$

$$= \frac{1}{4r} - r \left(x - \frac{1}{2r} \right)^2$$



Completing the square

It is maximum when $x = \frac{1}{2r}$

$$\frac{1}{R+r} = \frac{1}{2r}, \text{ so } R = r$$

(You have seen this “proof” before!, remember ?)

25. Magnetic field due to P : along SOQ

Magnetic field due to Q : along POP

Magnetic field due to S : along ROP

Magnetic field due to R : along SOQ

To produce a resultant field from O to P,

magnetic field due to Q = magnetic field due to S (both from O to P)

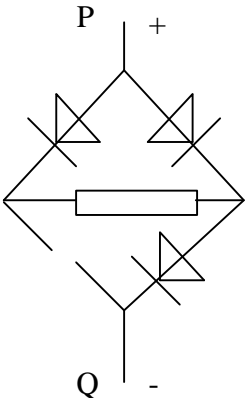
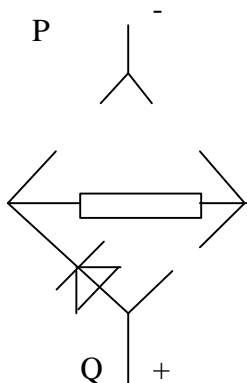
Q : current out of page ; S: current into page
 magnetic field due to P = magnetic field due to R (opposite and hence cancel)
 [P: into, R: into] or [P: out, R: out]
 The answer is (D)

26. $E = V/d = 4.5\text{kV}/1.5 \text{ mm} = 3 \times 10^6 \text{ Vm}^{-1}$.
 $A = eE/m = 1.6 \times 10^{-19} \times 3 \times 10^6 / 9.1 \times 10^{-31} = 5.3 \times 10^{17} \text{ ms}^{-2}$

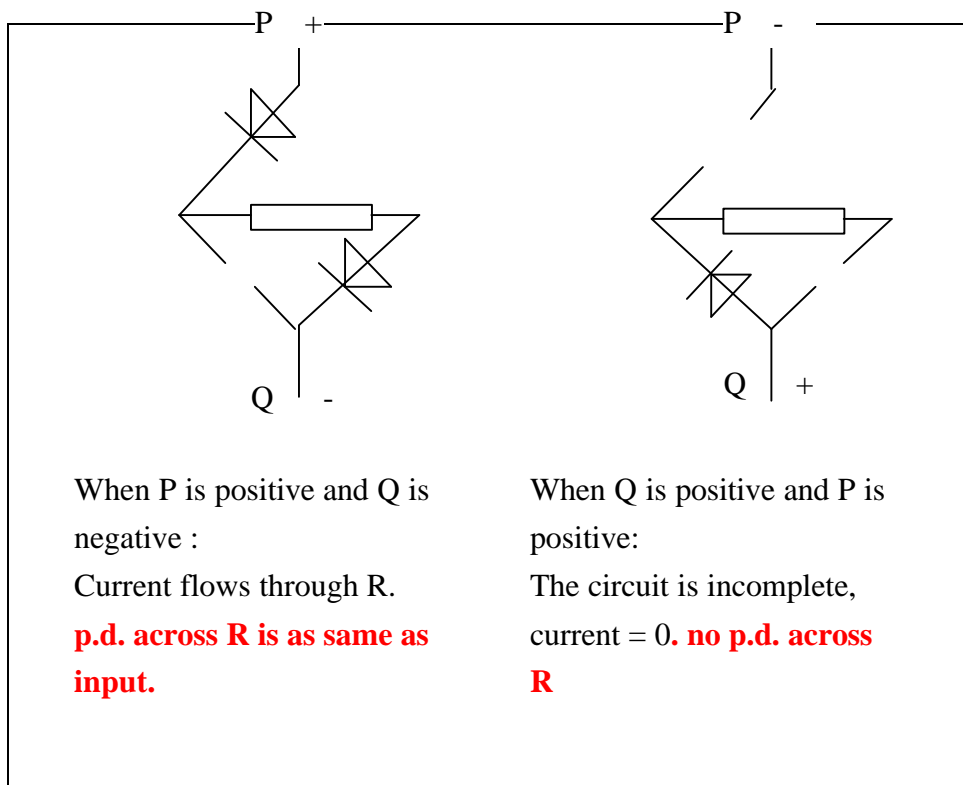
27. $eE = Bev$, so $v = E/B$.
 Undelected \Rightarrow same velocity

28. (1) Incorrect. The motor stops, the armature does not cut magnetic field.
 (2) Incorrect. Induced e.m.f = $NBA\omega$. No rotation, $\omega = 0$, so induced emf = 0
 (3) Correct. Current $I = (V - \epsilon)/R$. When $\epsilon = 0$, I is large.

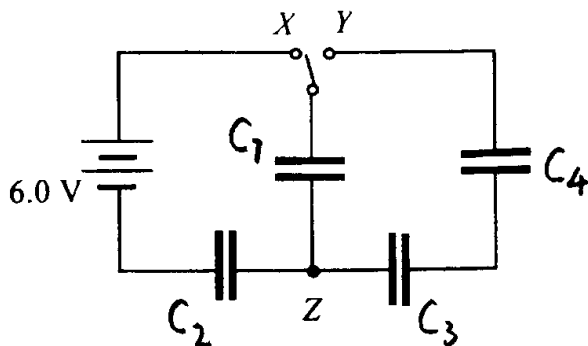
29. Case1: D were reversed in the circuit

	
<p>When P is positive and Q is negative : the two ends of the resistor essentially connects to P, so no p.d. across R</p>	<p>When Q is positive and P is positive: the circuit is not complete, no current, no p.d. across R.</p>

Case 2: D were removed



30.



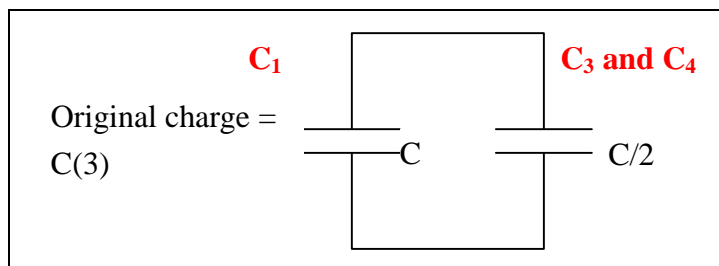
Let $C_1 = C_2 = C_3 = C_4 = C$

When the switch is connected to X, C_1 and C_2 are charged

P.d. across $C_1 = \text{p.d. across } C_2 = 3 \text{ V.}$

Charge on $C_1 = C(3)$

When the switch is shifted to Y, the equivalent cap of C_3 and $C_4 = C/2$



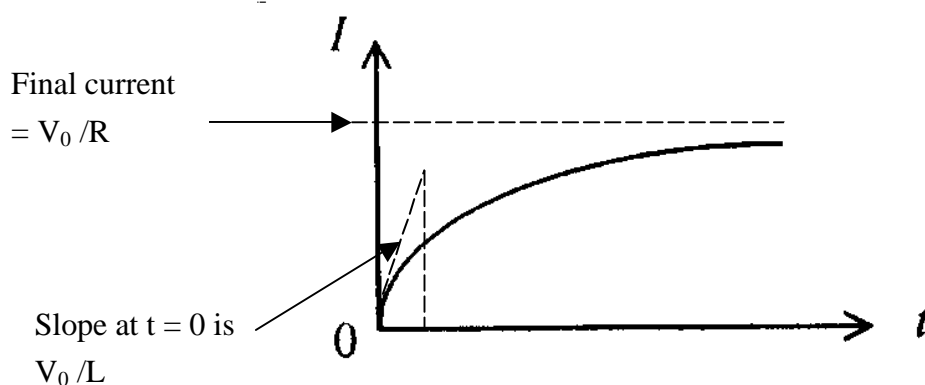
The original charge on C_1 , i.e. $C(3)$ is now divided into two parts, in proportion to the capacitances C and $C/2$. [$Q = CV$, same voltage, so $Q \propto C$]

Final charge remaining in $C_1 = \frac{2}{3}(C)(3) = C(2)$

Final p.d. across $C_1 = 2C/2 = 2 V$.

[Note; when the switch is shifted to Y, the charge on C_2 will not leave because one side of C_2 is open.]

31. A typical graph showing the growth of current with time



- A. If the solenoid has inductance only, the current will rise linearly. If the solenoid has resistance only, the current will rise instantly to the steady value V_0/R
- B. Without values on the axes, we cannot deduce that the emf induced in the solenoid is proportional to the rate of change of current although, in fact, it is true.

[Suppose you are ignorant about induction, someone told you that the induced emf was in the form $e = -\frac{dI}{dt} - kI$, where k is a constant. Then the equation for the circuit would become $V_0 - \frac{dI}{dt} = I(R + k)$. The current I solved from this equation would have the exact shape (not the corresponding values) of the curve shown above. In other words, just from the **shape of the curve**, we cannot make a conclusion about the exact mathematical expression of the induced emf]

- 32. (1) (2) The inductance causes a delay in the growth of current passing through bulb B.
- (3) When the switch is open, the back emf of L will apply to the series-combination of bulb A and bulb B. Hence, the slow-decaying current will pass through both bulbs.

33. (1) **CIVIL**

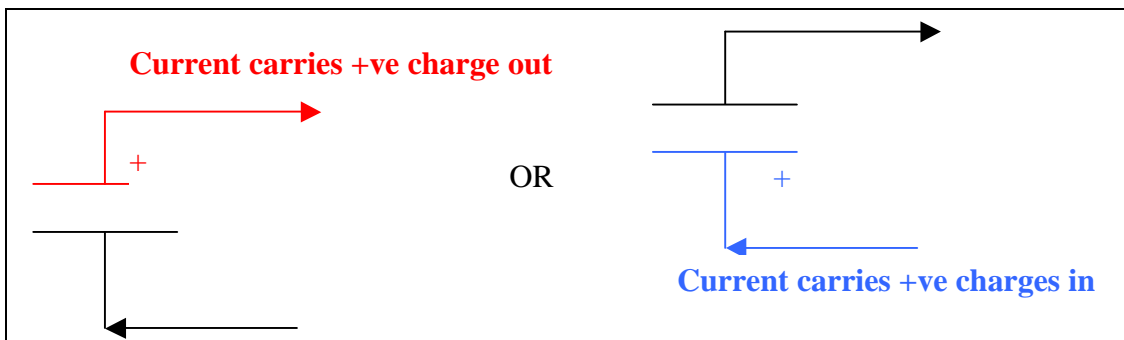
(2) Impedance $Z = \sqrt{\left(\frac{1}{\omega C}\right)^2 + R^2}$. When ω increases, Z decreases.

(3) $\tan \phi = \frac{X_c}{R} = \frac{1}{\omega CR}$. ω increases $\Rightarrow \tan \phi$ decreases $\Rightarrow \phi$ decreases $\Rightarrow \cos \phi$ increases. [Power factor = $\cos \phi$]

34. From the direction of magnetic flux inside L, we find the current is flowing clockwise at that moment. There are two possibilities

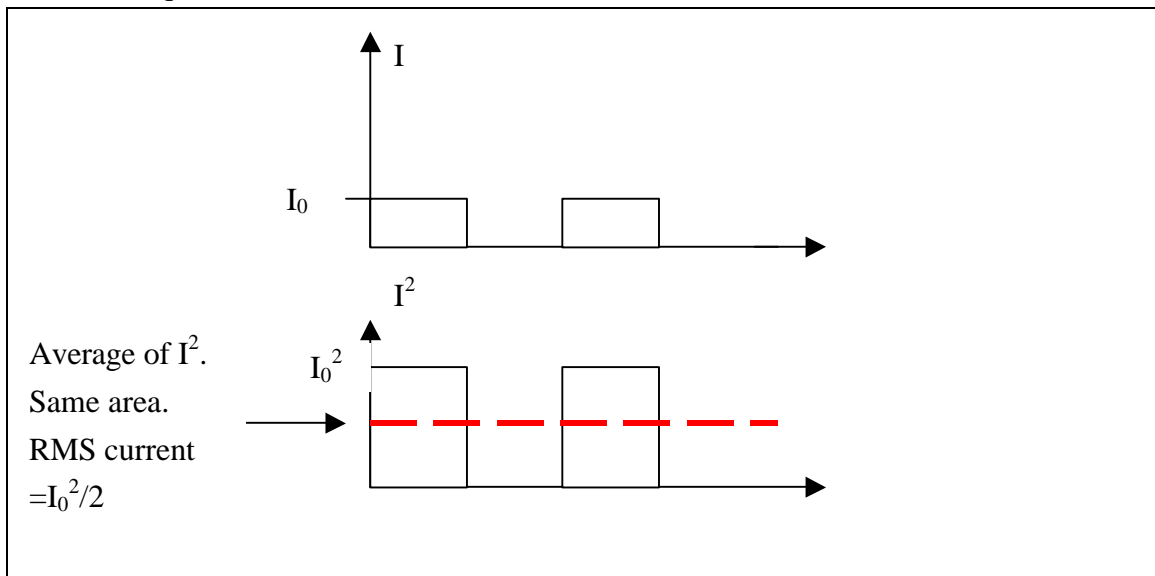
Case I. If the upper plate is positively charged, the current carries positive charges away from it. So it is a discharging process.

Case II. If the lower plate is positively charged, the current carries more positive charges to it. So it is a charging process.



35. RMS current of the sinusoidal waveform = $\frac{1}{\sqrt{2}}$ A

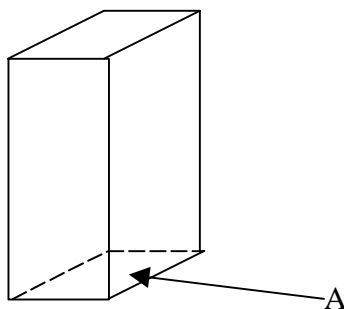
To the square waveform



$$\text{RMS current of the square waveform} = \sqrt{\frac{I_0^2}{2}} = \frac{I_0}{\sqrt{2}}$$

Same power, same rms current, so $\frac{I_0}{\sqrt{2}} = \frac{1}{\sqrt{2}}$ or $I_0 = 1 \text{ A}$.

36. Consider a simple model:

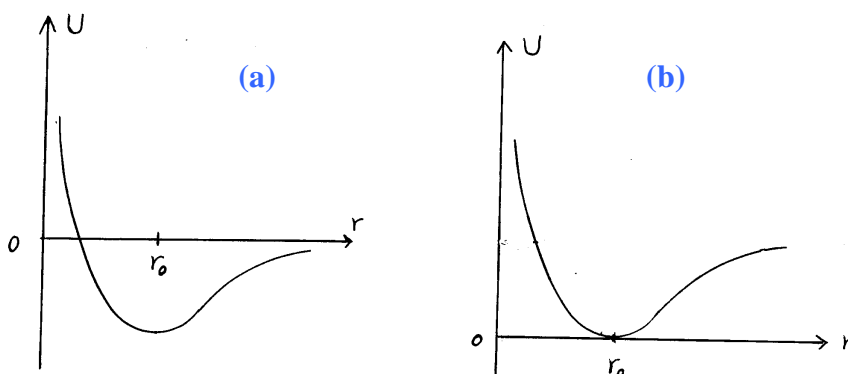


If the dimensions are doubled, the volume will be increased by 8 times. The density is unchanged, so the weight is also increased by 8 times. The area A is increased by 4 times only. The stress on the surface A is weight/area. Weight is increased by 8 times and area is increased by 4 times, so the stress is increased by 2 times.

37. (a) is the traditional U-curve [U is taken as zero at infinity]

(b) is the U-r graph with $U = 0$ when $r = r_0$

The value of U is relative to the reference point (level) chosen.

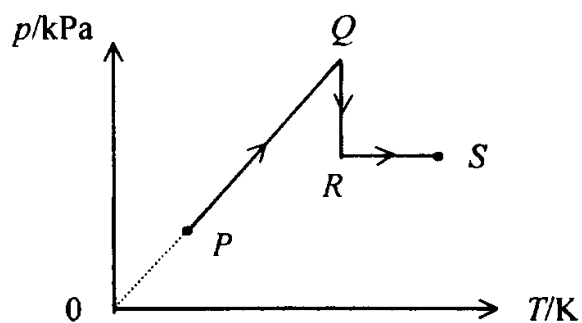


When $r < r_0$, the force is repulsive; when $r > r_0$, the force is attractive.

$$\text{Once again, } F = -\frac{dU}{dr}$$

Obviously, the statement “When r is very large, U is close to zero” is incorrect

38.



It is a P-T diagram, not a P-V diagram

Use **"PV/T is a constant"**

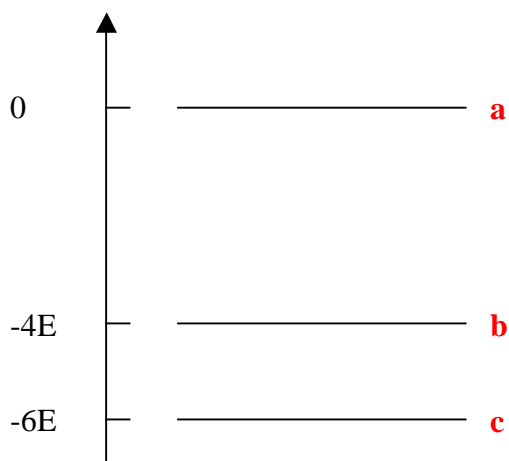
Process OQ: P/T is a constant, so V is also a constant, no WD.

Process QR: P is reduced at constant T \Rightarrow V is expanded \Rightarrow WD by the gas on the surroundings.

Process RS: T is increased at constant P \Rightarrow V is expanded \Rightarrow WD by the gas on the surroundings.

39. (1) Collisions between molecules and the walls are perfectly elastic. Otherwise, the molecules would come to rest finally !

40..



Energy required to jump from c to a = 6E

Energy required to jump from b to a = 4E

Energy required to jump from c to b = 2E

When an electron collides with an atom, some of its incident KE may be absorbed by the atom. The incident electron may bounce off with some remaining KE.

When a photon collides with an atom, all its energy will be absorbed by the atom if the energy is just enough to cause a transition. If the energy is not suitable, the photon will not be absorbed and bounces off elastically.

- (1) an electron with KE $3E$.

Transition from c to a or transition from b to a may occur. If so, the electron loses KE, so the collision is inelastic.

- (2) a photon with energy $2E$.

Transition from c to b may occur. If so, all the energy of the photon is absorbed. The collision is inelastic

- (3) a photon with energy $3E$

No transition requires the energy $3E$. The photon is absorbed totally or not absorbed, no intermediate state.

41. $hf - \phi = eV$

- (A) Incorrect. The max KE of photoelectrons does not depend on the photoelectric current. With the frequency fixed, the max KE is the same no matter what photoelectric current is.
- (B) Incorrect. Freq varies with max KE linearly but not $f = 0, K = 0$. When $f <$ threshold freq, no electrons are rejected (max KE = 0). Threshold freq $\neq 0$.
- (C) Incorrect. The number of photoelectrons ejected is controlled by the intensity of the incident light. Yes, the frequency will affect the intensity as well, but it is not generally true that the intensity increases linearly with frequency (the exact relationship between I and f is up to the experimental conditions).
- (D) Incorrect. Max KE is controlled by the frequency, not the intensity of the incident light.
- (E) Correct. With the intensity of light increased, more photons will arrive the metal and cause more electrons to be rejected.. One photon is absorbed by one electron. Two photons reject two electrons, 10 photons reject 10 electrons. They are proportional to each other.

42. Gain = $1 + R_f/R_i$. The resistor QP is divided into two parts, which are proportional to their lengths.
- (1) Incorrect. At P, $R_i = 0$, so the gain is infinite.
 - (2) Correct. At Q, $R_f = 0$, gain = $1 + 0 = 1$
 - (3) Correct. The ratio R_f/R_i is independent of the actual resistance of R. The gain only depends on the ratio R_f/R_i .
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43. (A) At P, KE = 0, so the electric PE is a max.
 (B) The total energy is a constant.
 (C) The angular momentum is a constant. [Take the nucleus as the origin, the electric force on the α particle is radial and thus causes no torque. No external torque, the total angular momentum is conserved.]
 (D) If the KE was greater, the α particle could go to a nearer position.
 (E) If the atomic number was greater, more photons in the nucleus and thus exert a greater force on the α particle. The α particle would be stopped at a farther position.
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44. The cardboard can block most α particles, so the reading should drop significantly. The aluminium sheet does not have much effect since α particles have already been blocked. γ rays can penetrate 1mm aluminium sheet. 5mm lead can only block part, not all, of γ radiation. The best answer is (A)
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45. (I) It is not a spontaneous process, since it is triggered by the incident 1_1H
 (II) Two lighter nuclei are fused to form a heavier one, so it is a process of fusion.
 (III) One 1_0n triggers the process, the products include three 1_0n which may cause further similar processes. This does represent a chain reaction.
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