Annex: Sample exam questions, 2011 and 1980s

Sample questions 1 and 2 are from 2011 (Intl.)AS level and Pre-U physics respectively, and have been annotated in red. They are almost devoid of concepts except a couple of definitions of energy. Small steps are spelt out so that not more than one thing needs to be addressed before the candidate is set firmly on the right path again. Nearly all effort is spent injecting numbers into formulae that at most require GCSE-level rearrangements. There is no element of derivation of results. These questions are seemingly entirely representative in style and content of AS and A2 level Physics exams. They are rather lengthy, even if you adjust for the white space into which the candidate has to write and also adjust for the photographs etc. in one case. One sees symptoms of direct teaching to the letter of the specification. All diagrams are provided.

Sample questions 3-7, also annotated in red, are:

1986 O-level: crosses disciplines, underlying concepts and formulae not pointed to. Certainly more difficult than the AS sample Q1 to which it has common elements. Much more difficult than A2 sample Q2 since concepts not given, synthesis required, etc.

1988 A-level: well structured in positive sense. [5] for discussion of a difficult and important idea (circular motion). (a) combines with magnetism, establishes orbit, calculates frequency. No diagram. (b) quite complex (diagram given). Asked for principle of question, then a calculation. Harder than most Cambridge entrance questions currently.

1988 A-level (special paper): As above, but even more challenging. No diagrams at all. Deep principles (conservation). Relevance of rotation.

1987 Oxford Entrance: A little harder than special paper above. Conservation law (momentum) for explosion, while falling. This question makes all the above demands plus making stronger mathematical requirements of candidate.

1983 Common Entrance: remarkably demanding for this age group, approaching the challenge of current AS. 3 marks here in the Physics section of a total of 44 marks; also analogous Chemistry and Biology sections, all 3 sections to be done in 1 hour (with 10 mins. to read questions)!! [i.e. less than 2 minutes for this question]

Summary

There is a staggering difference in the demands put on candidates for the analogous exams. Exams much lower down the school system are in effect more difficult than exams given now in the penultimate years. [There exists a current Physics Oxford entrance paper. It also tests much mathematics, and is different in style and function from its predecessor.]

All university entrants sat these difficult A-levels (not just IC, Oxbridge etc.)[1]. Admittedly then a lower fraction of pupils went on to HE, but presumably one could again aim for a school system to get a sizable fraction of pupils to manage exams of these standards. Children are not intrinsically unable to attack such problems. Demands on language were higher in the 1980s.

---

[1] Actually, in all 57,000 students sat these A-levels, in comparison with the 33,000 sitting A-level physics today.

2 **(a)** Explain what is meant by *work done*.

definition

....

.... [1]

(b) A car is travelling along a road that has a uniform downhill gradient, as shown in Fig. 2.1.

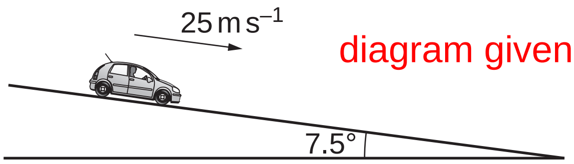


diagram given of simple situation

all numbers

Fig. 2.1

The car has a total mass of 850 kg. The angle of the road to the horizontal is 7.5°.

Calculate the component of the weight of the car down the slope.

quantum 1

units given

component of weight = ... N [2]

(c) The car in **(b)** is travelling at a constant speed of $25\,m\,s^{-1}$. The driver then applies the brakes to stop the car. The constant force resisting the motion of the car is 4600 N.

(i) Show that the deceleration of the car with the brakes applied is $4.1\,m\,s^{-2}$.

quantum 2

[2]

(ii) Calculate the distance the car travels from when the brakes are applied until the car comes to rest.

kinematics

(equations given in preface to test paper)

quantum 3

distance = ... m [2]

(iii) Calculate

1. the loss of kinetic energy of the car,

1/2 m v^2 (substitution into simple formula; arithmetic)

loss of kinetic energy = ... J [2]

2. the work done by the resisting force of 4600 N.

force x distance (definition asked for in (a)) = work

force given in (c). Distance evaluated in c(ii)

work done = ... J [1]

(iv) The quantities in **(iii) part 1** and in **(iii) part 2** are not equal. Explain why these two quantities are not equal.

....

.... [1]

a nice subtlety, but minimal marks allowed for it???

For Examiner's Use

10 Fig. 10.1 shows part of an array of wind turbines on farmland.

Fig. 10.1

(a) Each turbine converts the kinetic energy of the wind into electrical energy. 1.16×10^{7} kg of air, travelling at a speed of $20\,\mathrm{m\,s^{-1}}$, pass through the turbine each minute.

Calculate the maximum power of the turbine in MW assuming all of the kinetic energy of the wind is transferred to the turbine.

(Can't be all KE since wind passes through turbine)

1/2 mv^2 (per second gives power)

(simple physics, prescribed and directed)

units given

maximum power = ... MW [2]

(b) Blades of length l sweep out area A with each rotation.

When air of density ρ and wind speed v passes the blades then the maximum power P transferred to the turbine is also given by the expression:

$$P = \tfrac{1}{2}A\rho v^{3}$$

not 1/2 but 8/27 maximum prefactor (due to Vena Contracta) gradient given - why?!

Fig. 10.2 is a graph of ln*P* against ln*v* for different wind speeds. The gradient of the line is 3.

A straightforward plot of the ln(P) they are asked to get in (i) below.

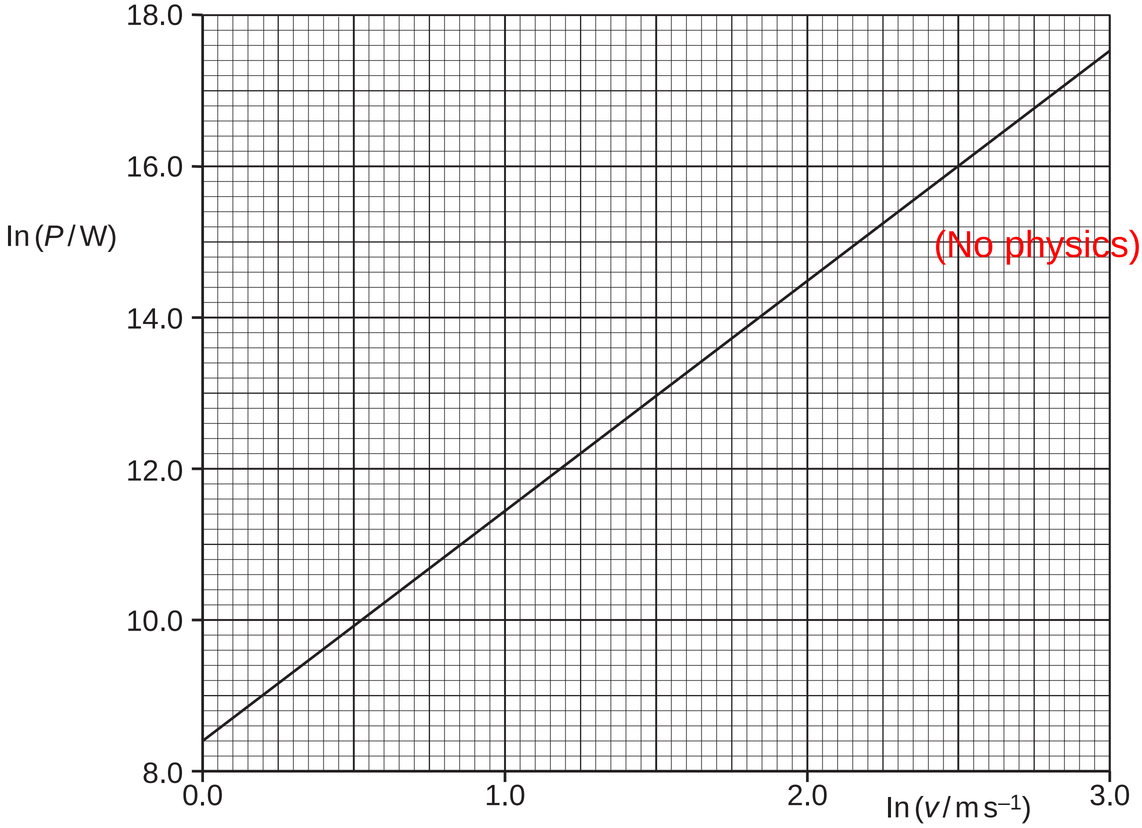


Fig. 10.2

(i) State the expression for the intercept on the ln*P* axis in terms of *A* and ρ.

straight line (GCSE?) (no physics)

.... [1]

(ii) State the value of this intercept.

read off graph -> C (no physics) .... [1]

(iii) Use the value of the intercept stated in **(ii)** to determine the blade length *l*. The density of air ρ is 1.23 kg m^{-3}.

rearrange e^c =1/2 rho A and A = pi r^2
(no physics)

units given

blade length = ... m [2]

For Examiner's Use

For Examiner's Use

(c) As the wind passes each blade a torque is exerted on it causing it to rotate about its horizontal axis. The blade has a moment of inertia.

why??

State, in words, the equation that relates torque to moment of inertia.

T = I d(omega)/dt ??, but in words.

Student to recite "T = moment of inertia times angular acceleration"

.... [2]

(d) Fig. 10.3 shows a typical waterwheel used in a mill to generate rotational kinetic energy. Water exerts a torque on the wheel as it pours from above into the buckets built into the rim of the wheel.

Fig. 10.3

Assume the wheel is a large ring of dense oak wood, of mass M. Fig. 10.4 is a diagram of the wheel.

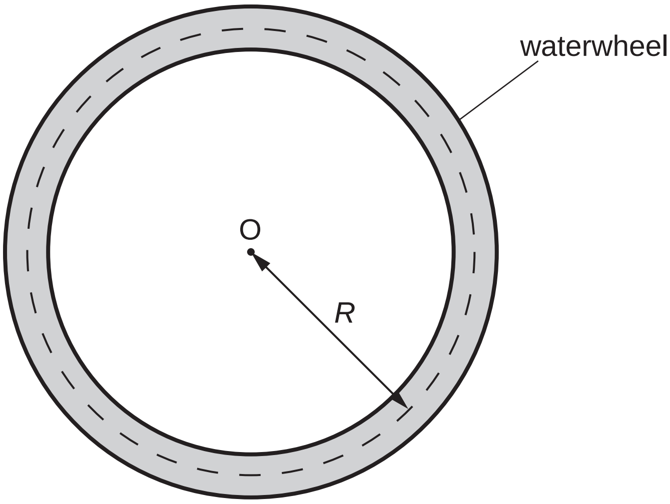


Fig. 10.4

For Examiner's Use

(i) Show that the moment of inertia of the waterwheel can be taken to be

$$I = MR^2$$

as long as the waterwheel is treated as a thin ring of average radius R.

entirely trivial for a thin ring

[2]

(ii) The waterwheel rotates at 4 revolutions per minute.

Calculate its angular speed in rad s^{-1}.

arithmetic: 4/60 revolutions per second
x 2pi to get radians/second
need to remember omega = 2 pi f

angular speed = ... rad s^{-1} [1]

(iii) The maximum power of the waterwheel is 6.5 kW. The wheel comes to rest in 30 minutes once the water stops flowing. As it slows down its average output power is 3.25 kW.

1. Show that the loss in rotational kinetic energy of the wheel as it comes to rest is approximately 6 MJ.

[2]

2. State an assumption made in the calculation in **1**.

....

.... [1]

For Examiner's Use

(iv) Using information given in **(ii)** and **(iii)**, determine the moment of inertia of the wheel. Give the unit with your answer.

1/2 I omega^2 = kinetic energy
been asked for KE and omega in (iii) and (ii) (given in case forgotten this). Rearrange for I, do arithmetic.
Physics input: remember kinetic energy formula

moment of inertia = ... unit .... [4]

(v) The radius of the wheel is 5.5 m.

Determine the mass *M* of the waterwheel.

got I above. Use I = mR^2 of d(i) above, rearrange for m=I/R^2, then arithmetic. No physics.

mass of waterwheel = ... kg [2]

[Total: 20]

The physics input in the whole question is minimal - recalling a couple of formulae and notion of power = energy/time
Rest is GCSE maths and a little arithmetic.

1986 O-level

1 (*a*) A model electric train of mass 1 kg runs on a level track at a steady speed of 0.4 m/s. The resistance to forward motion is 4 N.

(i) What is the magnitude of the forward force exerted by the engine? [1]

(ii) Calculate the power required to maintain this speed. [2]

Synthesis of mechanics and electricity.

(iii) Calculate the current required to produce this amount of power from a 12 V battery. [2]

Required concepts as in current AS/A2 but not structured to give answer.

(iv) Calculate the extra power required when this train climbs a slope of 1 in 20 (see Fig. 1) at the same steady speed. [3]

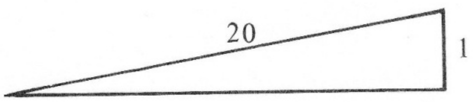


Fig. 1

Figure given since definition is established (slope = 1:20 along *slant*).

(*b*) A power unit, connected directly to the 240 V a.c. mains, can be used instead of a battery (Fig. 2).

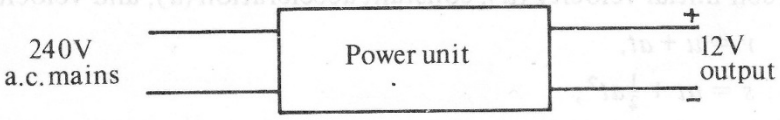


Fig. 2

(i) What are the two essential components in the power unit? Explain why they are essential. [4]

(ii) If the unit can also be used to vary the speed, what additional component might it contain? [1]

(iii) Draw a labelled circuit diagram which shows the arrangement of the three components you have named. [3]

(*c*) Although the domestic consumer only requires 240 V, electric power is transmitted over long distances at very high voltages, such as 250 000 V, using wires suspended from pylons.

(i) Why are very high voltages used for long distance transmission? [2]

Candidate has to establish principles him/herself (Ohm + power not given).

(ii) An engineer has to choose between aluminium and copper for the material of the wire. Name two things which have to be taken into consideration and explain why. [4]

Conductivity + weight, i.e. mechanics + electricity.

(iii) How is the electricity prevented from flowing to earth through the metal pylons? [1]

(iv) What other factors would have to be considered if it were proposed to place the wires underground? [2]

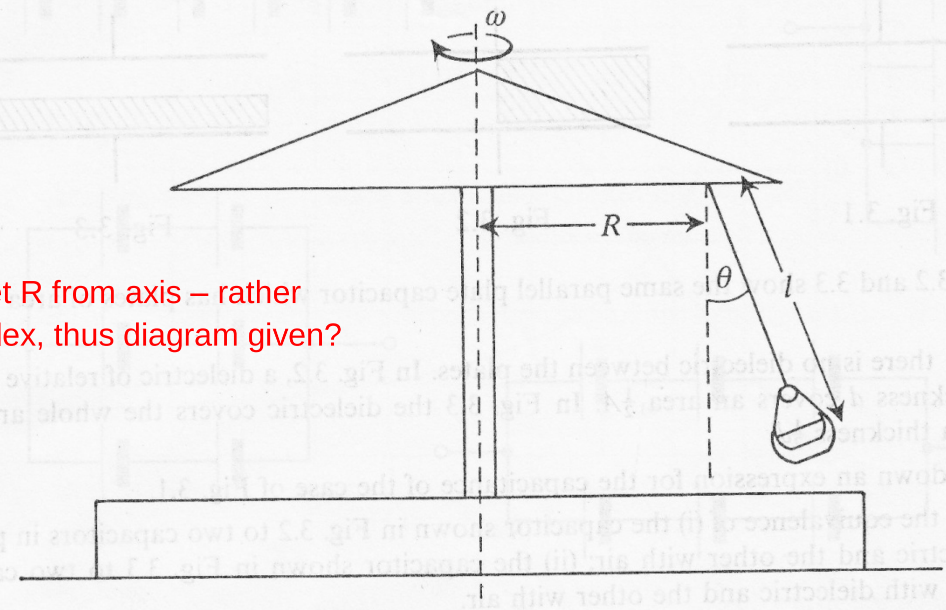
(Capacitance – leakage to earth when AC)

1988 A-level

2 Show that a particle travelling in a circular path of radius r has an acceleration v^2/r directed toward the centre of the circle. Understanding principles + derivation/maths/diagram [5]

(*a*) An electron of mass m and charge $-e$ has a speed v. It travels in a uniform magnetic flux density B applied in a direction perpendicular to its motion. Show that its path is a circle and find an expression for the frequency of the circular motion. Show that this frequency is independent of the radius of the circle. [6]

Mechanics + electromagnetism. Orbital frequency independent of radius.



Off set R from axis – rather complex, thus diagram given?

Fig. 2.1

(*b*) The vehicles of a fairground ride are supported by light cables with their upper ends at a radius R from the axis of rotation. The centre of mass of a vehicle is at a distance l from the upper point of support. Explain why, when the ride is rotating with angular velocity ω, the cables are inclined at an angle θ to the vertical, as shown. Show also that [4]

Discussion of principles required, since next part only [2].

calculation

$$\omega^2 = \frac{g \tan\theta}{R + l\sin\theta}.$$ [2]

Calculate the rate of rotation, in rev s^{-1}, for which $\theta = 15°$, given that $R = 3.0$ m and $l = 2.5$ m. [3]

Insertion of numbers only 3/20. But good to get feel of sizes.

1988 A-level, Special Paper

Diagrams by candidate.

1 Define *gravitational field* and *potential*, and state the relation between them. Sets scene. [3]

Throughout this question assume the Earth to be a perfect uniform solid sphere of radius 6400 km. *For this question* use the value $g = 9.8$ m s^{-2}. The *escape velocity* U is defined as the velocity relative to the Earth's surface which must be given to a body for it just to escape from the Earth's gravitational field.

(*a*) Neglecting the rotation of the Earth, derive an expression for U from first principles. Show that its numerical value is 11.2 km s^{-1}. Explain why the direction of projection does not affect the magnitude of U. Gravitational potential, energy principles. [6]

(*b*) As a result of the rotation of the Earth, the measured value of g at the Equator is different from that at the Pole. Explain this and calculate the percentage difference.(centripetal + potential)[4]

(*c*) Calculate the velocity of the Earth's surface at the Equator due to its rotation. Hence explain why the value of U at the Pole differs from that at the Equator. The direction of projection from the Equator is now important. Explain this in as much detail as you can. Does the result in (*b*) have any relevance to the determination of U? Challenging synthesis of ideas (none given to candidate) [7]

1987 Oxford entrance.

1. A mass M at height h above flat ground and falling vertically with velocity v breaks up explosively into two equal parts. The kinetic energy given to the system in the explosion is E. The two halves leave the point of explosion at angles θ and ψ with respect to the downward vertical.

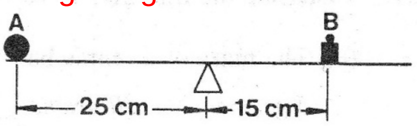
State the conservation laws that apply to the motion of the exploding system and, neglecting any change of mass, write down equations derived by application of these laws. **2, 5**

Consider the case that $E = Mv^2$ and one of the halves emerges at $\theta = 90°$. Show that $\cos\psi = 2/\sqrt{5}$ and that the distance separating the points where the two halves hit the ground is given, neglecting air resistance, by

$$v\sqrt{\frac{2h}{g}}+\frac{2v^2}{g}\left[\left(1+\frac{gh}{2v^2}\right)^{1/2}-1\right].$$ **6, 7**

1983 Common entrance.

Diagram given



A.3. A wooden rule, 50 cm long, is balanced on a fulcrum at its middle point. A lump of Plasticine at **A** needs a 100 gram mass at **B** to keep the rule balanced.

(*a*) What is the mass of the Plasticine? Show how you get your answer.

Idea of torques and their balance required. Component parts to torque required. Simple calculation. Not far off parts of current Pre-U question on torques in context of turbine.

(3 *marks*)

(*b*) There is an upward force acting on the rule when it is balanced with the Plasticine on it. Where is this upward force applied to the rule?

Newton's first law - force balance overall as well as torques.

(1 *mark*)