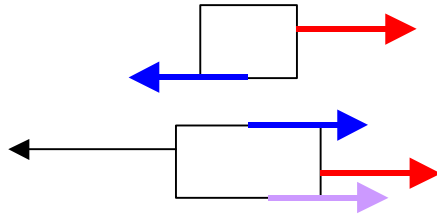


Year: 1997

Question Number: 1,2,3,4,5,6,9,12,14,15,16,17,18,19,20,21,24,25,26,27,33,40,41,42,43

1997MC(1)



Red force: tension =  $T$

Blue force = friction between the two blocks =  $f_r$

Violet force = friction between the lower block and the floor =  $f_r$

The upper block is stationary, so  $T = f_r$

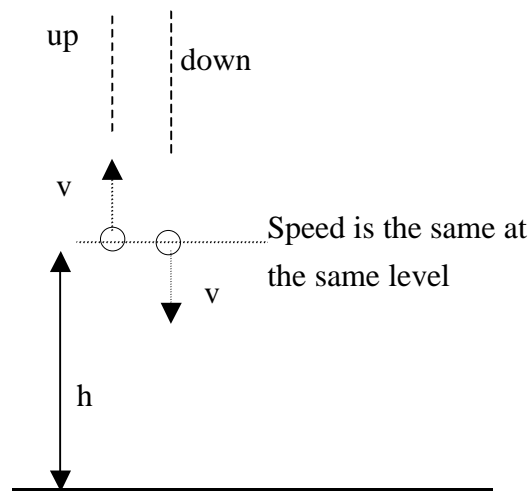
The lower block is stationary, so the external force =  $2f_r + T = 3f_r = 6\text{ N}$

1997MC (2)

Total energy before reaching the ground =  $mgh + mv^2/2$

Total energy after rebound =  $mgh$

- (1) Correct, because there is energy loss during the rebound
- (2) Correct
- (3) Incorrect,



Let  $h$  be the height of the table

By conservation of energy

$$\frac{1}{2}mu^2 + mgh = \frac{1}{2}mv^2, \text{ so}$$

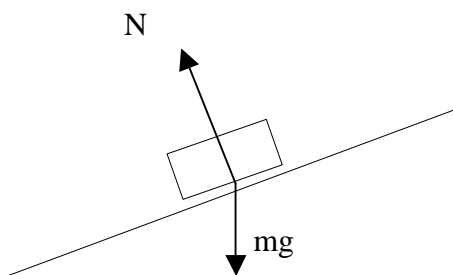
$$h = \frac{v^2 - u^2}{2g} \quad \dots \dots \dots (1)$$

Vertical motion  $h = \frac{1}{2}gt^2$

$$t = \sqrt{\frac{2h}{g}} \quad \dots \dots \dots (2)$$

Putting (1) into (2), we will get the answer.

1997MC (4).



The acceleration is horizontal, so upward force = downward force

$$N\cos\theta = mg \quad \dots \dots \dots (1)$$

The centripetal force is provided by  $N\sin\theta$ , so  $N\sin\theta = mv^2/R \quad \dots \dots \dots (2)$

From (1) and (2),  $\tan\theta = mv^2/Rg$

$$v = \sqrt{Rg \tan\theta} = 5.4ms^{-1}$$

[Remark: We do not say  $N = mg \cos\theta$  and  $a = g\sin\theta$ , because NOW, **THE ACCELERATION IS HORIZONTAL, NOT PARALLEL TO THE PLANE**]

1997MC (5)

Let  $r$  be the radius of the loop.

KE at the top of the loop is  $mg(h-2r)$ , so the speed at the top of the loop  $v = \sqrt{2g(h-2r)}$

Net force at the top  $F = mg + R$ , which is the centripetal force required.

$$mg + R = mv^2/r = 2mg(h - 2r)/r$$

So R increases linearly with h.

1997MC(6)

- (1) Incorrect. The two fragments should have the same magnitude of momentum  
 $M_1 V_1 + M_2 V_2 = 0$
- (2) Correct. Speed = P/m, so smaller mass, larger speed
- (4) Correct. By writing KE = P<sup>2</sup>/2m, where p is the momentum. Smaller mass, larger KE

1997MC (9)

Basic facts about SHM:

a leads v by  $\pi/2$

v leads by x by  $\pi/2$

- (1) correct (2) correct (3) incorrect, because a and x are in antiphase

1997MC (12)

Reflection of a transverse wave from a denser medium :  $\pi$  change, that means the wave is inverted

Reflection of a transverse wave from a less dense medium: no change in shape

1997MC (14)

- (1) Doppler effect, so the frequency will change.
- (2) Longer distance, intensity is reduced, so amplitude is smaller
- (3) If "speed" refers to the speed of propagation of wave in air, O.K., it doesn't change, but if "speed" refers to the speed of sound relative to the men on the ship, it is changed

1997 MC(15)

- (1) Incorrect. Path difference  $3000 \text{ nm}/400 \text{ nm} = 7.5 = 7 + 1/2$

It is the 8th dark fringe.

$m = 0 \rightarrow$  1st dark fringe

$m = 1 \rightarrow$  2nd dark fringe

so on

- (2) Incorrect. The fringe pattern is independent of the separation between the light source and the slits.

- (3) Correct.  $3000/500 = 6$  (so P becomes a bright fringe)

1997MC (16)

Pipe A; wavelength of fundamental note =  $4L_A$

Pipe B; wavelength of fundamental note =  $2L_B$

Same fundamental note, so same wavelength,  $4L_A = 2L_B$      $L_A:L_B = 1:2$

1997MC (17)

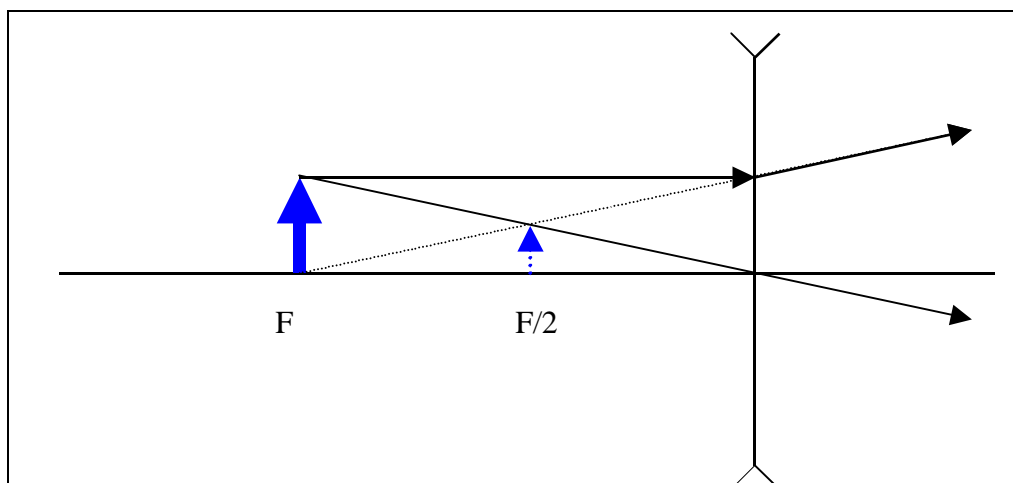
Optical path difference is increased if water is introduced (because wavelength is shorter in water).

For a particular order of fringe  $m$ ,  $2d = m\lambda$ . After water is introduced, the condition becomes  $2nd' = m\lambda$ . Because  $n > 1$ , so  $d' < d$ . The same order now appears at a smaller thickness of film (i.e. at a smaller radius).

1997MC (18)

To a convex lens, object at  $2F$ , object is formed at  $2F$ , so to  $L_1$ ,  $2f = 10$  cm,  $f = 5$  cm

To a concave lens, object at  $F$ , image is formed at  $F/2$



To  $L_2$ ,  $f = 20$  cm  $>$   $10$  cm

The best answer is D.

1997MC(19)

$$d \sin \theta = m\lambda$$

$$d \sin(90^\circ - 65^\circ) = \lambda \dots\dots\dots(1)$$

[Note:  $\theta$  is the angle measured from the zeroth order, which is  $90^\circ$  as measured by the protractor]

$$d \sin \theta = 2\lambda \dots\dots\dots(2)$$

Divide (2) by (1)       $\sin \theta = 2 \sin 25^\circ$

$$q = 58^\circ$$

The **protractor reads**  $90^\circ - 58^\circ$  or  $90^\circ + 58^\circ$

1997 MC(20)

Some facts about material

Stiffness (stiff/soft): slope of the elastic (linear) part

P is stiffer because it has a larger slope

Strength (strong/weak): highest point of the curve

Q has a greater strength because it has a higher ultimate tensile stress

Ductility (ductile/brittle): length of the plastic region

Q is more ductile because it has a longer plastic region

1997MC(21)

(2) **The number of conduction electrons per unit volume solely depends on the type of material.**

For instance, someone asks you : "There is a copper block of  $1 \text{ m}^3$  , how many free electrons does it contain? " O.K. What will you do? You will use the molar mass of copper, Avogadro's constant, etc to calculate, rather than saying : "I can't calculate because I don't know what voltage is applying to it"

Yes,  $I = nqAv$ , but it tells me nothing about what quantities  $n$  depends on.

Among the four quantities  $n$ ,  $q$ ,  $A$ ,  $v$ , which is/are constant ? We CANNOT KNOW from the equation itself. Only from the given information and other Physics, we know  $n$ ,  $q$  and  $A$  (same wire) are unchanged , so  $I$  is proportional to  $v$ .

Everybody knows density  $r = \frac{M}{V}$  . Would you say  $r$  is proportional to  $M$  ?

Another example is speed of waves  $v = f\lambda$ . Would we say  $v$  is proportional to  $f$  ?

NO ! " $v=f\lambda$ " is always true, but  $v$  may or may not depends on  $f$  (c.f. light in vacuum and light in glass)

**" $y = kx$ " means  $y$  is proportional to  $x$  only when  $k$  is a constant**

1997MC (24)

Volume control is usually a variable resistor

1997MC (25)

Mass is proportional to volume.

Length of X = 3(Length of Y)

Cross-sectional area of x = (Cross-sectional area of Y)/3 (because of same mass)

Resistance  $R \propto \frac{l}{A}$        $R_X:R_Y = 9:1$

Power  $P = I^2R$        $P_X:P_Y = 9(1^2):1(2^2) = 9 : 4$

1997MC (26)

Basic facts about motor

Battery voltage =  $V$ , induced emf =  $\epsilon$ , internal resistance =  $R$ 

$$V - \epsilon = IR$$

$$e \propto \text{angular speed}$$

Power delivered by the battery =  $VI$ Power loss in armature coil =  $I^2R$ Mechanical power developed =  $VI - I^2R = \epsilon I$ 

1997MC (27)

(1) Time constant of an RC circuit =  $RC$ , so the unit of  $RC$  is second.(2) Time constant of an LR circuit =  $L/R$ , so the unit of  $L/R$  is second.(3) Resonant frequency =  $\frac{1}{\sqrt{LC}}$ , so the unit of  $\sqrt{LC}$  is second (so  $LC$  is not)

1997MC (33)

(1) The glass wall is in thermal equilibrium. Its temperature does not rise after reaching the equilibrium. On the whole, the glass wall does not gain a net energy

(2) No, if the resistance is high, the power of the lamp will be very small. This is irrelevant to the low efficiency of the lamp bulb.

(3) Most of the energy is dissipated as thermal energy. The thermal energy is radiated to outside in the form of IR

1997MC (40)

$$\text{Total impedance } Z = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$$

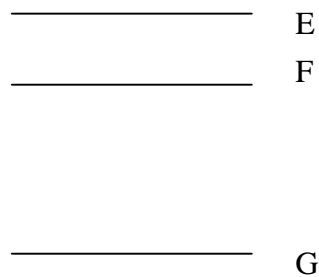
RMS current (ammeter reading)  $I_{\text{rms}} = V_{\text{rms}}/Z$ As freq increases,  $Z$  decreases, so RMS current increases.RMS voltage across C (voltmeter reading) =  $I_{\text{rms}} X_C$ 

$$= \frac{V_{\text{rms}}}{\omega C \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}} = \frac{V_{\text{rms}}}{\sqrt{(\omega CR)^2 + 1}}$$

When frequency increases, RMS voltage across C decreases.

[Quick thinking: a cap behaves as a "perfect conducting wire" at high frequencies, so as frequency increases, total current rises and the p.d. across C drops]

Suppose the three levels are E, F and G.



Longest wavelength of photon comes from the transition from E to F

$$h \frac{c}{\lambda_2} = E - F \quad \dots \dots \dots (1)$$

Shortest wavelength of photon comes from the transition E to G

$$h \frac{c}{\lambda_1} = E - G \quad \dots \dots \dots (2)$$

Let the wavelength of the photon originating from the transition is F to G be  $\lambda$

$$h \frac{c}{\lambda} = F - G \quad \dots \dots \dots (3)$$

Since (3) = (2) - (1)

$$\frac{1}{\lambda} = \frac{1}{\lambda_1} - \frac{1}{\lambda_2} \quad \text{or} \quad \lambda = \left( \frac{1}{\lambda_1} - \frac{1}{\lambda_2} \right)^{-1}$$

[If F is closer to G, the longest wavelength comes from F to G.. Nevertheless, the result is the same]

1997MC (42)

It is a summing amplifier

$R_f = 20\text{k}\Omega$ .

Two input voltages to V.

One input voltage:  $V_1 = 30\left(\frac{2}{3}\right) - 15 = 5 \quad R_{i1} = 10 \text{ k}\Omega$

The other input voltage:  $V_2 = 30\left(\frac{1}{3}\right) - 15 = -5V \quad R_{i2} = 20 \text{ k}\Omega$

$$V_{\text{out}} = -R_f \left( \frac{V_1}{R_{i1}} + \frac{V_2}{R_{i2}} \right) = -5V$$

Let  $m$   $\alpha$ -particles and  $n$   $\beta$ -particles are emitted

One  $\alpha$  particle will decrease the mass number by 4.

$$226 - 206 = 4m \quad m = 5$$

One  $\alpha$  particle decreases the atomic number by 2 and one  $\beta$  particle increases the atomic number by 1.

$$88 - 82 = m(2) - n \quad n = 4$$

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