Predicted paper · May 2027

IB Physics

Higher level · Paper 1

2 hours

Instructions

- Section A (Paper 1A): 40 multiple-choice questions, one mark each. Choose the one best answer and circle the letter.
- Section B (Paper 1B): data-based questions on experimental work, 20 marks. Answer in the spaces provided.
- Total: 60 marks. Answer all questions.
- You need a clean copy of the IB physics data booklet and a calculator.
- Sit it in one go, timed. Then mark it with the mark scheme, honestly.

Name .....

Date .....

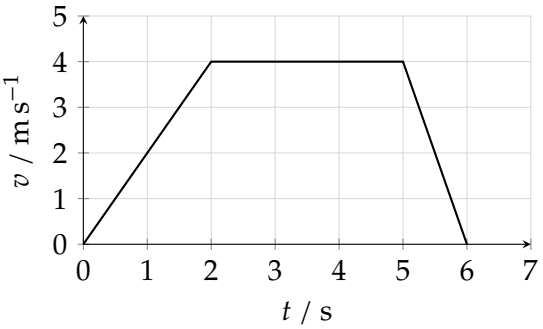
Score .....

Every question in this paper is new, written by Pietro Meloni to the shape of the papers set on the current (2025) syllabus. It is not IB material and it is not a leaked paper: it is a prediction of the topics and the style, for practice under timed conditions.

Mark scheme and the other papers in the set: scan the code

Section A · Paper 1A

1. An electric scooter starts from rest on a straight road. The graph shows how its velocity v varies with time t.



What is the distance travelled by the scooter in the first 6.0 s?

A. 12 m

B. 18 m

C. 20 m

D. 24 m

2. A delivery drone flies horizontally at a constant speed of $15\,\mathrm{m\,s^{-1}}$, 4.9 m above flat ground. It releases a parcel. Air resistance is negligible. What is the speed of the parcel just before it reaches the ground?

A. $9.8\,\mathrm{m\,s^{-1}}$

B. $15\,\mathrm{m\,s^{-1}}$

C. $18\,\mathrm{m\,s^{-1}}$

D. $25\,\mathrm{m\,s^{-1}}$

3. A crate of mass 40 kg is pulled across a horizontal warehouse floor by a horizontal force of 120 N. The coefficient of dynamic friction between the crate and the floor is 0.20. What is the acceleration of the crate?

A. $1.0\,\mathrm{m\,s^{-2}}$

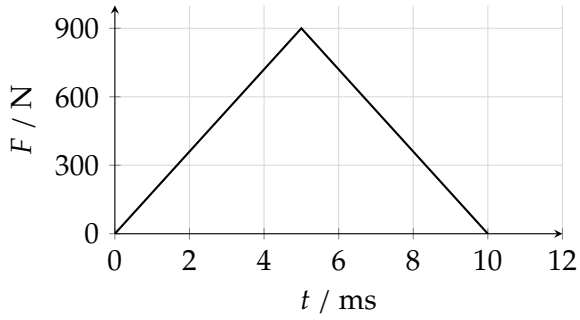
B. $2.0\,\mathrm{m\,s^{-2}}$

C. $3.0\,\mathrm{m\,s^{-2}}$

D. $5.0\,\mathrm{m\,s^{-2}}$

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4. A football of mass 0.45 kg is at rest on the ground. A player kicks it. The graph shows how the force F on the ball varies with time t during the kick.



What is the speed of the ball as it leaves the player's foot?

A. $2.0\,\text{m s}^{-1}$

B. $4.5\,\text{m s}^{-1}$

C. $10\,\text{m s}^{-1}$

D. $20\,\text{m s}^{-1}$

5. A car travels around a flat, horizontal bend of radius 50 m. The coefficient of static friction between the tyres and the road is 0.80. What is the maximum speed at which the car can go round the bend without skidding?

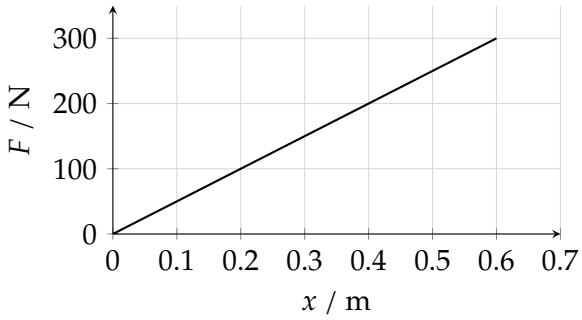
A. $6.3\,\text{m s}^{-1}$

B. $20\,\text{m s}^{-1}$

C. $25\,\text{m s}^{-1}$

D. $390\,\text{m s}^{-1}$

6. The graph shows how the tension F in a physiotherapy resistance band varies with its extension x.



What is the elastic potential energy stored in the band when its extension is 0.40 m?

A. 40 J

B. 80 J

C. 90 J

D. 180 J

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7. A lift and its passengers have a total mass of 800 kg. The lift rises at a constant speed of $1.5\,\text{m}\,\text{s}^{-1}$. The efficiency of the lift motor is 60 %. What is the electrical power input to the motor?

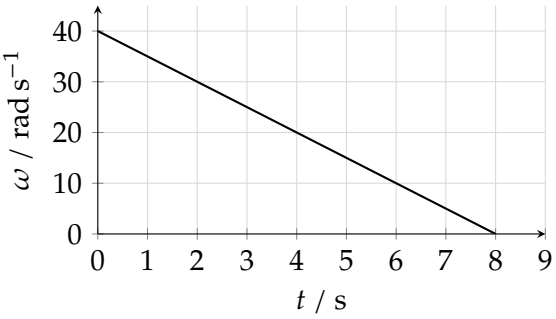
A. 2.0 kW

B. 7.1 kW

C. 12 kW

D. 20 kW

8. A potter's wheel is switched off. The graph shows how its angular velocity ω varies with time t until it stops.



How many revolutions does the wheel make while it slows down to rest?

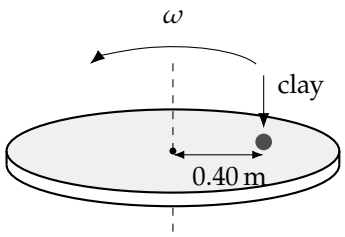
A. 6.4

B. 25

C. 51

D. 160

9. A horizontal turntable has a moment of inertia of $0.60\,\text{kg}\,\text{m}^2$ about its vertical axis and rotates freely with an angular velocity of $3.0\,\text{rad}\,\text{s}^{-1}$. A lump of clay of mass 0.50 kg is dropped vertically onto the turntable and sticks to it at a distance of 0.40 m from the axis.



What is the angular velocity of the turntable and clay immediately after the clay lands?

A. $2.3\,\text{rad}\,\text{s}^{-1}$

B. $2.6\,\text{rad}\,\text{s}^{-1}$

C. $3.0\,\text{rad}\,\text{s}^{-1}$

D. $3.4\,\text{rad}\,\text{s}^{-1}$

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10. A spacecraft travels at a constant speed of $0.80c$ relative to the Earth to a star that is 12 light-years from the Earth in the Earth frame. What is the time taken for the journey according to a clock on the spacecraft?

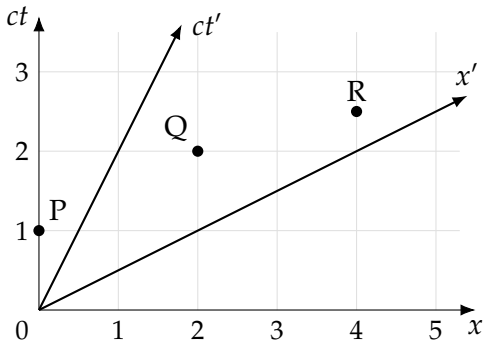
A. 9.0 years

B. 12 years

C. 15 years

D. 25 years

11. The spacetime diagram shows the axes of frame S and the axes of frame S′, which moves at $0.50c$ relative to S. Three events P, Q and R are shown.



Which statement describes the order of the events according to an observer at rest in S′?

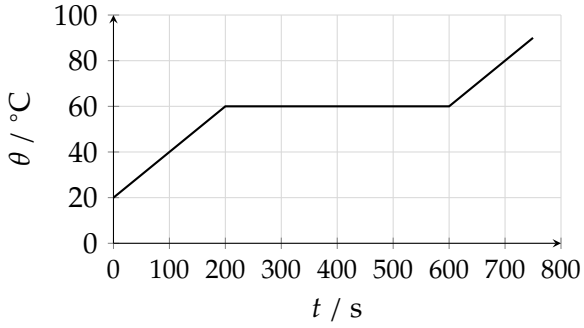
A. P and Q are simultaneous and R occurs after them.

B. R occurs first, then P and Q occur simultaneously.

C. P occurs first, then Q, then R.

D. P, Q and R are all simultaneous.

12. A sample of wax of mass 0.50 kg, initially solid, is heated by a 200 W heater. All the energy from the heater is transferred to the wax. The graph shows how the temperature θ of the wax varies with time t.



What is the specific latent heat of fusion of the wax?

A. $4.0 \times 10^4\,\text{J kg}^{-1}$

B. $8.0 \times 10^4\,\text{J kg}^{-1}$

C. $1.6 \times 10^5\,\text{J kg}^{-1}$

D. $2.4 \times 10^5\,\text{J kg}^{-1}$

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13. Two spheres X and Y behave as black bodies. The table gives their radii and surface temperatures.

Sphere	Radius	Surface temperature / K
X	r	$2T$
Y	$2r$	T

What is $\frac{\text{power radiated by X}}{\text{power radiated by Y}}$?

A. 4

B. 8

C. 16

D. 64

14. Which statement explains why methane in the atmosphere contributes to the greenhouse effect?

A. Methane absorbs most of the ultraviolet radiation arriving from the Sun.

B. Methane molecules reflect infrared radiation from the surface back towards the ground.

C. Methane increases the albedo of the atmosphere.

D. Methane molecules have natural frequencies of vibration equal to frequencies of the infrared radiation emitted by the surface, so they absorb it and re-emit it in all directions.

15. A fixed mass of an ideal gas in a cylinder sealed by a movable piston has a volume V at a temperature of 27 °C. The pressure of the gas is tripled and its temperature is raised to 327 °C. What is the new volume of the gas?

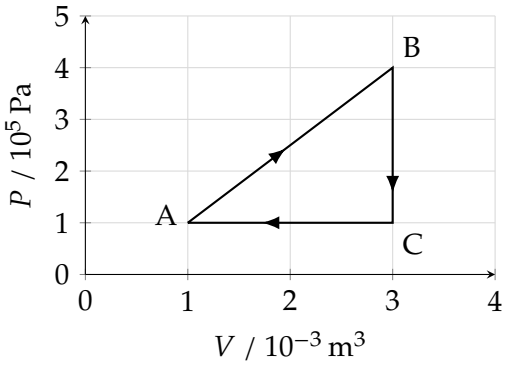
A. $V/3$

B. $2V/3$

C. $4V$

D. $6V$

16. An ideal gas is taken round the cycle $A \to B \to C \to A$ shown on the graph of pressure P against volume V.



What is the net work done by the gas in one cycle?

A. 300 J

B. 600 J

C. 800 J

D. 1200 J

17. In a certain time, 1200 J of thermal energy flows through a window from a room at a constant temperature of 300 K to the outside air at a constant temperature of 240 K. What is the total change in entropy of the room and the outside air?

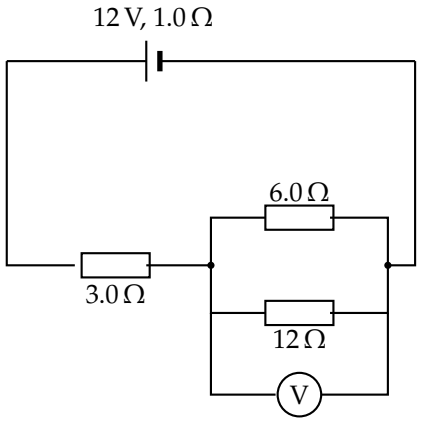
A. $-9.0\,\text{J K}^{-1}$

B. $-1.0\,\text{J K}^{-1}$

C. 0

D. $+1.0\,\text{J K}^{-1}$

18. A cell of emf 12 V and internal resistance 1.0 Ω is connected to three resistors as shown. The voltmeter is ideal.



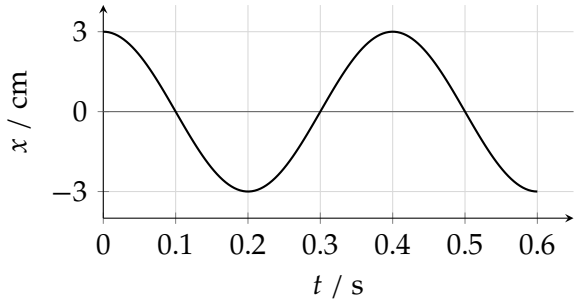
What is the reading of the voltmeter?

A. 4.5 V
B. 6.0 V
C. 6.9 V
D. 9.8 V

19. Wire X and wire Y are made of the same metal. Wire X has twice the length and twice the diameter of wire Y. What is $\frac{\text{resistance of X}}{\text{resistance of Y}}$?

A. 0.5
B. 1.0
C. 2.0
D. 8.0

20. A mass of 0.25 kg hangs from a light spring and oscillates vertically. The graph shows how its displacement x from equilibrium varies with time t.



What is the spring constant of the spring?

A. 3.9 N m^{-1}
B. 9.8 N m^{-1}
C. 25 N m^{-1}
D. 62 N m^{-1}

21. A buoy floating on a calm lake is pushed down and released. It then moves vertically with simple harmonic motion of amplitude 0.50 m and period 4.0 s. What is the speed of the buoy when its displacement from equilibrium is 0.30 m?

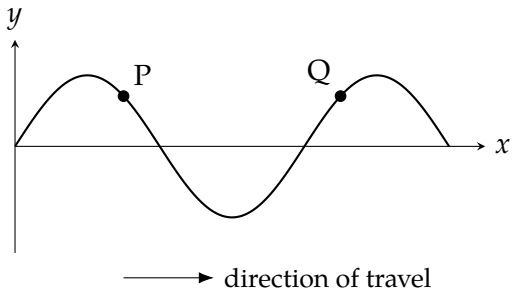
A. $0.31\,\text{m}\,\text{s}^{-1}$

B. $0.47\,\text{m}\,\text{s}^{-1}$

C. $0.63\,\text{m}\,\text{s}^{-1}$

D. $0.79\,\text{m}\,\text{s}^{-1}$

22. A transverse wave travels to the right along a rope. The graph shows the displacement y of the rope against distance x at one instant. P and Q are two points on the rope.



What are the directions of the velocities of P and Q at this instant?

A. P upwards, Q downwards

B. P downwards, Q upwards

C. P and Q both upwards

D. P and Q both downwards

23. In a double-slit experiment with monochromatic light, the fringe spacing on a screen is s. The slit separation is doubled and the distance from the slits to the screen is tripled. The wavelength is unchanged. What is the new fringe spacing?

A. $s/6$

B. $2s/3$

C. $3s/2$

D. $6s$

24. Monochromatic light of wavelength 600 nm is incident normally on a diffraction grating with 500 lines per millimetre. What is the total number of bright maxima that can be observed, including the central maximum?

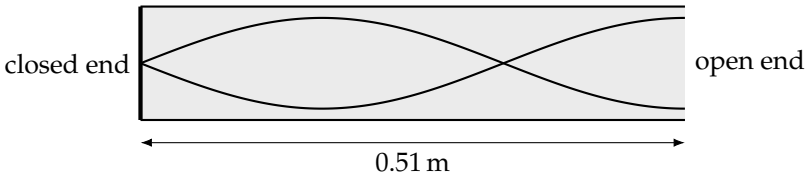
A. 3

B. 4

C. 6

D. 7

25. A pipe of length 0.51 m is closed at one end and open at the other. The diagram shows the standing wave of displacement in the air in the pipe for one mode of vibration. The speed of sound in the air is $340\,\text{m}\,\text{s}^{-1}$.



What is the frequency of this mode?

A. 170 Hz

B. 330 Hz

C. 500 Hz

D. 670 Hz

26. Two moons orbit the same planet in circular orbits. The orbital radius of moon B is four times the orbital radius of moon A. What is $\dfrac{\text{orbital period of B}}{\text{orbital period of A}}$?

A. 4

B. 8

C. 16

D. 64

27. A planet has half the mass and half the radius of the Earth. The gravitational field strength at the surface of the Earth is $9.8\,\text{N}\,\text{kg}^{-1}$. What is the gravitational field strength at the surface of the planet?

A. $2.5\,\text{N}\,\text{kg}^{-1}$

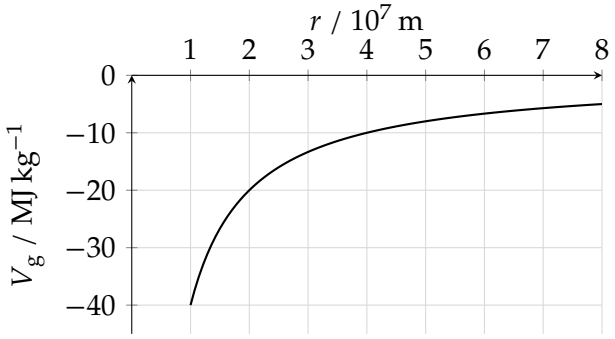
B. $4.9\,\text{N}\,\text{kg}^{-1}$

C. $9.8\,\text{N}\,\text{kg}^{-1}$

D. $20\,\text{N}\,\text{kg}^{-1}$

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28. The graph shows how the gravitational potential V_g due to a planet varies with distance r from the centre of the planet.



A satellite of mass 200 kg moves from an orbit of radius 2.0×10^7 m to an orbit of radius 4.0×10^7 m. What is the change in the gravitational potential energy of the satellite?

A. $+1.0 \times 10^7$ J

B. $+2.0 \times 10^9$ J

C. $+4.0 \times 10^9$ J

D. $+6.0 \times 10^9$ J

29. Two small charged spheres exert an electric force F on each other. The charge on one sphere is doubled and the distance between the spheres is tripled. What is the new force between the spheres?

A. $2F/9$

B. $2F/3$

C. $6F$

D. $18F$

30. Two long straight parallel wires X and Y are perpendicular to the page. They carry equal currents in opposite directions: into the page in X and out of the page in Y. Point M is midway between the wires.



What is the direction of the magnetic field at M?

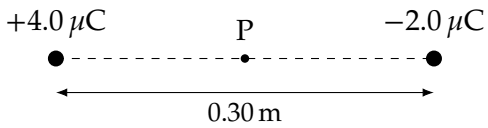
A. There is no field at M.

B. Towards the top of the page

C. Towards the bottom of the page

D. Towards Y

31. Two point charges of $+4.0\ \mu C$ and $-2.0\ \mu C$ are fixed 0.30 m apart. Point P is midway between them.



What is the electric potential at P?

A. 1.2×10^5 V

B. 3.6×10^5 V

C. 8.0×10^5 V

D. 2.4×10^6 V

32. A proton moving perpendicular to a uniform magnetic field follows a circular path of radius r. An alpha particle with the same kinetic energy moves perpendicular to the same field. The mass of an alpha particle is four times the mass of a proton and its charge is twice the charge of a proton. What is the radius of the path of the alpha particle?

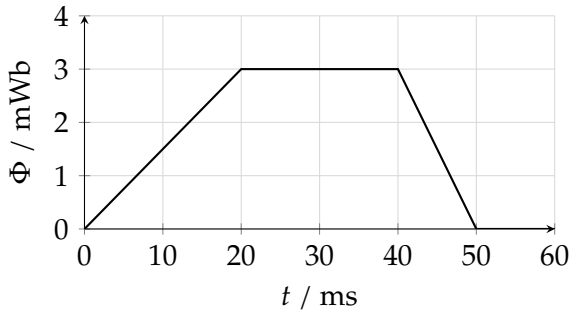
A. $r/2$

B. r

C. $2r$

D. $4r$

33. A coil of 50 turns is placed in a magnetic field. The graph shows how the magnetic flux Φ through one turn of the coil varies with time t.



What is the maximum magnitude of the emf induced in the coil?

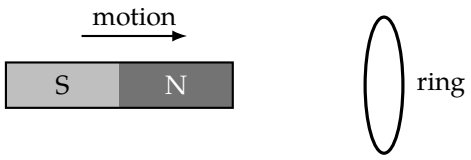
A. 0.30 V

B. 3.0 V

C. 7.5 V

D. 15 V

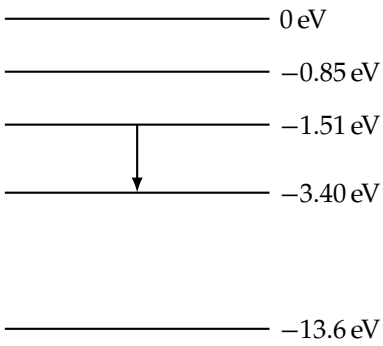
34. The north pole of a bar magnet is moved towards a fixed metal ring along the axis of the ring.



Which describes the direction of the induced current in the ring, as seen from the magnet, and the force on the ring?

A. clockwise, attracted towards the magnet
B. clockwise, repelled from the magnet
C. anticlockwise, attracted towards the magnet
D. anticlockwise, repelled from the magnet

35. The diagram shows some of the energy levels of an atom. An electron makes the transition shown by the arrow.



What is the wavelength of the photon emitted in this transition?

A. 2.5×10^{-7} m
B. 3.7×10^{-7} m
C. 6.6×10^{-7} m
D. 8.2×10^{-7} m

36. Nucleus X has eight times the nucleon number of nucleus Y. What are the ratio of their radii R_X/R_Y and the ratio of their densities ρ_X/ρ_Y?

	R_X/R_Y	ρ_X/ρ_Y
A.	2	1
B.	2	8
C.	8	1
D.	8	8

37. Monochromatic light falls on a metal surface and photoelectrons are emitted. The intensity of the light is doubled and its frequency is unchanged. What happens to the maximum kinetic energy of the photoelectrons and to the number of photoelectrons emitted per second?

	maximum kinetic energy	*number per second*
A.	doubled	doubled
B.	doubled	unchanged
C.	unchanged	doubled
D.	unchanged	unchanged

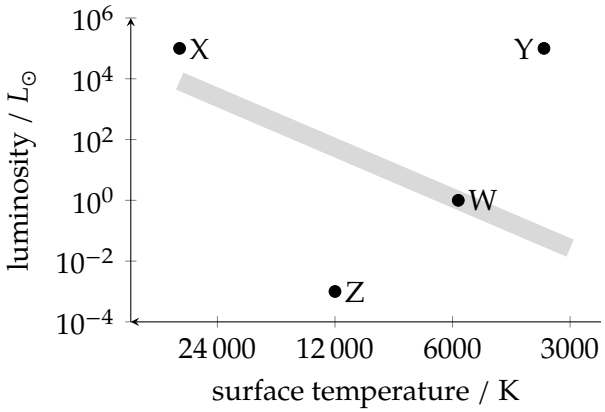
38. Which particles are emitted when a nucleus undergoes beta-plus (β^+) decay?

A. an electron and an antineutrino
B. an electron and a neutrino
C. a positron and an antineutrino
D. a positron and a neutrino

39. A nuclear power station has an electrical power output of 1.2 GW and an overall efficiency of 40 %. Each fission of a uranium-235 nucleus in the reactor releases 200 MeV of energy. What is the number of fissions per second in the reactor?

A. $1.5 \times 10^{19}\ \text{s}^{-1}$
B. $3.8 \times 10^{19}\ \text{s}^{-1}$
C. $9.4 \times 10^{19}\ \text{s}^{-1}$
D. $9.4 \times 10^{25}\ \text{s}^{-1}$

40. The Hertzsprung–Russell diagram shows the positions of four stars W, X, Y and Z.



Which star has the largest radius?

A. W
B. X
C. Y
D. Z

Section B · Paper 1B

1. A student investigates how the period T of a mass–spring system depends on the mass m hung from the spring. A slotted mass is attached to the lower end of a vertical spring, pulled down a short distance and released. The student times 10 complete oscillations with a stopwatch of resolution 0.01 s.

For $m = 0.300\,\text{kg}$ the student repeats the timing three times:

Trial	1	2	3
Time for 10 oscillations / s	7.38	7.52	7.44

(a) Determine the period T for $m = 0.300\,\text{kg}$ and its absolute uncertainty. **[2]**

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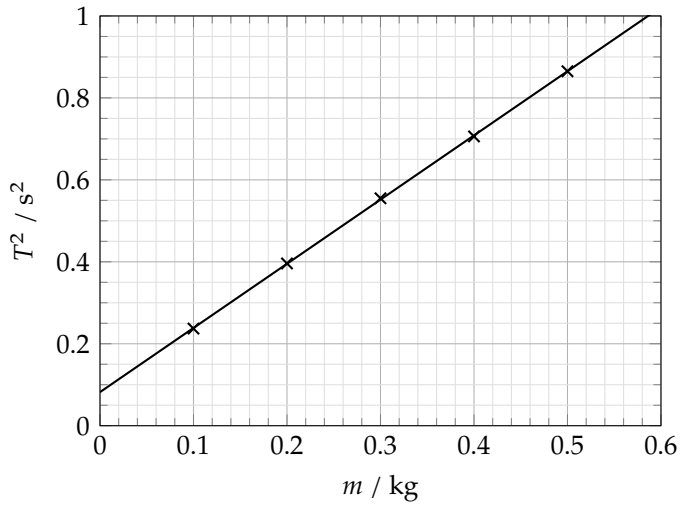
(b) Using the equation for the period of a mass–spring system, explain why a graph of T^2 against m is expected to be a straight line, and state an expression for its gradient in terms of the spring constant k. **[2]**

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The student repeats the measurement for five masses. The graph shows T^2 against m with the line of best fit.



(c) Determine the spring constant k of the spring. **[2]**

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(d) The line of best fit does not pass through the origin. Suggest a reason for this. **[1]**

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(e) State one variable, other than the spring, that the student should keep constant in this experiment. **[1]**

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2. A student measures the specific heat capacity of aluminium. An electric immersion heater is placed in a hole drilled in an aluminium block of mass 1.000 kg, and a liquid-in-glass thermometer is placed in a second hole. The heater is switched on at time $t = 0$ and the temperature θ of the block is read every 60 s.

The potential difference across the heater is $V = (12.0 \pm 0.1)\,\text{V}$ and the current in it is $I = (4.10 \pm 0.05)\,\text{A}$. Both stay constant during the experiment.

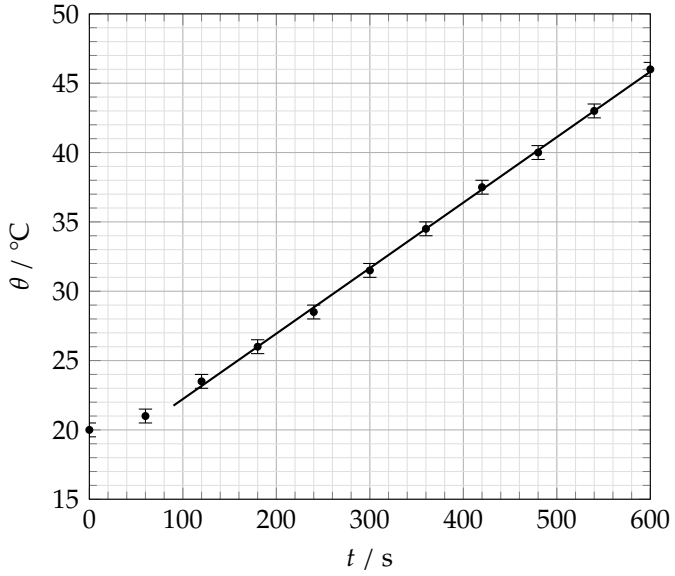
(a) Calculate the power of the heater and its absolute uncertainty. **[2]**

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The graph shows the readings of θ against t. The uncertainty in each temperature reading is $\pm 0.5\,^{\circ}\text{C}$; the uncertainty in t is negligible. The line of best fit is drawn through the points from $t = 120\,\text{s}$ onwards.



(b) Determine the gradient of the line of best fit. **[2]**

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(c) By drawing on the graph the lines of maximum and minimum gradient, determine the absolute uncertainty in the gradient. **[2]**

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(d) Determine the specific heat capacity of aluminium and its absolute uncertainty. **[3]**

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(e) The accepted value of the specific heat capacity of aluminium is $900\,\text{J}\,\text{kg}^{-1}\,\text{K}^{-1}$. Discuss, with reference to your answer to (d), whether the difference is due to random or to systematic error. **[2]**

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(f) Suggest one change to the method that would reduce the difference in (e). **[1]**

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Predicted paper · May 2027

IB Physics

Higher level · Paper 2

2 hours 30 minutes

Instructions

- Answer all questions in the spaces provided. Total: 90 marks.
- Show your working: most marks go to the method, not to the final number.
- Give answers to an appropriate number of significant figures, with units.
- You need a clean copy of the IB physics data booklet and a calculator.

Name .....

Date .....

Score .....

Every question in this paper is new, written by Pietro Meloni to the shape of the papers set on the current (2025) syllabus. It is not IB material and it is not a leaked paper: it is a prediction of the topics and the style, for practice under timed conditions.

Mark scheme and the other papers in the set: scan the code

1. In a freight yard, a railway wagon X of mass 2.4×10^4 kg rolls at $1.5\,\text{m s}^{-1}$ along a straight horizontal track towards a stationary wagon Y of mass 1.6×10^4 kg. The wagons collide and couple together. Friction is negligible.

(a) Calculate the speed of the coupled wagons immediately after the collision. **[2]**

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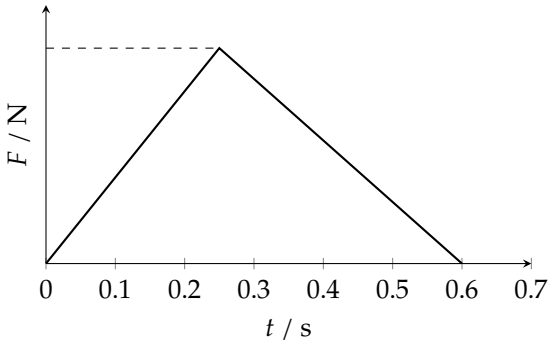
(b) Show that about 1×10^4 J of kinetic energy is transferred to other forms in the collision. **[2]**

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(c) The graph shows how the force F exerted on Y by X varies with time t during the collision.



Determine F_{max}. **[2]**

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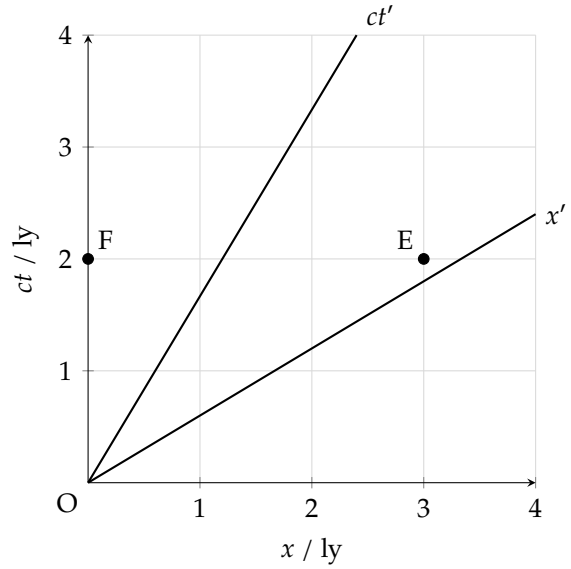
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2. A spacecraft moves away from Earth at a constant speed of $0.60c$. Frame S is the rest frame of Earth and frame S′ is the rest frame of the spacecraft. The spacecraft passes Earth at event O, where $x = x' = 0$ and $t = t' = 0$.

Two events are shown on the spacetime diagram for frame S, together with the axes of S′:

- event E: a navigation beacon flashes at $x = 3.0\,\text{ly}$, $ct = 2.0\,\text{ly}$
- event F: a lamp on Earth flashes at $x = 0$, $ct = 2.0\,\text{ly}$.



(a) Calculate the angle between the ct axis and the ct' axis. **[1]**

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(b) Calculate the coordinates x' and ct' of event E in frame S′. **[3]**

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(c) Events E and F are simultaneous in frame S. Deduce, by drawing on the spacetime diagram, which of the two events happens first in frame S′. **[2]**

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(d) Show that the spacetime interval between O and E has the same value in S and in S′. **[1]**

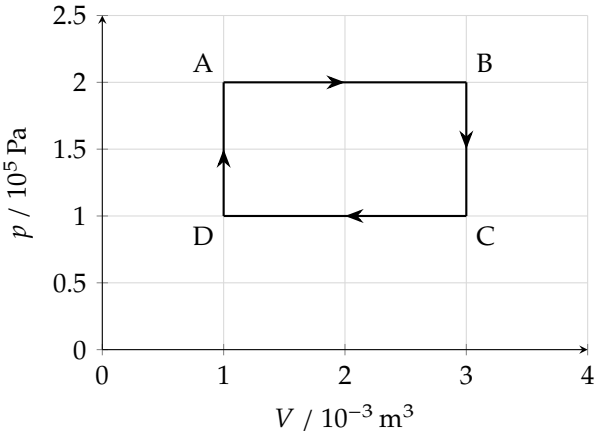
3. A steel scuba-diving cylinder has an internal volume of $1.20 \times 10^{-2}\ \text{m}^3$. It is filled with air at a pressure of 2.00×10^7 Pa and a temperature of 20 °C. Treat the air as an ideal gas.

(a) Calculate the amount of air, in mol, in the cylinder. **[2]**

(b) The cylinder is left in a car in the sun and the temperature of the air rises to 45 °C. The volume of the cylinder does not change. Calculate the new pressure of the air. **[1]**

(c) Explain, using the kinetic model of an ideal gas, why the pressure of a gas at constant volume increases when its temperature rises. **[3]**

4. A fixed mass of an ideal monatomic gas is taken around the cycle ABCDA shown on the pressure–volume diagram. AB and CD are at constant pressure; BC and DA are at constant volume.



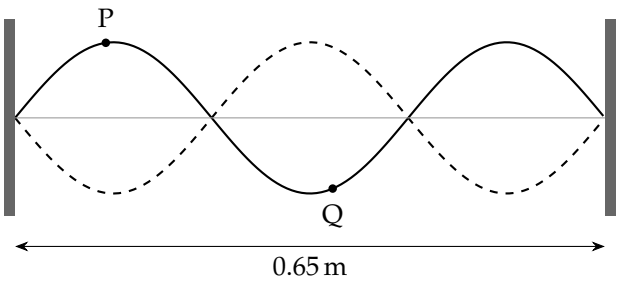
(a) Calculate the net work done by the gas in one cycle. **[1]**

(**b**) Show that the thermal energy transferred to the gas during the change A → B is about 1 kJ. **[3]**

(**c**) Thermal energy is also transferred to the gas during the change D → A. Determine the efficiency of the cycle. **[2]**

(**d**) State, with a reason, the change in the entropy of the gas over one complete cycle. **[1]**

5. A guitar string is fixed at two points 0.65 m apart. It vibrates in a standing wave of frequency 660 Hz. The diagram shows the string at an instant of maximum displacement (solid line) and half a period later (dashed line). P and Q are two points on the string.



(**a**) Calculate the speed of the travelling waves on the string. **[2]**

(**b**) Determine the frequency of the first harmonic of the string. **[1]**

(c) State the phase difference between the oscillations of P and Q. **[1]**

(d) Outline how the standing wave is formed on the string. **[2]**

6. Phobos, a moon of Mars, moves in a circular orbit of radius 9.38×10^6 m about the centre of Mars. The mass of Mars is 6.42×10^{23} kg.

(a) Explain why the speed of Phobos stays constant although a resultant force acts on it. **[2]**

(b) Calculate the orbital period of Phobos. **[2]**

(c) Mars rotates once on its axis every 8.86×10^4 s. A communications satellite is to stay above the same point on the equator of Mars. Determine the radius of its circular orbit. **[2]**

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7. Violet light of wavelength 405 nm from a laser falls on a clean potassium surface in an evacuated photocell. The work function of potassium is 2.30 eV.

(a) Show that the energy of one photon of this light is about 3 eV. **[2]**

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(b) Determine the stopping potential of the photocell. **[2]**

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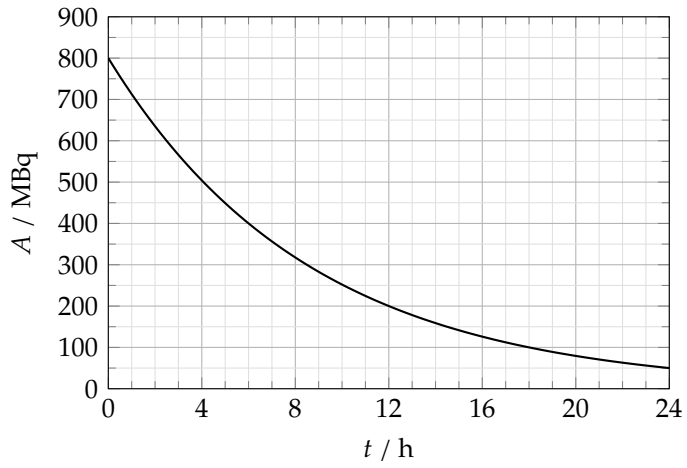
(c) Estimate the de Broglie wavelength of the fastest electrons emitted from the surface. **[2]**

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8. A hospital uses a gamma-emitting tracer to image a patient's thyroid. The graph shows how the activity A of a sample of the tracer varies with time t.



(a) Determine the half-life of the tracer. **[1]**

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(b) On the graph, sketch how the activity varies with time for a sample of the same tracer that initially contains half as many radioactive nuclei. **[2]**

(**c**) The tracer is prepared in a laboratory and reaches the hospital 18.0 h later. The patient must receive a sample of activity 800 MBq. Calculate the activity that the sample must have when it leaves the laboratory. **[2]**

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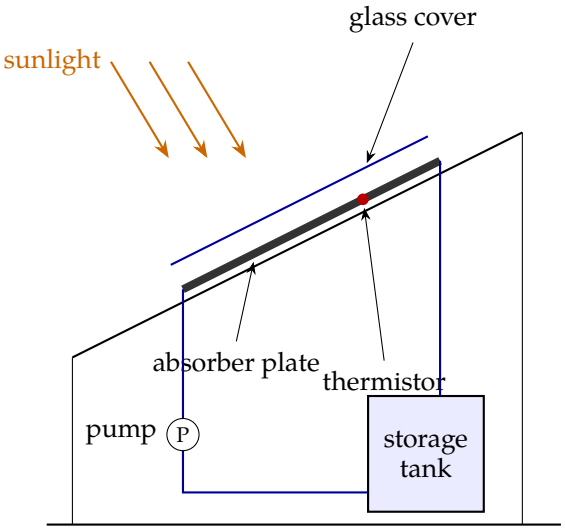
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(**d**) Outline one reason why a gamma emitter, rather than an alpha emitter, is used as a tracer inside the body. **[1]**

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9. A house has a solar water heater on its roof. Water is pumped from a storage tank through pipes fixed to a black absorber plate of area 2.0 m^2. A sheet of glass covers the plate. A thermistor fixed to the plate is part of the circuit that switches the pump on.



(**a**) The solar constant is 1.36×10^3 W m^{-2}. At noon on a clear summer day, the intensity of the sunlight arriving at the glass cover is 850 W m^{-2}. Outline **two** reasons why this intensity is less than the solar constant. **[2]**

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(**b**) The albedo of the absorber plate is 0.10. Ignoring the glass cover, show that the power absorbed by the plate at noon is about 1.5 kW.

[2]

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(c) At noon the absorber plate is at a temperature of 70 °C. Glass transmits electromagnetic radiation of wavelength shorter than about 3 μm but absorbs radiation of longer wavelengths.

(i) Calculate the wavelength at which the radiation emitted by the plate has its maximum intensity. **[1]**

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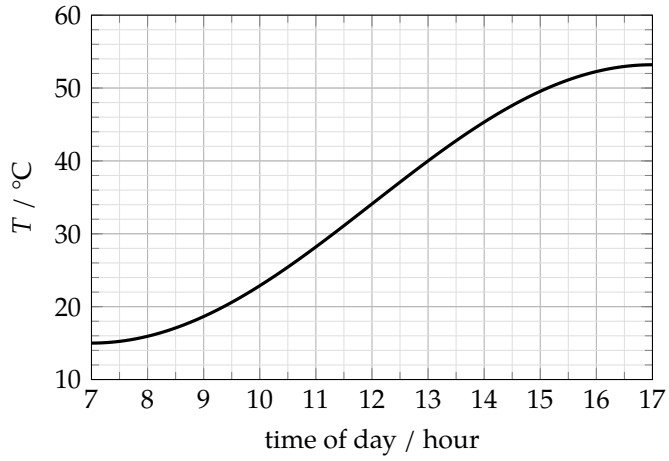
(ii) Explain how the glass cover reduces the rate at which the plate loses energy by radiation. **[2]**

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(d) The tank holds 150 kg of water. The specific heat capacity of water is 4180 J kg^{-1} K^{-1}. The graph shows how the temperature T of the water in the tank varies with time of day on the same clear summer day. Assume that no thermal energy is lost from the tank.



(i) Determine, using the graph, the rate at which thermal energy is transferred to the water at 12:00. **[3]**

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(ii) Hence calculate, at 12:00, the efficiency of the heater, defined as the rate at which thermal energy is transferred to the water divided by the power of the sunlight incident on the 2.0 m^2 of glass cover. **[1]**

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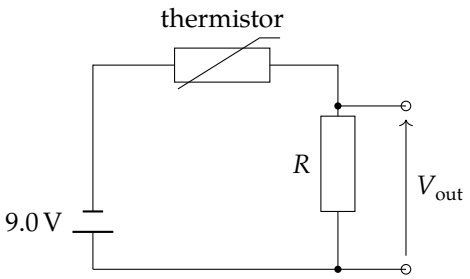
(e) On a winter day the mean intensity of the sunlight arriving at the glass cover is about 300 $W\,m^{-2}$ for 6 hours, and the efficiency of the heater is about 40 %. Estimate the increase in the temperature of the water in the tank during that day. **[2]**

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(f) The pump is switched on by the circuit shown. The thermistor is in series with a fixed resistor of resistance R across a 9.0 V supply of negligible internal resistance. The pump switches on when the potential difference V_{out} across the fixed resistor reaches 4.0 V. The table gives the resistance R_T of the thermistor at different temperatures.



T / °C	R_T / kΩ
20	12.5
30	8.0
40	5.3
50	3.6
60	2.5

(i) Explain why V_{out} increases as the temperature of the plate increases. **[2]**

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(ii) The pump must switch on when the plate reaches 40 °C. Calculate R. **[2]**

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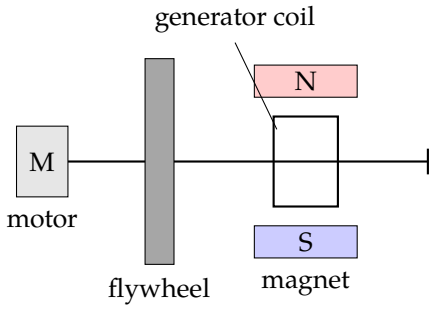
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(g) On the winter day in (e), the water in the tank is at 20 °C at 17:00. An electric heater of resistance 25 Ω, connected to the 230 V mains supply, then heats the water to 55 °C. While the heater is on, the tank loses thermal energy to the surroundings at a constant rate of 50 W. Determine the time for which the heater must be on.

[3]

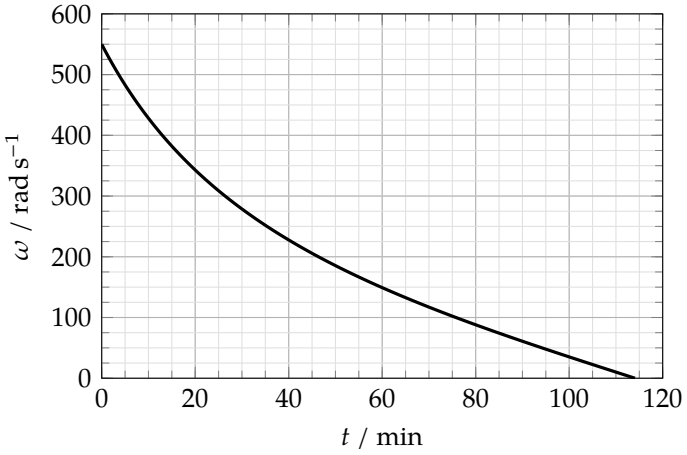
10. A flywheel energy store is tested in a laboratory. The flywheel is a uniform steel disc of mass 42 kg and radius 0.24 m, mounted on a horizontal axle. The same axle carries an electric motor and the coil of a generator that rotates between the poles of a magnet. The moment of inertia of a uniform disc of mass M and radius r about its axis is $\frac{1}{2}Mr^2$. The moments of inertia of the axle and the coil are negligible.



(a) Show that the moment of inertia of the flywheel is about 1.2 kg m^2. **[2]**

(b) Starting from rest, the motor exerts a constant torque of 9.0 N m on the flywheel until its angular velocity is 550 rad s^{-1}. Frictional torques are negligible during this time. Calculate the time taken. **[2]**

(c) The motor is then disconnected and the flywheel is left to slow down because of friction in the bearings and air resistance. The generator coil is not connected to anything. The graph shows the variation of the angular velocity ω of the flywheel with time t.



(i) Determine, using the graph, the frictional torque acting on the flywheel at $t = 0$. **[3]**

(ii) Estimate the number of revolutions the flywheel makes from $t = 0$ until it stops. **[2]**

(d) The generator coil has 400 turns, each of area $5.0 \times 10^{-3}\,\text{m}^2$, and rotates with the flywheel in a uniform magnetic field of strength 0.40 T.

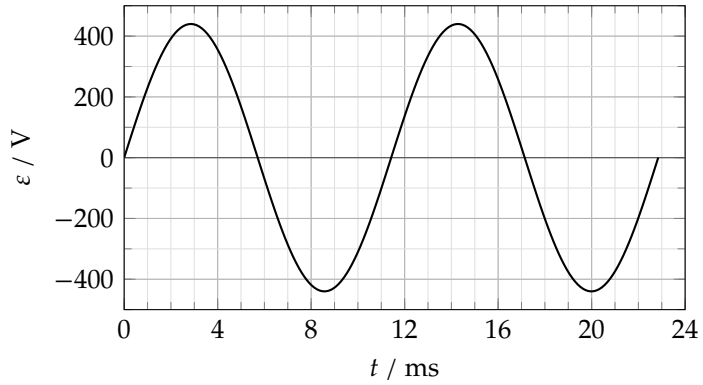
(i) Outline why the emf induced in the coil is alternating. **[2]**

(ii) The peak emf of a coil of N turns rotating with angular velocity ω is $\varepsilon_0 = NBA\omega$. Calculate the peak emf when $\omega = 550\,\text{rad}\,\text{s}^{-1}$. **[1]**

(iii) The graph shows the variation of the emf ε with time t when $\omega = 550\,\text{rad}\,\text{s}^{-1}$. On the same axes, sketch the variation of ε with t when the angular velocity of the flywheel has

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fallen to 275 rad s^{-1}. **[2]**



(e) In an emergency, the motor is disconnected and the ends of the generator coil are connected to a resistor, so that there is a current in the coil. The total resistance of the circuit is constant. The flywheel experiences an average braking torque.

(i) Explain why the average braking torque on the flywheel is proportional to its angular velocity ω. **[3]**

(ii) The resistor is connected when $\omega = 550$ rad s^{-1}, and at that moment the average braking torque is 40 N m. Friction is negligible compared with the braking torque. By considering the angular impulse on the flywheel, deduce the total number of revolutions the flywheel makes from that moment. **[3]**