ATTAINMENT TARGETS PHYSICS JAMES BOSWELL EXAM (JULY 2023)

Domain B. Waves

Presumed known:
The candidate can:

- Design and use a numeric model[1].

The candidate knows:

- A model language for a computer model in model rules or in a graphic representation;
- The following phenomena:
    - sound;
    - echo;
- The following relationships:
    - the relationship between the amplitude of an oscillogram and the sound strength of the registered tone;
    - the relationship between the frequency of an oscillogram and the pitch of the registered tone.

Subdomain B1. Information transfer

Attainment target
The candidate can use the characteristics of vibrations and waves to analyse and explain, among other things, information transfer in different contexts.

Specification
The candidate can:

1. analyse and graphically represent,
   • by means of a numeric model show the relationship between the physical requirement for a harmonic vibration (force proportional to and in the opposite direction of the displacement) and its mathematical description (sine function);
   • subject concepts: period, reduced phase, phase difference;
2. make calculations on the natural frequency of a spring-mass system,
   • subject concepts: natural frequency, resonance;
3. analyse and graphically represent wave phenomena,
   • subject concepts: reduced phase, phase difference, propagating wave, propagation speed, sound speed, light speed, transverse, longitudinal;
4. analyse the relationship between the wavelength and the length of the vibrating medium,
   • subject concepts: node, antinode, fundamental, overtone;
   • at least in the context of: musical instruments;
5. determine from displacement-time and displacement-position graphs the physical characteristics (see specifications 1 and 3) of vibrations and waves,
   • at least in the context of: cardiogram;

[1] Presumed known from the school exam (subdomain I2).

6. describe information transfer between a sender and receiver[2],
   • subject concepts: radio wave, carrier wave, amplitude modulation, digital coding, sample frequency, bandwidth, channel separation, bit, data transfer rate;
   • at least in the context of: telecommunications (TV, radio, telephone).

The following formulas are included in these specifications:

$$f = \frac{1}{T} \qquad v = f\lambda \qquad \overrightarrow{F_{res}} = -C\vec{u}$$

$$T = 2\pi\sqrt{\frac{m}{C}}$$

$$\Delta\varphi = \frac{\Delta t}{T} \qquad \Delta\varphi = \frac{\Delta x}{\lambda} \qquad v_{max} = \frac{2\pi A}{T}$$

$u = A\sin(\frac{2\pi}{T}t)$, not: calculate *t* if *u* has been given

$$\ell = n\tfrac{1}{2}\lambda \qquad \ell = (2n-1)\tfrac{1}{4}\lambda$$

Subdomain B2. Medical imaging

Attainment target
The candidate can describe characteristics of ionising radiation and the effects of this radiation on humans and the environment. The candidate is also able to describe and analyse medical imaging techniques by means of physical principles and elaborate on the diagnostic function of these imaging techniques.

Specification
The candidate can:

1. describe emission, propagation, and absorption of electromagnetic radiation
   • subject concepts: absorption, emission, electromagnetic wave, photon;
2. name the different types of ionising radiation, their characteristics, and how these are generated, as well as the risks these kinds of radiation pose to humans and the environment, and make calculations with (equivalent) dose,
   • calculate and determine the activity at a given time from an (*N*,*t*) graph;
   • write the equation for a nuclear reaction;
   • subject concepts: radiation source, radioactive decay, isotope, nucleus, proton, neutron, electron, atomic mass unit ionising and penetrating power, range, X-rays, α, β and γ radiation, cosmic radiation, background radiation, irradiation, contamination, effective total bodily dose in relation to radiation protection norms, dose meter;
   • at least in the context of: nuclear diagnostic medicine, radiation protection;
3. solve problems in which the half-life time or half-value thickness plays a role,
   • subject concepts: penetration curve, half-life curve;
   • at least in the context of: medical diagnostics;
4. describe medical imaging techniques by means of their background in physics, name the (dis)advantages of these techniques and give reasons for choosing a particular technique in a

[2] Candidates are not expected to be able to flexibly apply the knowledge regarding this specification.

given situation.
• imaging techniques: X-ray image, CT scan, MRI scan, PET scan, echography, and nuclear diagnostics;
• backgrounds in physics: half-value thickness of human tissues, magnetic field and resonance, annihilation, creation of an electron-positron pair, ultrasonic sound wave, speed of sound in human tissues, absorption, transmission, reflection, tracer.

The following formulas are included in these specifications:

$E_f = hf \qquad c = f\lambda$

$A = -\frac{dN}{dt} \qquad A = \frac{\ln 2}{t_{1/2}} N$

$D = \frac{E}{m} \qquad H = w_R D \qquad A = N + Z$

$A = A_0 \left(\frac{1}{2}\right)^{\frac{t}{t_{1/2}}}$

$N = N_0 \left(\frac{1}{2}\right)^{\frac{t}{t_{1/2}}}$

$I = I_0 \left(\frac{1}{2}\right)^{\frac{d}{d_{1/2}}}$

Domain C. Motion and interaction

Presumed known:
The candidate can:
• make simple calculations with the following formula:

$\rho = \frac{m}{V}$

The candidate knows:
• the following phenomena:
- the structure of our solar system: Sun, moon, and planets;
• the following subject concept:
- energy storage.

Subdomain C1. Force and motion

Attainment target
The candidate can qualitatively and quantitatively analyse and explain the relationship between force and changes in motion in contexts by using Newton's laws.

Specification
The candidate can:

1. make calculations on uniform linear motions;
2. determine characteristics of motions by using position-time graphs and velocity-time graphs,
 • recognise the following motions: uniform linear motion, uniformly accelerated/decelerated motion, free fall, falling object with air resistance;

• determine the average velocity from an position-time graph;

• determine the velocity at a given time from an position-time graph, using the insight that the velocity is the time-derivative of position.

• determine the (gravitational) acceleration at a given time from an position-time graph, using the insight that the acceleration is the derivative of velocity to time;

• determine the displacement and the average velocity from a velocity-time graph using the surface;

3. analyse forces working on a system both by means of a vector drawing as by using trigonometric relations, among which the combining and decomposing into components and determining the size and or direction of forces.
   • forces: gravity, sliding friction force, rolling resistance force, air resistance force, normal force, tension force, muscle force, spring force;
4. explain and apply Newton's first law,
   • subject concept: inertia;
5. explain and apply Newton's second law;
6. explain and apply Newton's third law,
   • subject concepts: action force, reaction force, weight;
7. on the basis of an analysis of forces, choose a suitable numeric model for a motion and use the model to analyse the motion.

The following formulas are included in these specifications:

$s = vt$, v being constant

$$v_{\text{av}} = \frac{\Delta x}{\Delta t} \quad a_{av} = \frac{\Delta v}{\Delta t}$$

$$v = \frac{dx}{dt} \qquad a = \frac{dv}{dt}$$

$$F_g = mg \quad F_s = Cu$$

$$F_{f,air} = \frac{1}{2}\rho c_w A v^2$$

$$\overrightarrow{F_{AB}} = -\overrightarrow{F_{BA}}$$

$$F_{f,s,max} = fF_N$$

$$\overrightarrow{F_{\text{res}}} = \sum_i \overrightarrow{F_{\text{i}}} = m\vec{a}$$

Subdomain C2. Energy and interaction

Attainment target

The candidate can use the concepts of conservation of energy, efficiency, work, and heat to describe and analyse energy conversions in contexts.

Specification

The candidate can:

1. make calculations regarding force, displacement, work, velocity, and power,
   • determine the work from a force-displacement graph;
2. analyse energy conversions in motions,
   • apply the law of conservation of energy and the relation between work and kinetic energy;
   • at least the motions: free fall, falling motion with friction, vertical throw, vibration, and bouncing motion;
   • energies: kinetic energy, potential energy, energy in a spring, chemical energy, heat;
   • subject concepts: potential energy, (positive and negative) work, friction work, periodic motion;
   • at least in the contexts: energy consumption and reduction in traffic, moving humans.

The following formulas are included in these specifications:

$$W = Fs\cos\alpha$$

$$P = \frac{E}{t} \qquad P = \frac{W}{t} \qquad P = Fv$$

$$E_k = \tfrac{1}{2}mv^2$$

$$E_g = mgh \qquad E_s = \frac{1}{2}Cu^2$$

$$E_{ch} = r_v V \qquad E_{ch} = r_m m$$

$$\sum W = \Delta E_k$$

$$\Sigma E_{in} = \Sigma E_{out}$$

$$\eta = \frac{E_{useful}}{E_{in}} = \frac{P_{useful}}{P_{in}}$$

Subdomain C3. Gravity

Attainment targets
The candidate can analyse and explain motions by means of the gravitational interaction in the context of the universe.

Specification
The candidate can:

1. analyse a circular motion with constant velocity,
   • make calculations on a centripetal force only in situations in which only a single force takes on the role of the centripetal force;
   • subject concepts: orbital period, radius, velocity;
2. analyse motions of objects in a gravitational field by means of the gravitational force and the gravitational energy,
   • by means of a numeric model analyse the motions of planets, comets, and other heavenly

bodies;
• apply the relationship between the escape velocity and the mass and radius of a heavenly body;
• explain how the gravitational acceleration at the planet surface depends on the mass and the radius of the planet;
• subject concepts: gravitational interaction, elliptical path, geostationary path;
• at least in the contexts: moon, planet, satellite.

The following formulas are included in these specifications:

$$F_g = G\frac{mM}{r^2} \qquad E_g = -G\frac{mM}{r}$$

$$v = \frac{2\pi r}{T}$$

$$F_{cp} = \frac{mv^2}{r}$$

Domein D. Charge and field

Presumed known:
The candidate can:
• draw and interpret electrical circuits.

The candidate knows:
• the following subject concepts:
  - conductor, insulator.

Subdomain D1. Electrical systems

Attainment target
The candidate can analyse electrical circuits in context by using Kirchoff's laws. In addition, the candidate can analyse energy conversions.

Specification
The candidate can:

1. explain the phenomenon of electric current as a displacement of charge as a result of voltage.
   • use the definitions of current intensity, voltage, and specific resistance;
   • subject concepts: free electron, ion, elementary charge, voltage source, battery;
2. apply Kirchoff's laws as laws for the conservation of current intensity in a point and of voltage in a circuit;
3. analyse electrical circuits and make calculations for series and parallel circuits for voltage, current intensity, resistance, and conductivity,
   • in mixed circuits only reasoning and making simple calculations[3];
   • apply the correct way of connecting an ammeter and a voltmeter;

[3] A simple calculation is a calculation of *at maximum two* thought leaps.

• apply the following components in a circuit: diode, LDR, NTC, PTC, ohm resistor, lamp, motor, heating element, fuse, residual-current device;
• subject concepts: current division, voltage division, short circuit;

4. analyse the power and efficiency of energy conversions in an electrical circuit,
   • calculations on electrical energy in joule and in kilowatt-hour;
   • at least in the contexts: light sources and devices in the home (incandescent bulb, energy-saving bulb, LED, electromotor, heating element, and kWh-meter), energy consumption, energy reduction.

The following formulas are included in these specifications:

$$G = \frac{1}{R}$$

$$I = \frac{Q}{t} \qquad U = \frac{\Delta E}{Q} \qquad \rho = \frac{RA}{\ell}$$

$$I = GU \qquad U = IR$$

For a point in a circuit:

$$\sum_{\mathrm{i}} I_{\mathrm{i}} = 0$$

For a current circuit:

$$\sum_{\mathrm{i}} U_{\mathrm{i}} = 0$$

For a series circuit:

$$U_{\mathrm{tot}} = U_1 + U_2 + \ldots \qquad I_{\mathrm{tot}} = I_1 = I_2 = \ldots \qquad R_{\mathrm{tot}} = R_1 + R_2 + \ldots$$

For a parallel circuit:

$$U_{\mathrm{tot}} = U_1 = U_2 = \ldots \qquad I_{\mathrm{tot}} = I_1 + I_2 + \ldots \qquad G_{\mathrm{tot}} = G_1 + G_2 + \ldots$$

$$P = UI \qquad E = Pt$$

$$\eta = \frac{E_{useful}}{E_{in}} = \frac{P_{useful}}{P_{in}}$$

Subdomain D2. Electric and magnetic fields

Attainment target
The candidate can describe, analyse and explain electromagnetic phenomena in contexts with the help of electric and magnetic fields.

Specification
The candidate can:

1. describe an electric field as a result of the presence of an electric charge,
   • determine the direction of the electric field;
   • subject concepts: repelling and attracting electric force, homogeneous and radial electric field, field line;
2. apply the relationship between voltage and kinetic energy to a charged particle in a homogeneous electric field,
   • use electrical energy as a source of potential energy;
   • explain the electronvolt unit;
   • at least in the contexts: X-ray tube, linear accelerator;
3. describe a magnetic field as a result of the presence of moving a moving electric charge,
   • determine the direction of the magnetic field for a permanent magnet, a straight electric wire, and a coil;
   • subject concepts: uniform and non-uniform magnetic field, field line, electromagnet;
   • at least in the context: geomagnetic field;
4. describe the effect of a magnetic field on an electric current and on a moving charge,
   • determine the size and direction of the Lorentz force;
   • at least in the contexts: electromotor, loudspeaker;
5. analyse electromagnetic induction phenomena in different situations,
   • use the definition of flux;
   • apply the insight that the induction voltage is linearly proportional to the number of turns and the flux changes per time unit;
   • at least in the following situations: a moving magnet in a coil and a turning single-turn wire coil in a uniform magnetic field;
   • at least in the contexts: dynamo, microphone.

The following formulas are included in these specifications:

$$F_{el} = f\frac{qQ}{r^2} \qquad \overrightarrow{F_{el}} = q\overrightarrow{E}$$

$$\Delta E_k = -\Delta E_{el} \qquad \Delta E_{el} = qU$$

$$F_L = BI\ell \qquad F_L = Bqv$$

$$\Phi = B_{\perp}A$$

$$U_{ind} \propto N \qquad U_{ind} \propto \frac{d\Phi}{dt}$$

Domain E. Radiation and matter

Subdomain E2. Electromagnetic radiation and matter

Attainment target
The candidate can describe and explain (in astrophysical and other contexts) the interaction between radiation and matter by means of the concepts atom spectrum, absorption, emission, and radiation energy.

Specification
The candidate can:

1. describe and apply Bohr's atom model,
   • determine wavelengths and frequencies of spectral lines from energy level diagrams;
   • explain absorption and emission spectra;
   • subject concepts: photon, ground state, excited state, ionisation energy;
2. analyse starlight,
   • use a Hertzsprung-Russell diagram to classify stars based on temperature, total radiation capacity, and size;
   • analyse the radial velocity of stars by means of the spectrum;
   • decide whether elements are present in stars based on the spectrum;
   • subject concepts: Fraunhofer line, redshift, blueshift;
3. describe and apply the relationship between the emitted wavelengths and the temperature,
   • apply Wien's law;
   • subject concepts: Planck spectrum, continuous spectrum;
   • at least in the contexts: incandescent bulbs, stars;
4. explain how a star's perceived intensity on earth is related to the total radiation capacity of the star and the distance to the star,
   • apply Stefan-Boltzmann law;
   • subject concept: solar constant;
   • at least in the context: Sun;
5. describe how in the total spectrum of electromagnetic radiation observations of the universe are made from the earth and from space,
   • describe the different aspects of the electromagnetic spectrum and the characteristics of these types of radiation; gamma radiation, X-radiation, ultraviolet, (visible) light, infrared, radio waves, microwaves;
   • instruments: optical telescope, radio telescope, space telescope.

The following formulas are included in these specifications:

$$E_\mathrm{f} = hf \qquad E_\mathrm{f} = \frac{hc}{\lambda} \qquad E_\mathrm{f} = |E_\mathrm{m} - E_\mathrm{n}|$$

$$v = \frac{\Delta\lambda}{\lambda} c$$

$$\lambda_\mathrm{max} T = k_\mathrm{W}$$

$$I = \frac{P_{source}}{4\pi r^2} \qquad P_{source} = \sigma A T^4$$

Domain F. Quantum world

Subdomain F1. Quantum world

Attainment target
The candidate can apply the wave-particle duality and the Heisenberg's indeterminacy relation in contexts, and explain the quantisation of energy levels in a few examples by means of a simple quantum physics model.

Specification
The candidate can:

1. name light as a wave phenomenon and expound on this,
   • explain in which situations diffraction of light waves occurs;
   • explain an intensity pattern in terms of constructive and destructive interference;
2. apply the wave-particle duality to explain interference phenomena for electromagnetic radiation and matter particles;
   • make calculations with the de Broglie wavelength;
   • describe the double-slit experiment and explain what it means;
   • subject concepts: probability, probability density;
   • at least in the context: electron microscope;
3. use the photoelectric effect to shows that electromagnetic radiation is quantised,
   • subject concepts: photon, work function, energy quantum;
4. describe quantum phenomena in terms of the confinement of a particle,
   • estimate whether quantum phenomena can be expected by comparing the de Broglie wavelength with the order of magnitude of the confinement of the particle;
   • apply Heisenberg's indeterminacy relation;
   • describe the quantum model of the hydrogen atom and calculate the possible energies of the hydrogen atom;
   • describe the quantum model of a particle in a one-dimensional energy well and calculate the possible energies of the particle;
   • subject concepts: Bohr radius, zero-point energy;
5. describe the quantum tunnelling effect by means of a simple model and indicate how the probability of tunnelling depends on the mass of the particle and the height and width of the energy barrier,
   • at least in the contexts: Scanning Tunneling Microscope (STM), alpha decay.

The following formulas are included in these specifications:

$$p = mv \qquad \lambda = \frac{h}{p}$$

$$\Delta x \Delta p \geq \frac{h}{4\pi}$$

$$E_n = -\frac{13,6}{n^2} \quad \text{(in eV)} \qquad E_n = n^2 \frac{h^2}{8mL^2}$$

Domain H. Natural laws and models

Attainment target
The candidate can recognise, name, and apply fundamental principles and laws of physics in examples that fall within the subdomains of the central examination. The candidate is also able to use a model and judge the limits of the applicability and reliability of a certain model for a physical phenomenon.

Specification
The candidate can:

1. recognise, name, and apply fundamental principles and laws of physics in examples that fit the specifications of the vwo domains from this syllabus[4],
   • principles: universality, scale independency, thinking in order of magnitudes, analogy;
   • laws: laws of conservations, Newton's laws, law of squares;
   • subject concepts: natural law, natural constant, relationship, equation;
2. use examples that fit the specifications of the vwo domains from this syllabus to comment on how the concept of the model is used in physics and to judge the limits of the applicability and reliability of a certain model for a physical phenomenon,
   • apply the insight that a model is a simplified model of reality and relate this to the limited applicability of the model;
   • make a distinction between a conceptual model, a scale model, a numeric model, and a computer model;
   • subject concept: iterative process;
3. recognise model structures in computer models and study and comment on the behaviour of these model structures. In addition, on the basis of examples, explain where limits of predictability stem from.
   • model structures: decay and growth (1st order), oscillations and motions (2nd order);
   • subject concepts: calculating capacity, step size, initial condition.

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[4] This means that the candidate has sufficient overview of the entire school examination matter and can combine subjects from the different domains. This specification is emphatically <u>not</u> meant as an expansion of the subject matter with new knowledge.

Subdomain G1

Biophysics

sound and hearing

The candidate can:

1. Make calculations with the frequency and wavelength of sound and with interference phenomena of sound:
   - describe the relationship between frequency, wavelength, and speed of sound
   - use the concept of "path difference" in interference
2. Make calculations with echolocation and echography with sound:
   - describe the principle of echolocation
   - make calculations with the Doppler effect

The following formulas are part of these specifications:

$v = \lambda f$, $\Delta\varphi = \Delta s/\lambda$

Subdomain E1

Characteristics of substances and materials

Presumed to be known:

The candidate can: make simple calculations with the following formula:

$\rho = m/V$

The candidate knows the following subject concepts:

- molecule, atom

The candidate can describe and explain the physical characteristics of substances and materials in context using atomic and molecular models.

Specification

The candidate can:

1. use the molecular model of matter to explain phases and phase transitions,
   subject concepts: gas, liquid, solid, melt, freeze, evaporate, condense, sublimate;
2. explain heat transport using matter models,
   explain the relationship between the heat flow and the thermal conductivity of a substance and perform simple calculations on heat flow;
   subject concepts: conductivity, convection, radiation;
3. describe temperature changes in a substance as a result of the inflow or outflow of heat, describe temperature in terms of movement of particles and explain that there is an absolute zero, specific heat capacity as substance characteristic, convert from degrees Celsius to Kelvin and the other way around; linear and cubic coefficient of expansion;
4. describe the concept of thermal conductivity;
5. interpret stress-strain curves in terms of elastic and plastic deformation and perform calculations on elastic deformations, subject concept: tensile strength.
6. explain macroscopic phenomena by using the characteristics and interaction of molecules and apply the ideal gas law.
7. make calculations with the laws of refraction and reflection**:**
   a. making a drawing of the light path, mirror image
   b. angle of incidence, angle of refraction, refractive index, colours (dispersion)
   c. critical angle, total reflection

The following formulas are part of these specifications:

$Q = cm\Delta T$ $Q = C\Delta T$ $P = \lambda A\Delta T/d$ $\sigma = F/A$ $\varepsilon = \Delta l/l_0$ $E = \sigma/\varepsilon$

$p = F/A$ $pV = nRT$ $\Delta l/l_0 = \alpha\Delta T$ $\Delta V/V_0 = \gamma\Delta T$ $T_{kelvin} = T_{celcius} + 273.15$

$\frac{\sin i}{\sin r} = n$, $\sin i_{\text{crit}} = 1/n$