H2 PHYSICS

Exam papers with worked solutions

(Selected from Top JC)

SET E

PAPER 2

Compiled by

THE PHYSICS CAFE

1 **(a)** The *kilogram* and the *metre* are base units. Name two other base units.

Ampere, second, kelvin, the mole. any correct 2 answers [1]

(b) The capacitance of a conductor C is the amount of charge Q required to cause a unit change in its potential difference (p.d.), V.
Potential difference is defined as the electrical energy per unit charge converted to non-electrical energy.

The formula is $C = Q / V$

(c) **(i)** Express the unit for capacitance in base units.

Unit of C = unit of Q / unit of V

[C] = [Q] / [V]
= [Q] / [E] / [Q]
= $[Q]^2$ / [E]
= $(A\ s)^2 / (kg\ m^2\ s^{-2})$ [M1]
= $A^2\ kg^{-1}\ m^{-2}\ s^4$ [A1]

Base units = ……………………………….[2]

(ii) A student conducted an experiment to find the capacitance of a conductor. He recorded the following values:

Current passing through the conductor = 1.0 μA ± 10%
Time taken during the charging process = (0.4 ± 0.1) s
Potential difference across the conductor = (2.0 ± 0.2) V

Calculate, with its actual uncertainty, the value of the capacitance of the conductor.

C = Q / V
= I t / V
= $(1 \times 10^{-6})(0.4) / (2.0)$
= 0.20 μC [C1]

$$\frac{\Delta C}{C} = \frac{\Delta I}{I} + \frac{\Delta t}{t} + \frac{\Delta V}{V}$$

$$\frac{\Delta C}{(0.20\mu A)} = \frac{(0.10 \times 1.0)}{(1.0)} + \frac{(0.1)}{(0.4)} + \frac{(0.2)}{(2.0)}$$

ΔC = 0.09 μC (1 s.f) [C1]
C = (0.20 ± 0.09) μC [A1]

(0.20 ± 0.090) μC

Capacitance = ……………….. ± …………………[3]

For Examiners Use

2 A ski jumper lands 96 m from his take off point as shown in Figure 2.1 below. The slope is at an angle of 45° and the jumper is in the air for 4.3 s.

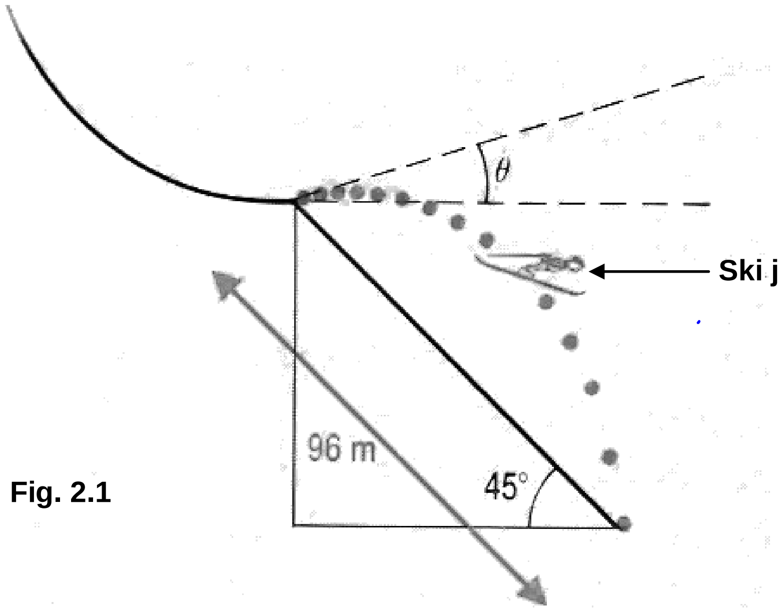

Fig. 2.1

Assuming that air resistance is negligible, find

(a) the horizontal distance traveled

S_x = 96.cos45° = 67.9 m (or 68 m) [A1]

Distance = ……………………… m [1]

(b) the horizontal component of the velocity at take off

$S_x = u_x(t)$ → u_x = 67.9/4.3 = 15.8 m s^{-1} (or 16 m s^{-1}) [A1]

Velocity = ………………… m s^{-1} [1]

(c) the vertical distance from take off to landing

S_y = 96.sin45° = 67.9 m (or 68 m) [A1]

Distance = …………………… m [1]

(d) the vertical component of the take off velocity

$S_y = u_y t + ½ at^2$ → - 67.9 = u_y(4.3) – ½ (9.81)$(4.3)^2$ [C1]
→ 4.3 u_y = 90.69 – 67.9 = 22.79
→ u_y = 5.3 m s^{-1} [A1]

(Note the direction is upward – no mark for making this observation.)

Velocity = ………………… m s^{-1} [2]

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(e) the angle of take off, θ

$\theta = \tan^{-1}(u_y / u_x) = 18.5°$ [A1]

θ = …………………………..° [1]

(f) the speed of take off.

$u^2 = u_y^2 + u_x^2$ [C1]
→ $u = (5.3^2 + 15.8^2)^{1/2}$
→ u = 16.7 m s^{-1} (or 17 m s^{-1}) [A1]

Speed = ………………………. m s^{-1} [2]

(g) State the effect on the maximum horizontal distance travelled by the ski jumper if air resistance is not negligible.

Shorter range (if air resistance is not negligible). [B1]

3 A student did the following experiments. The density of water is 1.0 x 10^3 kg m^{-3}.

(a) He finds that a rock whose mass is 100 g has an apparent mass of 82 g when submerged in water. Find the density of the rock.

Difference in weight = upthrust = weight of fluid displaced [C1]
$(100 – 82) \times 10^{-3} \times (g) = \rho_f V_f g$
(1): $0.018 = \rho_f V_f$

weight of rock, $mg = \rho_r V_r g$
(2): $0.100 = \rho_r V_r$
Since $V_f = V_r$,

(2) / (1): $\rho_r = (0.100)(\rho_f) / (0.018)$ [M1]
= (0.100)(1000) / (0.018)
= 5560 kg m^{-3}. [A1]

Density = …………………………… kg m^{-3} [3]

(b) He puts an ice-cube of mass 120 g in a glass of water. The ice-cube floats. Determine

(i) the upthrust on the ice-cube,

Upthrust = weight of floating ice
= 0.12 x 9.81
= 1.18 N [A1]

Upthrust = ... N [1]

(ii) the volume of the water displaced by the ice-cube.

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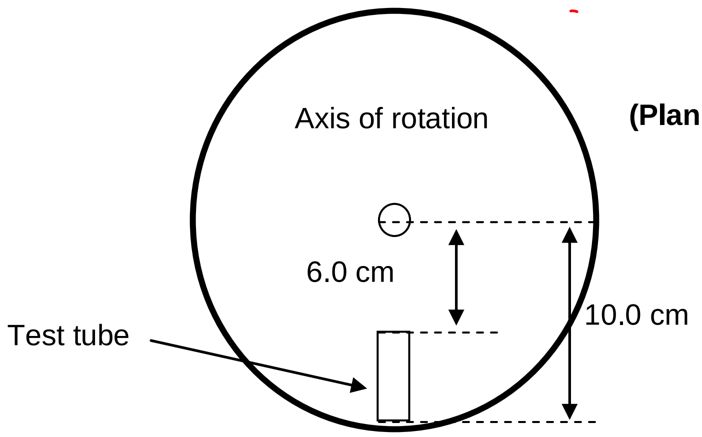
Upthrust = weight of water displaced (fully or partially submerged)
1.18 = ρ V g = (1000)(V)(9.81)
V = 1.2×10^{-4} m^3. [A1]

V = ... m^3 [1]

(c) He observes that in **(b)**, when the ice-cube floating in a jug of water melts, there is no change in the level of the water. Explain.

The <u>weight of the melted ice is the same as the ice</u>. [A1]
Hence the <u>upthrust remains unchanged</u> [A1]
and the water level remains constant.

4 **(a)** A centrifuge rotor, in Fig. 4.1 (not drawn to scale), rotates at 3 000 r.p.m. (revolutions per minute). The top of a test tube (perpendicular to the rotation axis) is 6.0 cm, and the bottom of the tube is 10.0 cm, from the axis of rotation. A test tube of blood is secured in the centrifuge. It can be assumed that the test tube of blood undergoes uniform circular motion.



(Plan view of centrifuge)

Fig. 4.1

Blood cells and plasma are separated and found at the bottom and top of the tube respectively after one minute in the centrifuge.

(i) Show that the frequency of the rotation is 50 Hz.

Frequency = 3 000 / 60 [C1]
= 50 Hz

Frequency = ... Hz [1]

(ii) Calculate the acceleration at the bottom of the tube.

w = 2πf
= 2 π (50)
= 314 rad s^{-1}. [C1]

a = r w^2
= 0.10 $(314)^2$
= 9860 m s^{-2}. [A1]

The acceleration is towards the axis of rotation.

Acceleration = ………………………… m s^{-2} [2]

(iii) Use the appropriate Newton's Laws of motion to explain why the heavier blood cells will be found at the bottom of the tube.

For Examiners Use

From N1L,
Heavier blood cells have larger inertia and require a larger centripetal force to keep it in uniform circular motion with the same angular frequency as the lighter cells. [C1]

From N2L,
Net force on cell F = mw^2r, for constant angular velocity w, centripetal force increases with radii, hence, the cells with largest mass are found at the bottom of the tube. [C1]

(b) The centripetal acceleration, *a*, of a body undergoing a uniform circular motion of radius *r* can be expressed as either (1) $a = \frac{v^2}{r}$ or (2) $a = r\omega^2$, where *v* and ω are linear and angular speeds of the body respectively.

For a uniform circular motion of constant period, student A thinks that *a* decreases with *r* according to equation (1), while student B argues that *a* increases with *r* according to equation (2).

Explain which student's argument is correct.

Only *w* is constant at all points in a body in uniform circular motion whereas *v* varies proportional to its displacement from the center of rotation. [M1]
Student B is correct. [A1]

5 **(a)** Explain the meaning of *coherence* in relation to the superposition of the two waves.

There is <u>constant phase difference</u> between the two waves. [C1]
The waves <u>maintain a constant phase difference</u> between them,

Mistakes:

The waves are in phase.
The waves have the same phase difference
The waves have the same frequency, wavelength and amplitude and are in phase.

(b) The apparatus illustrated in Fig. 5.1 (not drawn to scale) is used to demonstrate two-source interference using light.

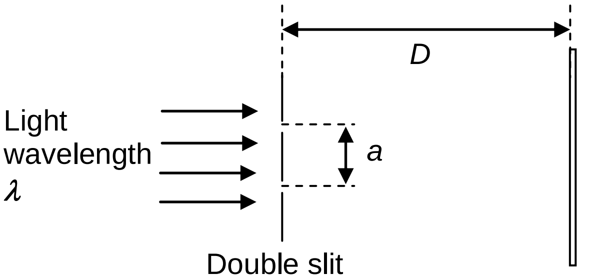


Fig. 5.1

The separation of the two slits in the double slit arrangement is *a* and the interference fringes are viewed on a screen at a distance *D* from the double slit. When light of wavelength λ is incident on the double slit, the separation of the bright fringes on the screen is *x*.

(i) Write down an expression relating λ, *a*, *D* and *x*. [1]

$x = \lambda D/a$ [A1]

(ii) Light of wavelength 500 nm is used in an experiment. The distance between the double slit and the screen is 1.0 m.
It is observed on screen that the first to the last of the 12 bright fringes span a distance of 3.0 cm. Calculate the separation of the two slits.

For Examiners Use

The value of x is 3.0 / 11 = 0.27 cm [C1]

Using $a = \lambda D / x$
$= (500 \text{ nm}) (1.0 \text{ m}) / (0.27 \times 10^{-2} \text{ m})$
= 0.183 mm [A1]

Slit separation = ………………………… mm [2]

(iii) Describe the effect, if any, on the separation and on the maximum brightness of the fringes in **(ii)** when the following changes are made. [3]

1. Red light is used instead with half the original amplitude of the light used in **(ii)**, while keeping *a* and *D* constant.

The wavelength is increased.
Using x = λ D / a, the separation will be larger. [C1]
The maximum brightness will also be (about ¼ times) less bright. [C1]

Mistake:

The maximum intensity is halved
The maximum intensity reduce by half
The maximum intensity reduced by a quarter.

2. The width of each slit is increased, while keeping *a*, λ and *D* constant.

The fringe separation will remain unchanged and the maximum brightness will increase.
[C1]

6 **(a)** A radioactive source has an initial number of *N* undecayed atoms and it's half-life is *T*. Sketch on the axis in Fig. 6.1 below a graph which shows qualitatively how the number of undecayed atoms varies with time. Indicate on your sketch for at least 2 half-lives. [2]

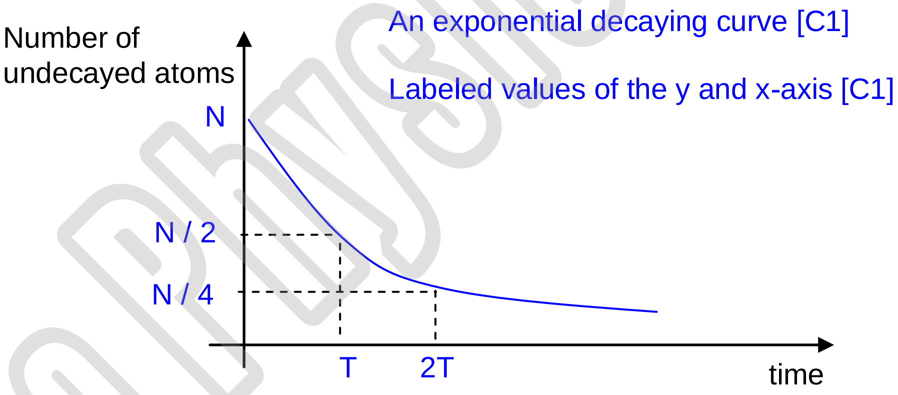


Fig. 6.1

(b) For a particular radioactive source, the decay constant is 1.8×10^{-6} s^{-1}, and N = 3.7×10^{21}.

For Examiners Use

(i) Calculate the half-life of the source.

T (half-life) = (ln 2) / (1.8×10^{-6})
= 3.85×10^{5} s. [A1]

Half-life = ……………………….. s [1]

(ii) Calculate the number of undecayed atoms after 30 days.

N = N_o exp (-λt)
= (3.7×10^{21}) exp [– (1.8×10^{-6})(30 x 24 x 60 x 60)] [M1]
= 3.48×10^{19}. [A1]

Number = ………………………….. [2]

(iii) Calculate the activity of the source after 30 days.

$A = \lambda N$
$= (1.8 \times 10^{-6})(3.48 \times 10^{19})$ [M1]
$= 6.26 \times 10^{13}\ s^{-1}$. [A1]

Activity = ……………………… s^{-1}. [2]

7 If a conducting liquid flows through a magnetic field, the conditions exist for an e.m.f. to be set up across the liquid. The principle is used in electromagnet flow meters to measure the rate of flow of liquid along a pipe. A diagram of this type of flowmeter is given in Fig. 7.1. As the liquid flows through the tube it cuts through the magnetic field set up by the field winding coils, causing an e.m.f. E_1 to be induced. The e.m.f. is sensed by two electrodes *X* and *Y* which are opposite each other and in contact with the liquid at right angle to the axis of the magnetic field.

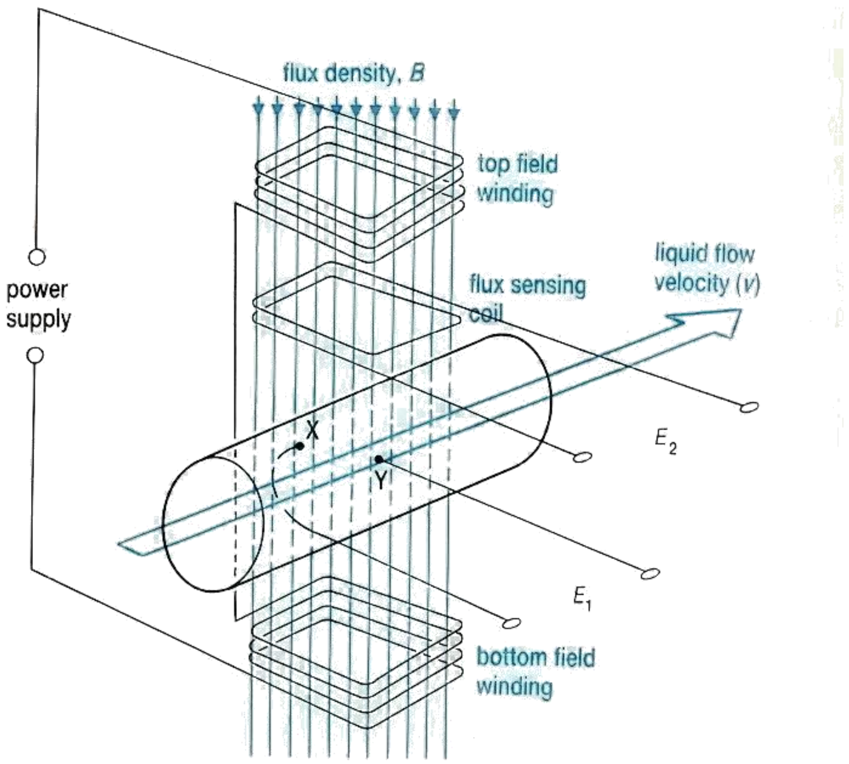


Fig. 7.1

In addition, there is a flux sensing coil which gives an output E_2 proportional to the magnetic flux density.

For Examiners Use

(a) Explain why the pipe, in the vicinity of the electrodes, have to be non-conducting.

To prevent shorting X and Y [A1]

(b) **(i)** Show that $E_1 = kvB$ where k is a constant. [2]

The charges accumulate at the edges of the vessel.

At equilibrium, the electric force qE balances the magnetic force qvB on an ion of charge q,.
That is, $qE = qvB$. Thus, $E = vB$. [M1]

The emf, $E_1 = E / d$, where d = diameter of the vessel. [B1]
Therefore $E_1 = vB/d = kvB$ (Shown) [A0]

(ii) Show that the velocity $v = k'\frac{E_1}{E_2}$ where k' is another constant. [2]

E_2 = Area of coil x rate of change in magnetic flux = $AB/\Delta t = zB$ [B1]

Thus, $E_1 / E_2 = kvB / zB \rightarrow E_1 / E_2 = (k/z)\ v$ [M1]

$\rightarrow v = k'\frac{E_1}{E_2}$ where k' = z/k [A0]

(c) Show that for a liquid travelling along a pipe of internal diameter 65 mm with a velocity of 0.73 m s^{-1}, when B = 0.35 T, the value of E_1 is 16.6 mV. [2]

$E_1 = vB/d = (0.73)(0.35)/(65 \times 10^{-3})$ [C1]
= 0.0166 V = 16.6 mV. [A1]

(d) Only a small conductivity is necessary for the liquid used in such a flowmeter. One of the following liquids is unsuitable. Make a reasoned guess which of these liquids is not suitable.

1. Sewage
2. Water
3. Hydrocarbon
4. Fruit Juice

Answer = Hydrocarbon [A1]

(e) What advantage is there in using platinum electrodes?

Platinum resists corrosion. [A1]

(f) Why does E_2 become zero if the power supply is d.c.?

No change in magnetic flux through the search coil. [A1]

For Examiners Use

(g) **(i)** How does using a.c. overcome the problem?

Ensure that there is a changing flux. [A1]

(ii) What complication occurs if an a.c. is used?

E_1 is not constant. [A1]

(h) **(i)** What liquid speed would you expect a flowmeter to read on a 450 mm bore pipe if liquid passes through the pipe at a rate of 200 $m^3\ h^{-1}$ (cubic metres per hour).

Speed = amount of flow per unit time / Area of vessel [C1]

$$v = \frac{200}{60x60} / \frac{\pi}{4}\left(450x10^{-3}\right)^2$$ [A1]

$$= 0.35 \text{ m s}^{-1}$$

Speed = ………………………… m s^{-1} [2]

(ii) State an assumption you are making.

The liquid is incompressible. [A1]

(i) In practice, there is a limit on the usable length of cable from electrodes to the measuring instrument. Explain why the usable length depends on the liquid being used.

If the conductivity of the liquid is low the internal resistance between X and Y is high. The resistance of the cable adds to this internal resistance and may reduce the output to too small a value. [A1]

(j) Electromagnetic flow meters are used to measure the blood flow rated in patients undergoing heart or arterial surgery. Suggest a possible advantage of using such a flow meter.

This method does not require the insertion of the probe into a vessel. [A1]

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