2002 ALPhysics Paper II MC Suggested Answer

1. Before the cord is cut,

   tension in the cord, $T_c = 2$ mg,

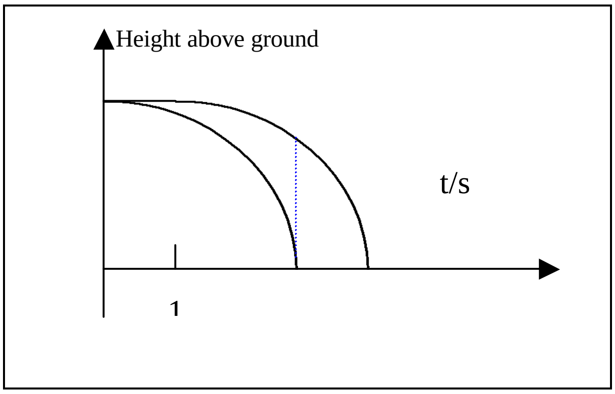
   tension in the spring, T_s = mg

   Just after the cord is cut,

   Net force acting on X = mg $+T_s$ = 2 mg, so the acceleration of X at that time = 2g

   Net force acting on Y = mg - T_s = 0, so the acceleration of Y at that time = 0

2. Their s-t graphs are



Obviously, the largest separation occurs at the moment when the first object reaches the ground (blue line).

$$80 = \frac{1}{2}(10)t^2 \qquad t = 4 \text{ s}$$

Height of the second object = $\frac{1}{2}(10)3^2$ = 45 m

Separation = 80 – 45 = 35 m

3. Wavelength of orange-red light ~ 5×10^{-7} m

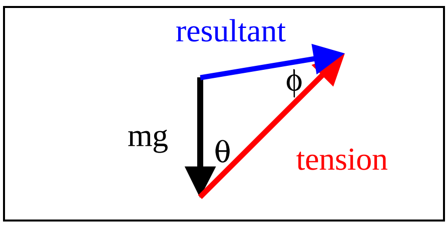
   $(5 \times 10^{-7})n = 1 \qquad n \sim 10^6$

4. (1) The block will eventually execute SHM. It has the maximum KE at the equilibrium point (i.e. mg = kx), which is below B and above C.

   (2) C is not the equilibrium point. C is the lowest turning point of the harmonic motion. At there, v = 0, but at the equilibrium point, v is the maximum.

   (3) The point of maximum compression (C) is below the equilibrium point (mg = kx).

5.



mg is fixed. The direction of the tension is fixed. Obviously, the resultant is the shortest when the angle ϕ is 90^0. Then, resultant = mgsinθ. This is the force required to keep the bob in equilibrium.

6. P continues to move in its original direction: part of momomtum and KE of P is transferred to X.
Q becomes stationary: all the original momentum and KE of Q go to Y.
R reverses its direction: R is still moving, so only part of KE is transferred to Z. R rebounds, so Z will get the greatest momentum

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7. Impulse = area of f-t graph = change of momentum

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8. (1) is possible: purely centripetal acceleration
(2) is possible: centripetal acceleration + tangential deceleration
(3) is impossible: only tangential acceleration, no centripetal acceleration

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9. Potential energy is proportional to the square of displacement.
KE = 3E/4, so PE = E/4 at x = A, PE = E, so x = A/2, PE = E/4

10.

- acceleration $\propto$ - displacement, so displacement-acceleration graph is a straight line passing through the origin and having a negative slope.
- Force = ma, so F-a graph is also a straight line.
- Kinetic energy $\propto$ v^2. Since $x^2 + (\frac{v}{w})^2 = A^2$, so $KE \propto x^2$

  KE-x graph is parabolic.
- $v = w\sqrt{A^2 - x^2}$. V-x graph is not parabolic.

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11. Gravitational PE loss = rotational KE gain
Mg(length/2) = Iω^2/2
[treat the whole mass is concentrated at the the centre of the stick]
0.1 ¡ 10 ¡ 0.3/2 = 3 ¡ 10^{-3} ¡ ω^2/2
ω = 10 rad s^{-1}

12.

- Due to friction, the total energy of the satellite is reduced, the satellite goes to a lower orbit, but moving at a higher speeed (do you remember the “paradox”?)
- Angular momentum is not conserved, because friction acts tangentially backwards and so produces a torque to reduce its angular momentum.
- Higher speed, lower orbit ⇨ shorter period

13.

- Let the origin be t = 0. Obviously, P is zero and goes to negative at t = 0, Q = 0 and goes to negative at a later time, so P leads Q.
- At t =0, P = 0, Q is maximum, so the phase difference between them is one-quarter of cycle (π/2).

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14. Ultrasonic is a longitudinal wave, which does not have any polarization.

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15. Grating formula: d sinθ = mλ.

To produce the largest angle θ, λ should be as large as possible, d should be as small as possible. The number "lines per mm" is inversely proportional to d. Red light has a longer wavelength than that of blue light.

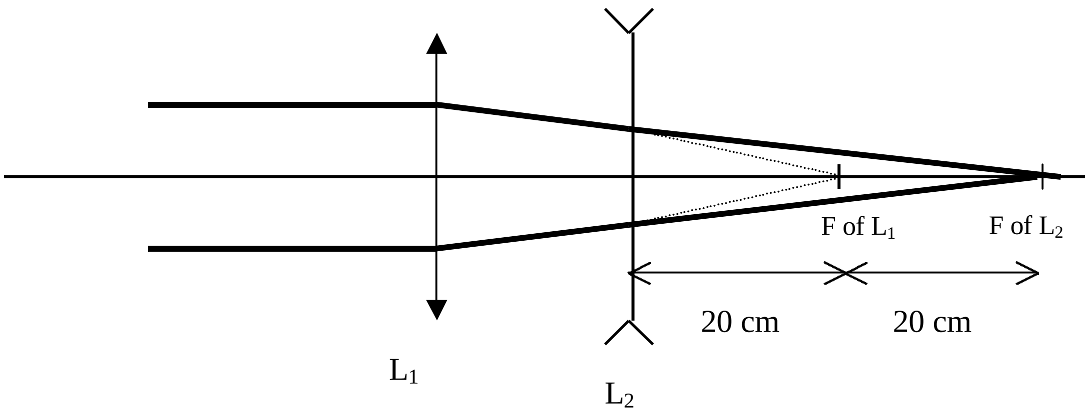
16.

- The image formed by a concave (diverging) lens:

  A real object is placed at F, a virtual image is formed at F/2 and on the same side as the object.

  Due to the reversibility of light, when a virtual image is placed at F/2, a real image will be formed at F and on the same side as the object.

- The first image formed by the convex lens is formed at "F of L_1". The image is virtual, because light is refracted by L_2 before it goes to that point. "F of L_1" is at a point of half the focal length of L_2 from L_2, so a real image is formed at "F of L_2".



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17. Possible wavelengths of stationary wave (two ends fixed)

λ_n = 2L/1, 2L/2, 2L/3, 2L/4, 2L/5, i.e. 2L/n

Possible frequencies $f_n = \dfrac{nc}{2L}$, where c is the speed of wave.

$f_{n+1} - f_n = \dfrac{c}{2L}$, so $450 - 400 = \dfrac{c}{2(1)}$, so c = 100 ms^{-1}

18.

- Moving source, stationary observer $\Rightarrow$ different wavelength, same wave speed
- Moving observer, stationary source $\Rightarrow$ observer will see a different wave speed, the wavelength is unchanged.

19. When the star recedes, the whole spectrum will shift to the red side.
When the star approaches, the whole spectrum will shift to the blue side.
Now, each line of the spectrum is broadened with the central unchanged. Both recession and apprpach take place. One possibility is that the star spins.
[Remarks: a similar situation occurs when we observe the spectrum of a hot vapour. This broadening is due to the random movement of the vapour molecules. Some molecules are receding, some are approaching. This broadening is termed as "doppler broadening"].

20.

- The motion is reversible. Suppose it goes X to Y. By reversing the velocity at Y, it will take the same route and go back to X
- Q is at the intersection point of the solid lines (left hand side of the figure). At first q goes outwards, but finally it returns, so Q attracts q. They should have different signs.
- Q (the intersection point of the solid lines) is nearer to X than Y. Q attracts q, q decelerates when it goes outwards, so it has a smaller speed at Y.
- Q may be positive or negative, so we cannot certain the electric potential at X is highre or lower than that at Y.

21.

- If the field is electric, the acceleration is vertical. The initial horizontal velocity does not change, so the motion at any time cannot be purely vertical. The deflection must be smaller than 90^0.
- Magnetic force = qvB, electric force = eE
- Magnetic force is always perpendicular to motion, it doesn't do work, so KE is unchanged.
- Magnetic force is mutually perpendicular to B and v. When the direction of v changes, the direction of force changes as well.

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22. Capacitance of the upper branch = C/2
Total C = C + C/2 = 3C/2

23.

- Capacitance of a paralle-plate capacitor = $\frac{e_0 A}{d}$
When one plate is slided upwards, the effective area is reduced, so C is reduced.
- The plates are isolated from the surroundings, so Q is unchanged.
- C=Q/V, C is decreased, Q is unchnged, so v is increased.

24.

- The cell does not have an internal resistance, so the whole 9V is dropped across V_1 and V_2. The p.d. across V_2 is 5V. Since resistance of V_1 = resistance of V_2, so the current in V_2 is larger than the current in V_1 by 1 unit. This 1 unit current comes from V_3. 4 units of cuurent gives 4 V, so 1 unit of current will give 1 V.
- Loop around R-V_3-V_1, the total p.d. is zero

  V_R +1V -4V = 0, so V_R = 3V

  [At the left connection point of R and V_1 , they are at the same potential. Now V_1 drops by 4 V and the current in V_3 is downwards, so the upper side of V_3 should have a highre potential, i.e. V across R is less than 4 V]

25.

- When the external resistance (R) is equal to the internal resistance of the source (r) of emf, **the power delivered to the external resistance** is the maximum.

  Power to the external resistance = $(\frac{V}{R+r})^2 R$
- However, the total power delivered by the source decreases with the external power R.

  Total Power = $\frac{V^2}{R+r}$

26.

Time constant = RC C = 2 ¡ Ñ10^{-3}/1000 = 2 ¡ Ñ10^{-6} F = 2μF.

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27. We thinks in this way: when the angle is 90^0, the induced emf = Blv;

when the angle is 0^0, the rod doesn't cut across magnetic flux, so no induced emf.

Obviously, induced emd depends on sinθ.

sin 60^0 = $\sqrt{3}/2$, so the induced emd = $\frac{\sqrt{3}Blv}{2}$

28.

- Induced emf is equal to the rate of change of total magnetic flux, which is proportional to the area of the coil.
- Induced current is inversely proportional to the resistance of the coil. The internal resistance is proportional to the perimeter of the coil.
- So, the induced current (I=V/R) is proportional to the factor

  $\frac{area\ of\ the\ coil}{perimeter\ of\ the\ coil}$.
- This factor is the same for the square and the circle.

29. The magnetic force between two wires carrying the same direction of currents is attractive. P is repelled by Q and attracted by R. The magnitudes of the two forces are equal, so the resultant force is exactly horizontal and pointing to the right.

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30. Power supplied by the source = εI = (5V)(2A) = 10 W

Power dissipated in the armature coil = $I^2R = 2^2(0.5)$ = 2 W

Efficiency = $\frac{10-2}{10}100\% = 80\%$

31.

Y_1 displays current,

Y_2 essentially displays V_C . But the key issue is that ”E” is taken as the **common ground,** so the display of Y_2 is reversed, as compared with Y_1.

“CIVIL”, Draw Y_1 leads Y_2 by 90^0 and then reverse Y_2.

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32. E = eV

$V = 3.6 \times 10^{-16}/1.6 \times 10^{-19}$ = 22.5 kV

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33. Characteristics of theV-I relationships:

V is greater than a certain value (called V_0), it conducts. Afterwards, V increases with I.

$(V-V_0) \propto I$.

There must be a cell with opposite polarity in the circuit, to represent V_0.

There must be a diode in the circuit to represent that only one direction of current can flow.

There must be a resistor in the circuit to represent the sloping part of the graph.

The cell, the diode and the resistor have to be connected in series.

34.

- The open loop gain A_0 depends heavily on the temperature and the frequency of the input signal. The closed-loop gain does not. Hence, negative feedback increases the stability.
- Closed-loop gain is much smaller less the enormous A_0.
- With negative feedback, the output can be distorted if the input is too large (the output is saturated). So distortion cannot be avoided by using the technique of negative feedback.

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35. Intensity = nhf. At a higher frequency, the number of incoming photons will decrease if the intensity is fixed. [Number of electrons released is also proportional to the number of striking photons]

36.

- KE = $P^2/2m$, where P is the momentum. h is not used.
- Energy = $E_f - E_i$, [Use h to calculate the photon frequency, but not the energy]
- Energy of photoelectrons = hc/λ - ϕ

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37. E = $-\frac{E_0}{n^2}$

hc/λ = $-\frac{E_0}{3^2} - (-\frac{E_0}{1^2}) = \frac{8E_0}{9}$

To ionize the atom, hc/λ' = E_0

Hence 1/λ = 8/9λ' or λ' = 8λ/9

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38. T is the absolute temperature.

- The line doesn't pass through the origin, so P is not proportional to T.
- P has to be proportional to T if V is kept constant. Now they are not directly proportional to each other, so V is not kept constant. At B, the pressure is smaller than that if V is kept constant (the line AB is below the straight line passing the origin and A). This means V is increased during the process.
- To a fixed mass of gas, PV/T = constant

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39. PV= nRT

Molar volume = $8.31 \times 273/10^5 = 0.0227\ m^3$

Number of molecules in 1 cm^3 = $6.02 \times 10^{23}/0.0227 \times 10^6$ [$m^3 = 10^6\ cm^3$]

$=10^{19}$

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40. KE is proportional to the absolute temperature

$v \propto \sqrt{T}$

At 160^0C, v $\sqrt{\frac{273+160}{273+80}}c$ = 1.1c

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41. Activity A = $A_0 e^{-\lambda t}$, where λ is the decay constant.

$\ln A = \ln A_0 - \lambda t$

Slope of the line = λ = 1/80.

Half-life = ln2/λ = 80ln2 = 55 s.

42.

- When the terminal velocity is attained, mg = air resistance. It is irrelevant to Bernoulli's equation.
- (2) and (3) are solved by using Bernoulli's equation. They are essentially the standard examples of learning the equation.

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43. At the quiescent point, C_{CE} = 3 V,

The collector current = 3 mA, the base current = 3 mA/80 = 3.75×10^{-5} A

$R_B = (6 - V_{BE})/I_B = (6-0.6)/3.75 \times 10^{-5} = 144\ k\Omega$

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44. $V_- = V_P$

Current in the 10 kΩ resistor connected to V_1, $I_1 = (V_1 - V_P)/10k\Omega$

Current in the 59 kΩ feedback resistor, $I_2 = (V_P - V_0)/50\ k\Omega$

The op-amp draws a negligible current, so $I_1 = I_2$

$(2.7 - V_P)/10 = (V_P + 0.9)/50$

$V_P = 2.1$ V

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45. mass $M = \rho(\pi d^2/2)l$

$d \propto \sqrt{\frac{M}{l}}$

$$\frac{\Delta d}{d}100\% = \frac{1}{2}\left(\frac{\Delta M}{M}100\% + \frac{\Delta l}{l}100\%\right)$$

$$= \frac{1}{2}(4\% + 2\%) = 3\%$$
