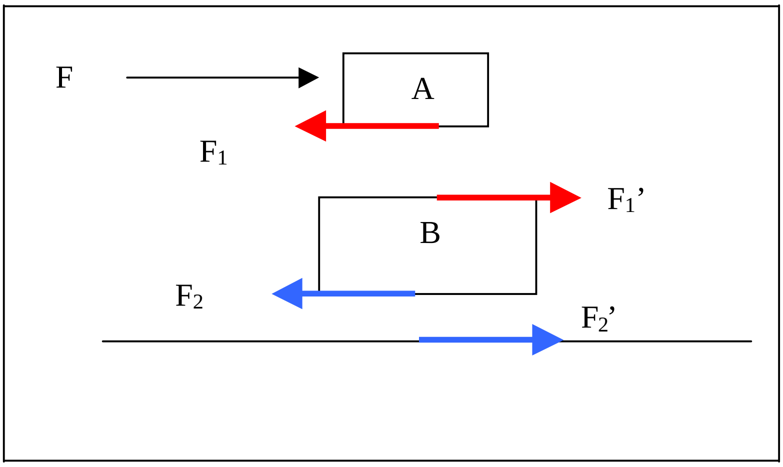
AL Physics MC Answers
Year: 2000
Questions: 1 - 45

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 remain 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). All these factors do not change, so F_2 is still equal to F.

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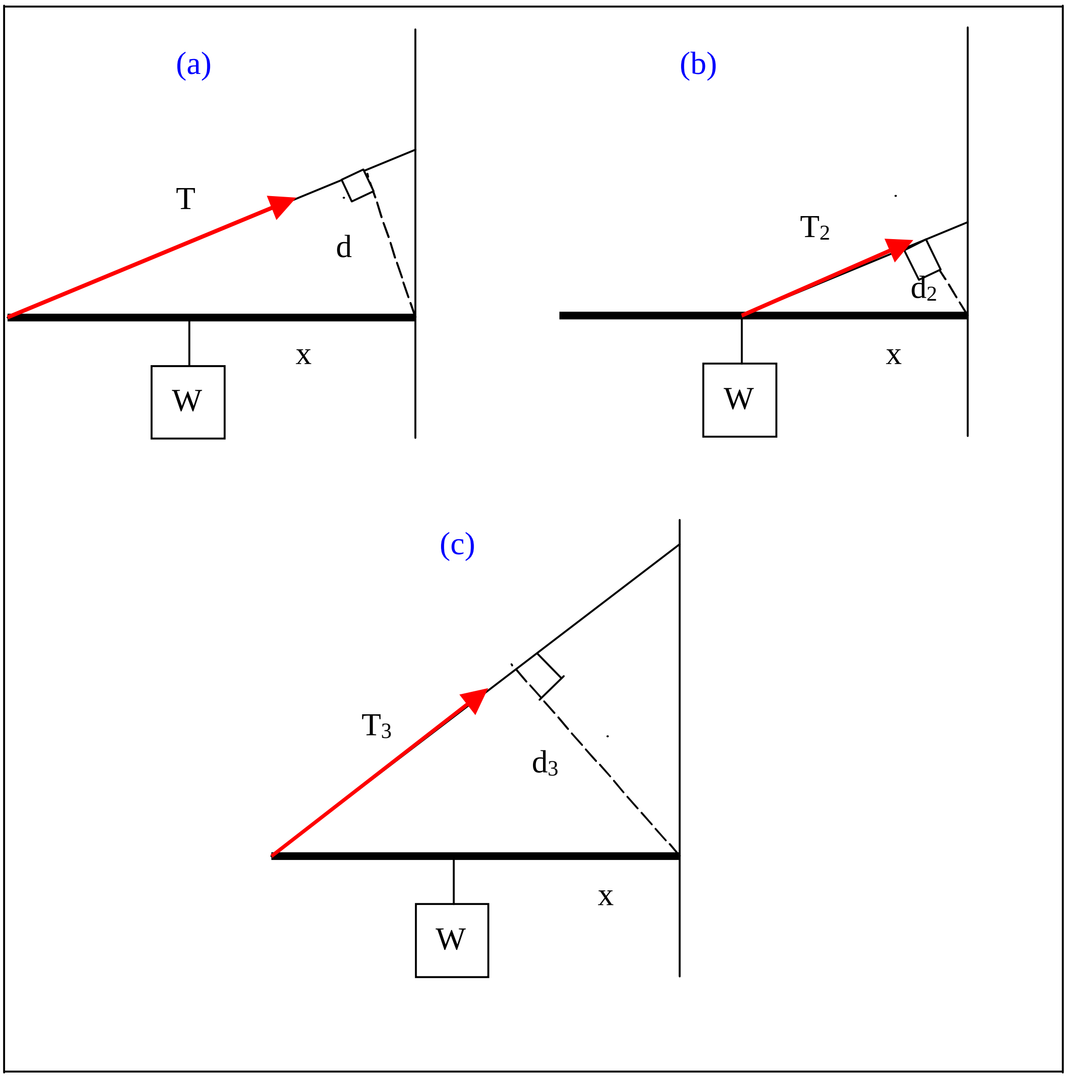
2. (1) Incorrect. R is much greater than W because the ball needs a large upward acceleration to reverse its velocity in a very short time interval.

(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 $T_3 < T$

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

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

$fr = mg\sin\theta - ma$

$fr = 0.5(10\sin 15^0 - a)$ and $fr = 0.5(10\sin 20^0 - 2a)$

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

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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.

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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

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

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.

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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 a 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)

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9. Low-attitude satellite, $v = \sqrt{gr}$, where g is the field strength at the surface and r is the radius. Period $T = \frac{2\pi r}{v} = \sqrt{\frac{r^3}{GM}}$

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

10. Method I

Extension at equilibrium x = mg/k = 0.1 x 10/12 = 0.0833 m

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

Initial total energy =

$$\frac{1}{2}mv^2 + \frac{1}{2}kx^2 - mgx = \frac{1}{2}(0.1)(0.5)^2 + \frac{1}{2}(12)(0.0833)^2 - 0.1 \times 10 \times 0.0883 = -0.0291\text{J}$$

(In calculating the g.p.e., h is measured from the position of natural length0

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

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

Solving the above quadratic equation, we get y = 0.129m (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)

$$a = \frac{0.1\times10-12\times0.0376}{0.1} = 5.5ms^{-2}$$

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

Method II

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

F = k (distance from equilibrium point) and E = $\frac{1}{2}$ k (distance from equilibrium point) ^{2} ,

then we can "forget" mg and g.p.e

.

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

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

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

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

Method III

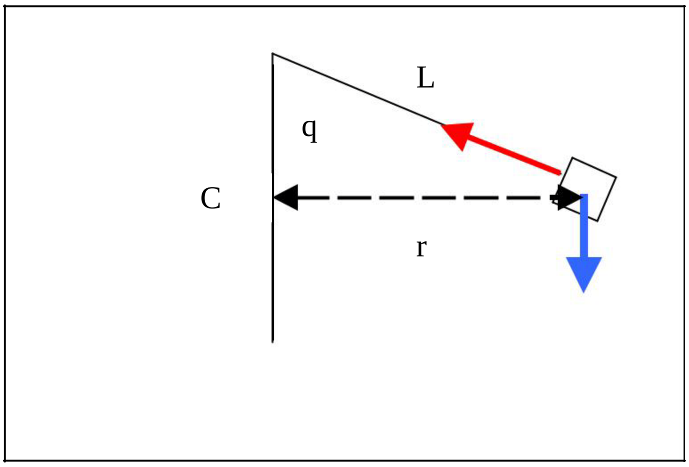
Speed at the equilibrium $\omega A = v_{max} = 0.5\ ms^{-1}$

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

Max acceleration = $\omega^2 A$ = 10.95 x 0.5 = 5.5 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	Tsinθ $T\sin\theta = m\omega^2 r$
Net force along the perpendicular direction = 0	$T\cos\theta = mg$
Equilibrium of W	T = W

Because of sin θ = r/L, so

$W/m = \omega^2 L$ ……….. (i)

$(W/m)\cos\theta = g$ ……………. (ii)

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

(1) *L* is constant and ω is decreased ➔ *W/m* is decreased ➔ $\cos\theta$ is increased ➔ θ is decreased ➔ θ will decrease as ω decreases.

But "θ will decrease with ω" means "θ will decrease as ω increases", so (1) is incorrect.

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

(3) *W* increases➔ $\cos\theta$ decreases ➔ θ increases.

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

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

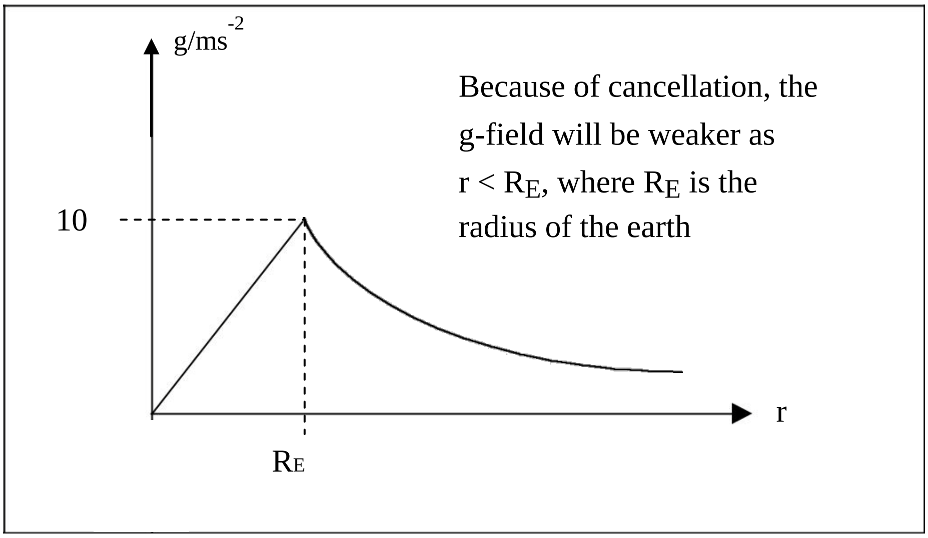
A. air resistance➔longer T ➔smaller g

B. stop watch runs slower ➔ longer T

C. longer string ➔larger g

D. Above the sea level, g is smaller

E. Below sea-level, g is also smaller.

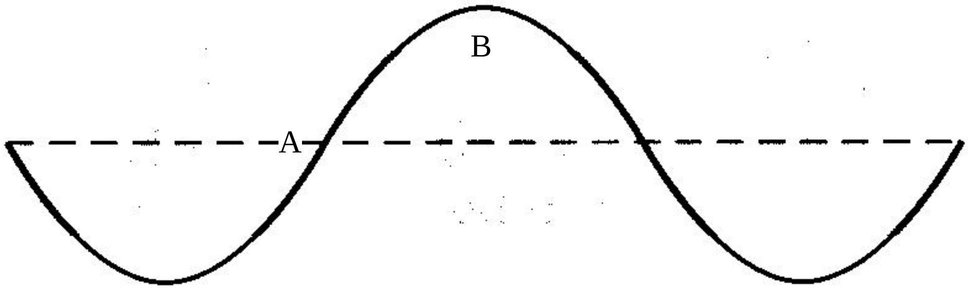


13. (1) Correct. Max velocity, $v_{max} = \omega A$. So as A is halved, v_{max} is halved.
(2) Incorrect Max elastic PE $\propto A^2$
(3) Incorrect, SHM is isochronous (period is independent of amplitude).

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 << driving frequency (C), the responder and the driver are nearly in anti-phase.
When natural frequency ≈ driving frequency (B), the responder is $\pi/2$ behind the driver.
When natural frequency >> driving frequency (A), the responder and the driver are nearly in phase.

16. How does a string store potential energy when a wave is propagating on it? The potential energy, of course, is not gravitational. It is the strain energy (elastic potential energy).



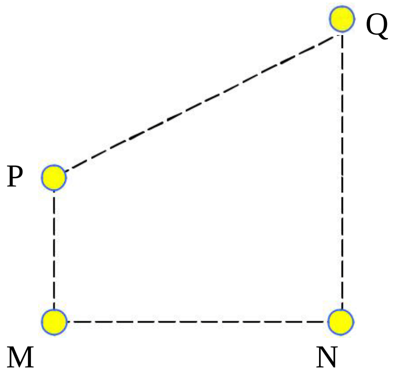
The dotted line represents the original string. The curve represents the string when a wave is passing. The length of the curve is longer than the dotted line. That means the string is extended. This is the reason why the string stores elastic potential energy. However, the extension is NOT uniform along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

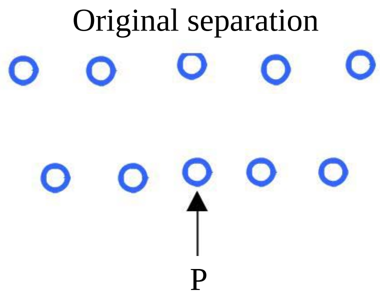
Elastic PE stored in the "spring" between P and Q $= \frac{1}{2}k(PQ - MN)^2$

. 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 that the wave propagates.

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

$1 = \lambda - vT$ (T is the period of the wave) ← standard derivation

$1 = \lambda - v\lambda/20$ ($T = \lambda$/speed of speed)

$1 = \lambda(1 - v/20)$ ……………………(1)

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

$3 = \lambda(1 + v/20)$ ………………. (2)

Solve v from (1) and (2)

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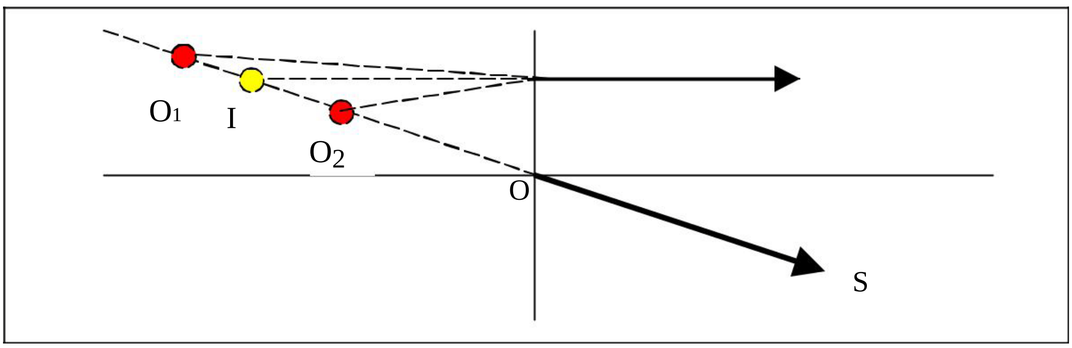
19. (1) Incorrect. White light in deficiency of yellow is not yellow

(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 = energy of transmitted light + energy of 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 point object 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.

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21. (1) Correct

Potential at +q

$V_1 = \frac{1}{4\pi\varepsilon_0}(\frac{Q}{d} + \frac{2q}{d})$, potential at +2q = $V_2 = \frac{1}{4\pi\varepsilon_0}(\frac{Q}{2d} + \frac{Q}{d}) = \frac{V_1}{2}$

(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.

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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 $V_P - V_Q < V_Q - V_R$

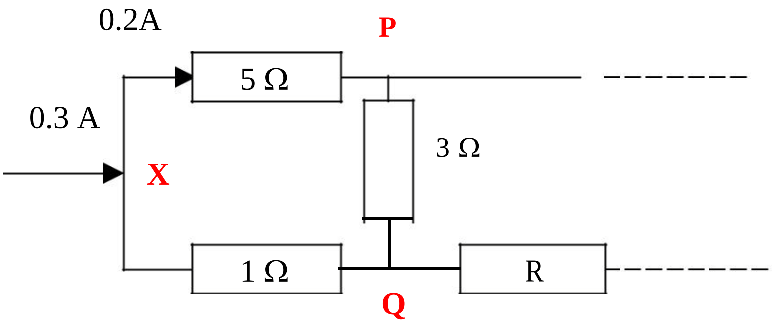
Since $V_P = 0V$, so **$V_R < 2V_Q$**

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

Hence,

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

23.



Current passing through 1 Ω resistor = 0.1 A

Potential drop as 0.2A passes through the 5Ω resistor = 1 V

(i.e. P is lower than X by 1 V)

Potential drop as 0.1A passes through the 1Ω resistor = 0.1 V

(i.e. Q is lower than X by 0.1 V)

In other words, **Q is higher than P by 0.9 V.**

Current passing through the 3 Ω resistor = 0.9/3 = 0.3 A (Q to P)

Current passing through R = 0.3 – 0.1 = 0.2 A (from right to left)

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

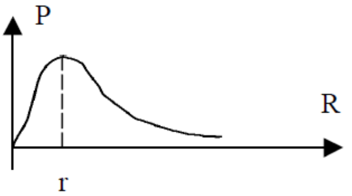
(2) Correct.

(3) Correct. It is a theorem.

Let r be the internal resistance..

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

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



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

$$= x - rx^2$$

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

Completing the square

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

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

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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)

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26. $E = V/d = 4.5kV/1.5\ mm = 3 \times 10^{6}\ Vm^{-1}$.

    $A = eE/m = 1.6 \times 10^{-19} \times 3 \times 10^{6}/9.1 \times 10^{-31} = 5.3 \times 10^{17}\ ms^{-2}$

27. $eE = Bev$, so $v = E/B$.

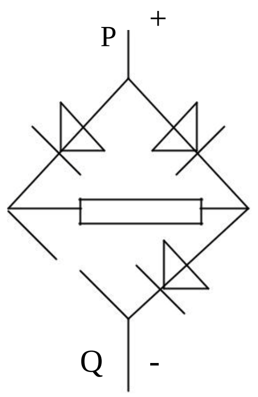
    Undeflected ➔ same velocity

28. (1) Incorrect. The motor stops, the armature does not cut magnetic field.

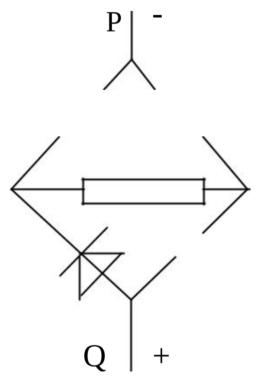
    (2) Incorrect. Induced e.m.f $= NBA\omega$ No rotation, $\omega = 0$, so induced emf = 0

    (3) Correct. Current $I = (V - \varepsilon)/R$. When $\varepsilon = 0$, I is large.

29. Case1: D were reversed in the circuit

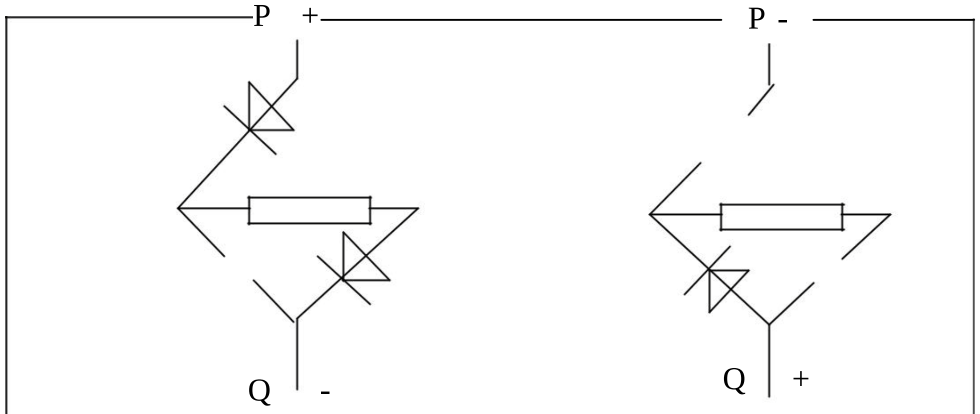


When P is positive and Q is negative : the two ends of the resistor essentially connects to P, so **no p.d. across R**



When Q is positive and P is positive: the circuit is not complete, no current, **no p.d. across R.**

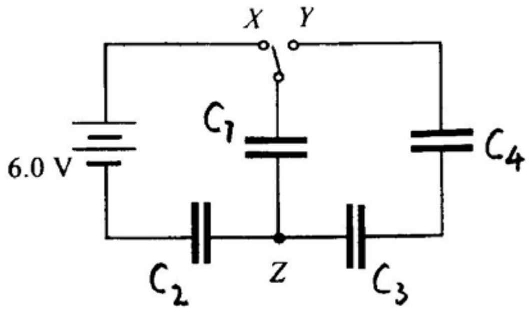
Case 2: D were removed



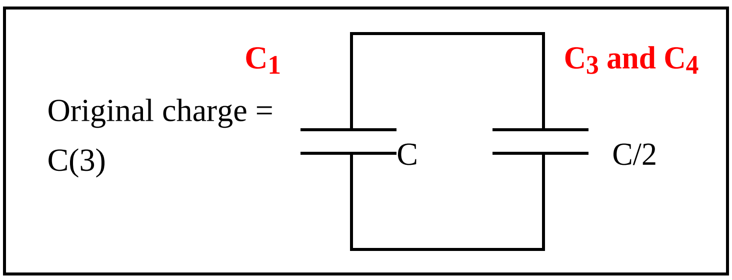
When P is positive and Q is negative :
Current flows through R.
p.d. across R is as same as input.

When Q is positive and P is positive:
The circuit is incomplete, current = 0**. no p.d. across R**

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 = p.d. across C_2 = 3 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 ∝ 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.]

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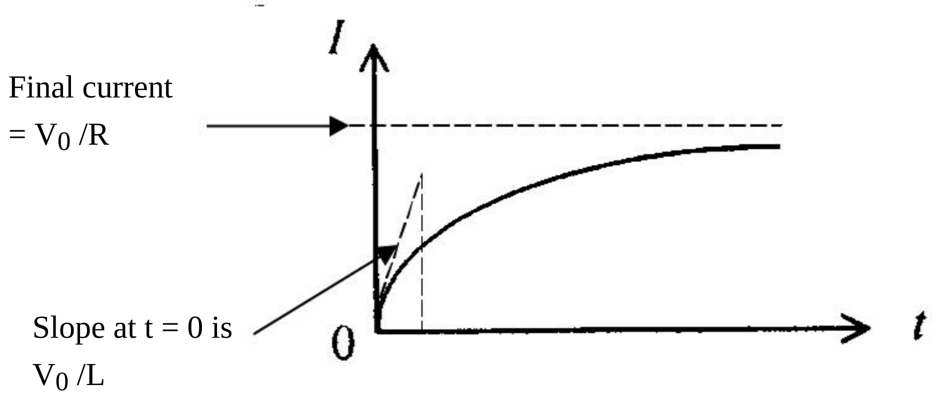
31. A typical graph showing the growth of current with time



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 were ignorant about EM induction, someone tells you that the induced emf is in the form $\varepsilon = -\frac{dI}{dt} - kI$, where k is a constant. Then the equation for the circuit becomes $V_o - \frac{dI}{dt} = I(R+k)$. The current I solved from this equation has 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]

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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) **CIV**IL

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

(3) $tan\phi = \frac{X_C}{R} = \frac{1}{\omega CR}$. When ω increases ➔ tanϕ decreases ➔ ϕ decreases

➔ power factor cos ϕ increases

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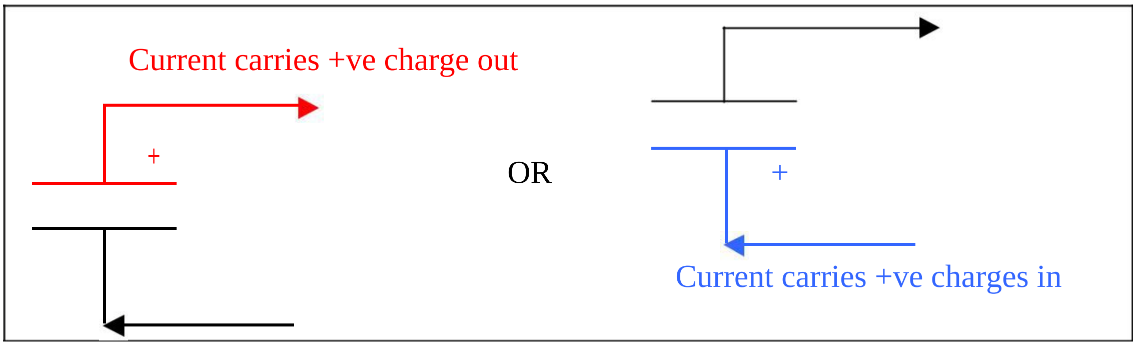
34. From the direction of magnetic flux inside L, we find the current is flowing clockwise at that moment. There are two possibilities

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.



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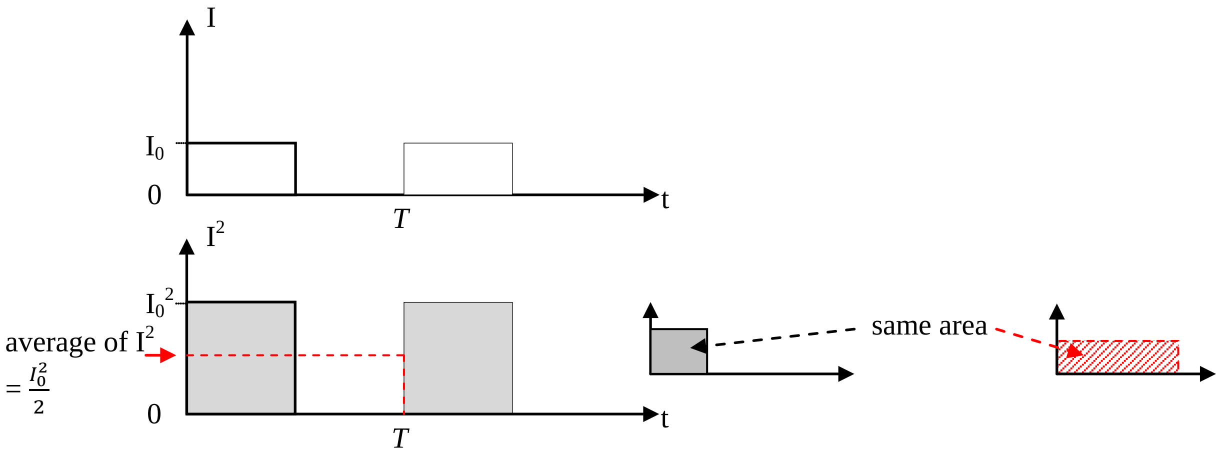
35. RMS current of the sinusoidal waveform = $\frac{1}{\sqrt{2}}$A

To the square waveform

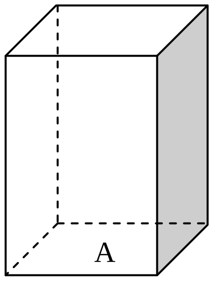


Average of $I^2 = \frac{I_0^2}{2}$

Square waveform's rms I = Root of the average of $I^2 = \sqrt{\frac{I_0^2}{2}} = \frac{I_0}{\sqrt{2}}$

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

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.

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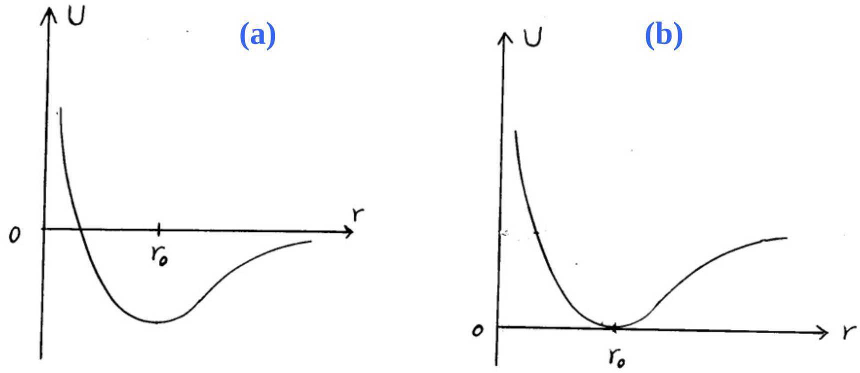
37. (a) is the traditional U-r curve (U is taken as zero at infinity)
(b) is the U-r graph with U = 0 when r = r_0 .
The value of U depends on the reference point (level) chosen.

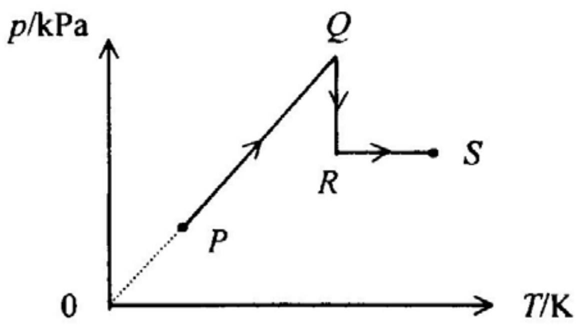


When r < r_0, the force is repulsive; when r > r_0, the force is attractive.

$$F = -\frac{dU}{dr}$$

Here, when r is very large, U is not close to zero.

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 ➔ V is expanded ➔ WD by the gas on the surroundings.

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

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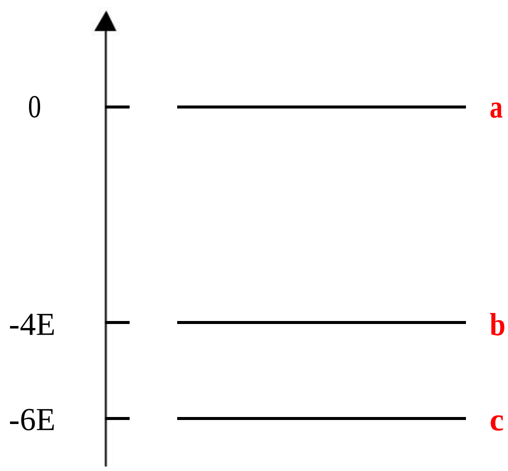
39. (1) Collisions between molecules and the walls are perfectly elastic. Otherwise, the molecules would come to rest finally !

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 b 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.

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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. Max *KE* varies with frequency f linearly but not passing through the origin $f = 0$, $K = 0$. When $0 < f <$ threshold freq, no electrons are rejected (max $KE = 0$).

(C) Incorrect. Intensity of the incident light $I = nhf$, where n is the number of incident photons per unit area per unit time. On the other hand, photoelectric current i is proportional to n, so $i \propto n = \frac{I}{hf}$. No matter I is constant or not, i does not vary linearly with f.

(D) Incorrect Max *KE* depends on 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.
Current $\propto$ Number of electrons ejected $\propto$ Number of photons striking the metal surface $\propto$ Intensity of incident light

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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.
