

HU Collection
Engineering and Science Admissions Test
Mock Set E
Physics

Time allowed: 40 minutes
Questions: 27 multiple choice
Calculators: not permitted
Written by: Kevin Hu
Date written: 28 October 2026

Name: _____ Date sat: _____ Score: _____ / 27

Instructions

Answer all 27 questions. Each question has exactly one correct option and is worth one mark. No marks are deducted for wrong answers, so answer every question. Calculators are not permitted. Take the gravitational field strength g to be 10 N kg^{-1} unless a question says otherwise. This paper is deliberately longer than the time allows: move on from any question that is costing you more than two minutes, and come back to it at the end.

Q	1	2	3	4	5	6	7	8	9	10
Ans										

Q	11	12	13	14	15	16	17	18	19	20
Ans										

Q	21	22	23	24	25	26	27			
Ans										

1. A medical scanner sends short pulses of ultrasound of frequency 2.0 MHz into a patient. Each pulse lasts $2.0 \mu\text{s}$. Ultrasound travels at 1500 m s^{-1} in soft tissue and at 4000 m s^{-1} in bone. Wherever a pulse meets a boundary between two different tissues, part of it is reflected back to the scanner as an echo.

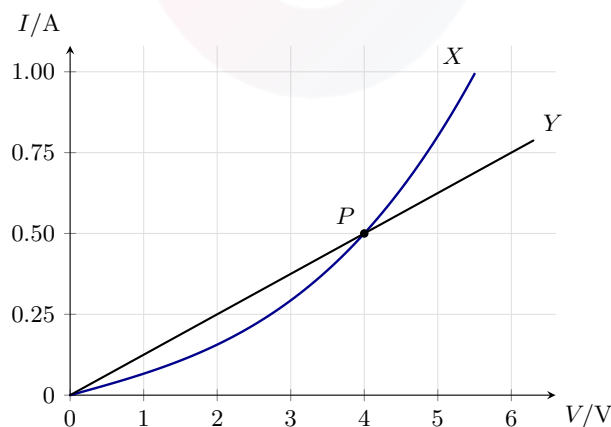
Consider the following statements.

- I. In bone, the wavelength of the ultrasound is 2.0 mm .
- II. When a pulse passes from soft tissue into bone, its frequency increases, because it travels faster in bone.
- III. Two boundaries in soft tissue, one 2.0 mm directly behind the other along the beam, give echoes that overlap in time when they return to the scanner.
- IV. In soft tissue, each pulse occupies a length of 3.0 mm along the beam.

Which of these statements are correct?

- A I, II and IV only
- B I and IV only
- C IV only
- D III and IV only
- E I, II, III and IV
- F I only
- G I, III and IV only
- H II, III and IV only

2. The graph shows how the current I in a component X varies with the p.d. V across it. X is a small NTC thermistor in still air, which warms up more as the current through it increases. The straight line shows the same information for a fixed resistor Y . The two graphs cross at the point P .



Which of the following statements is/are correct?

- I. At P , the resistance of X is equal to the resistance of Y .
- II. At P , the resistance of X is equal to 1 divided by the gradient of the curve at P .
- III. If X and Y are connected in series to a 6.0 V battery of negligible internal resistance, the p.d. across X is greater than the p.d. across Y .

- A II and III only
- B I only
- C II only
- D III only
- E I and III only
- F I, II and III
- G I and II only
- H none of them

3. Two solid balls have the same diameter and identical smooth surfaces, so that at any given speed the air resistance on one is the same as the air resistance on the other. Ball S is made of steel, and ball P is made of a plastic that is much less dense. Each ball is dropped from rest from a tall tower in still air, and each eventually falls at its own terminal velocity. Both terminal velocities are well above 5 m s^{-1} .

Which of the following statements is/are correct?

- I. Immediately after release, S has a greater acceleration than P , because the gravitational force on S is greater.
- II. At the moment when each ball is falling at 5 m s^{-1} , S has a greater acceleration than P .
- III. When each ball is falling at its terminal velocity, the air resistance on S is equal to the air resistance on P , because the balls have the same size and shape.

- A II only
- B II and III only
- C none of them
- D I, II and III
- E III only
- F I and II only
- G I and III only
- H I only

4. Polonium-210, $^{210}_{84}\text{Po}$, decays by emitting an alpha particle. Bismuth-210, $^{210}_{83}\text{Bi}$, decays by emitting a beta-minus particle. In each case consider a single *neutral* atom, and assume that at the moment of the decay the atom left behind keeps all of its orbiting electrons and gains no others.

Consider the following statements, in which e is the size of the charge on an electron.

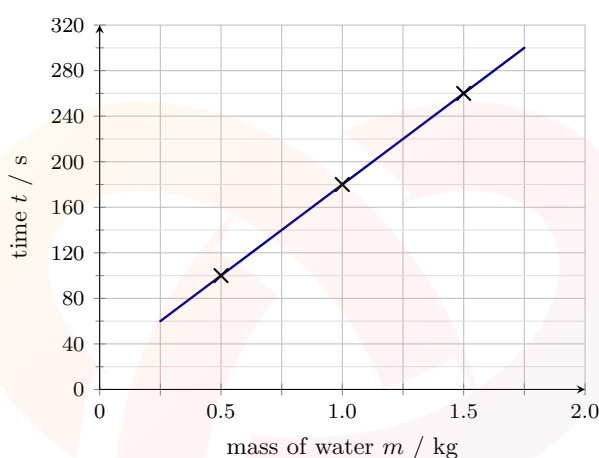
- I. Just after the polonium-210 atom decays, the atom left behind has a charge of $-2e$.
- II. Just after the bismuth-210 atom decays, the atom left behind is neutral, because the beta particle is an electron that has left the atom.
- III. The decay of bismuth-210 produces an atom of polonium-210.

Which of these statements must be true?

- A I and II only

- B** II and III only
- C** none of them
- D** I and III only
- E** I only
- F** I, II and III
- G** II only
- H** III only

5. An electric kettle is tested by heating different masses m of water, each starting at 20°C , and recording the time t taken for the water to reach 100°C . The results are plotted below.

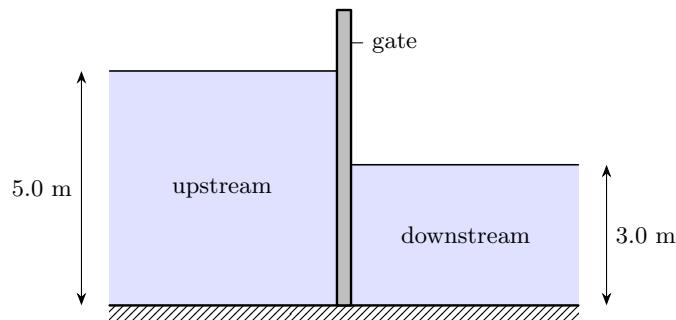


The element supplies energy at a constant rate. Assume that no energy is lost to the surroundings, and that the body of the kettle and its element are always at the same temperature as the water inside. The specific heat capacity of water is $4200 \text{ J kg}^{-1} \text{ K}^{-1}$.

How much energy is needed to raise the temperature of the empty kettle (body and element together) by 1 K ?

- | | | |
|-------------------|-----------------|-----------------|
| A 42 000 J | B 420 J | C 525 J |
| D 2100 J | E 1050 J | F 1575 J |

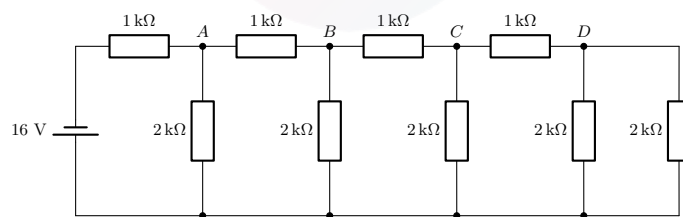
6. A canal lock is closed at one end by a single flat, vertical, rectangular gate 6.0 m wide, which seals against the vertical side walls and the horizontal floor of the canal. On the upstream side of the gate the water is 5.0 m deep, and on the downstream side it is 3.0 m deep, as shown. Both water surfaces are open to the atmosphere.



The density of water is 1000 kg m^{-3} and $g = 10 \text{ N kg}^{-1}$. What is the size of the resultant horizontal force exerted on the gate by the water and the air on its two sides?

- A 750 kN
- B 120 kN
- C 360 kN
- D 600 kN
- E 480 kN
- F 960 kN
- G 240 kN

7. A digital-to-analogue converter in a music synthesiser contains the resistor ladder shown, connected to a 16 V battery of negligible internal resistance. Each horizontal resistor has resistance $1.0 \text{ k}\Omega$ and each vertical resistor has resistance $2.0 \text{ k}\Omega$. The connecting wires have negligible resistance.



What is the power dissipated in the right-most $2.0 \text{ k}\Omega$ resistor?

- | | | |
|------------|----------|-----------|
| A 0.50 mW | B 2.0 mW | C 1.0 mW |
| D 0.125 mW | E 8.0 mW | F 0.25 mW |

8. A toy launcher fires a small ball vertically upwards using a compressed spring that obeys Hooke's law. The ball starts from rest against the compressed spring, and its greatest height is measured from this starting position. Some energy is dissipated by friction inside the launcher, and tests show that the amount dissipated is the same on every shot. Air resistance is negligible.

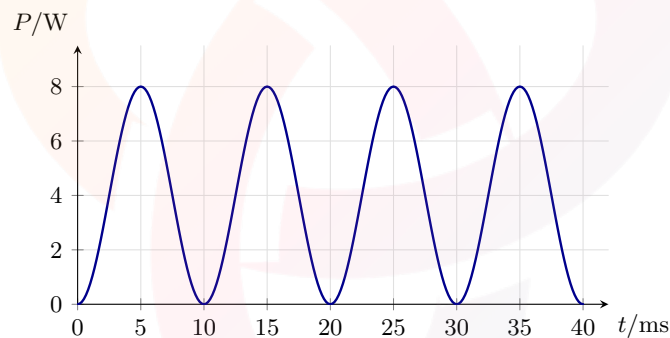
The table shows the results for two compressions of the spring.

compression of spring / cm	2.0	4.0	6.0
greatest height of ball / m	0.30	1.80	?

What greatest height would the ball reach when the spring is compressed by 6.0 cm?

- A** 3.30 m **B** 4.80 m **C** 4.30 m
D 2.70 m **E** 4.50 m **F** 4.05 m

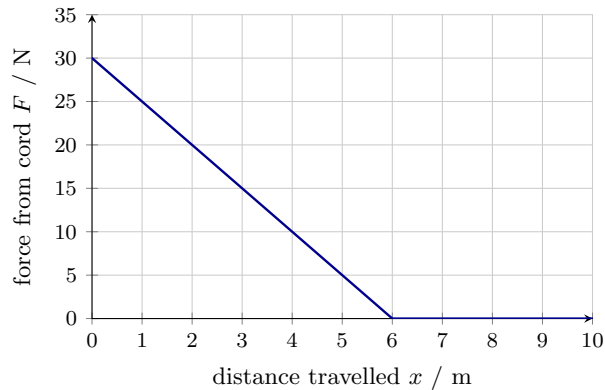
9. A simple a.c. generator consists of a flat coil rotating at a steady rate in a uniform magnetic field. Its output is connected to a fixed resistor, and the resistance of the coil and leads is negligible. The graph shows how the power P dissipated in the resistor varies with time t .



The resistor is replaced by one of twice the resistance, and the coil is made to rotate 1.5 times as fast. Nothing else changes. What are now the maximum power dissipated in the resistor, and the number of revolutions the coil makes each second?

- A** 6 W and 150 revolutions per second
B 6 W and 75 revolutions per second
C 18 W and 75 revolutions per second
D 12 W and 75 revolutions per second
E 9 W and 150 revolutions per second
F 9 W and 75 revolutions per second
G 18 W and 150 revolutions per second

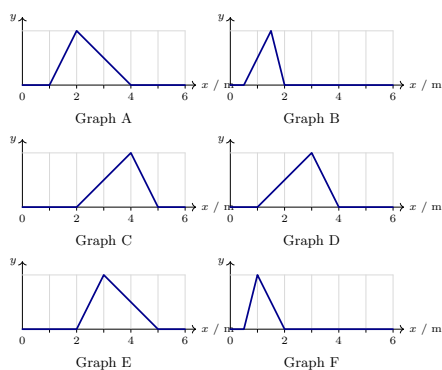
10. A training sled of mass 5.0 kg rests on level snow, attached to a stretched elastic cord. When it is released, the cord pulls it forwards along a straight line. The graph shows how the horizontal force F exerted by the cord varies with the distance x the sled has travelled. The cord goes slack at $x = 6.0 \text{ m}$ and exerts no force after that. Throughout its motion the sled experiences a constant frictional force of 10 N . Ignore air resistance.



What is the greatest speed of the sled, and how far from its starting point does it come to rest?

- A** greatest speed $4\sqrt{2} \text{ m s}^{-1}$; rests at $x = 9.0 \text{ m}$
- B** greatest speed $2\sqrt{3} \text{ m s}^{-1}$; rests at $x = 6.0 \text{ m}$
- C** greatest speed $2\sqrt{3} \text{ m s}^{-1}$; rests at $x = 9.0 \text{ m}$
- D** greatest speed 4.0 m s^{-1} ; rests at $x = 6.0 \text{ m}$
- E** greatest speed 6.0 m s^{-1} ; rests at $x = 9.0 \text{ m}$
- F** greatest speed 4.0 m s^{-1} ; rests at $x = 9.0 \text{ m}$

11. A long rope is stretched along the x -axis. A single transverse pulse travels along it in the $+x$ direction at a constant 2.0 m s^{-1} , without changing shape. A motion sensor at $x = 0$ records the sideways displacement y of the point of the rope there, giving the upper graph, which starts at time $t = 0$.



Which of the six lower graphs shows the shape of the rope at time $t = 2.5$ s?

A Graph A

B Graph B

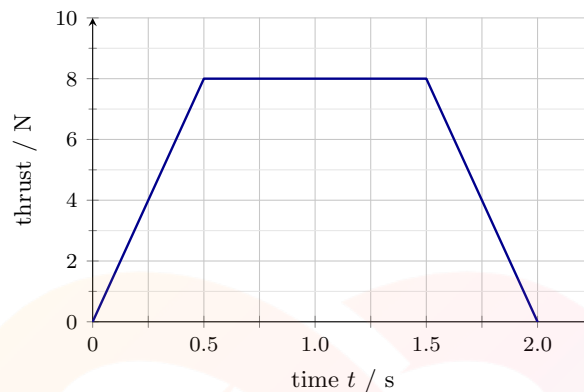
C Graph C

D Graph D

E Graph E

F Graph F

12. A model rocket of mass 0.40 kg stands upright on a launch pad. At $t = 0$ its motor is ignited, and the graph shows how the upward thrust of the motor varies with time. Treat the mass of the rocket as constant, ignore air resistance, and take $g = 10 \text{ N kg}^{-1}$.



What is the speed of the rocket at $t = 2.0$ s, when the motor stops?

A 28.75 m s^{-1}

B 8.75 m s^{-1}

C 11.25 m s^{-1}

D 30.0 m s^{-1}

E 12.5 m s^{-1}

F 10.0 m s^{-1}

13. When aviation fuel is pumped through a fine filter, the fuel becomes electrically charged. In a test rig, filtered fuel runs into an unearthed metal drum standing on an insulating mat, and charge builds up on the drum at a steady rate of $0.50 \mu\text{C}$ per second. The p.d. between the drum and earth is proportional to the charge on the drum, rising by 10 kV for every $1.0 \mu\text{C}$.

When the p.d. reaches 30 kV , a spark jumps from the drum to a nearby earthed pipe. Each spark lasts a negligible time and stops as soon as the p.d. of the drum has fallen to 10 kV ; the drum then charges up again, and the cycle repeats. Assume that charge leaves the drum only through the sparks, and that all the energy given up by the charge crossing the gap is released in the spark.

What is the energy released in each spark, and what is the time between successive sparks?

A 40 mJ and 6.0 s

B 60 mJ and 4.0 s

C 40 mJ and 4.0 s

D 20 mJ and 4.0 s

E 45 mJ and 6.0 s

F 45 mJ and 4.0 s

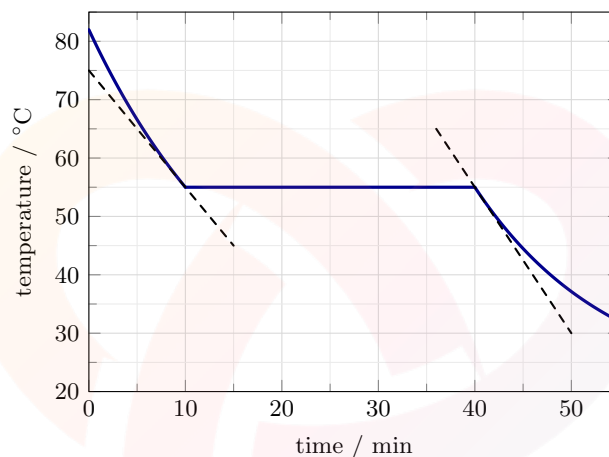
G 80 mJ and 4.0 s

14. A small space tug has a mass of 60 kg when empty. It carries two packages, each of mass 20 kg, and is initially at rest relative to a nearby space station. A spring launcher on the tug ejects the packages backwards, one at a time. Immediately after each ejection, the package that has just been ejected moves directly away from the tug with a speed of 6.0 m s^{-1} relative to the tug. All motion is along one straight line, and no external forces act.

What is the speed of the tug relative to the station after both packages have been ejected?

- A** 2.7 m s^{-1} **B** 3.5 m s^{-1} **C** 4.0 m s^{-1}
D 3.0 m s^{-1} **E** 2.4 m s^{-1} **F** 3.6 m s^{-1}

15. A test tube of molten wax is left to cool in a room. A temperature probe in the wax gives the cooling curve below. The wax solidifies at 55°C . The dashed lines are the tangents to the curve just before solidification starts and just after it ends.

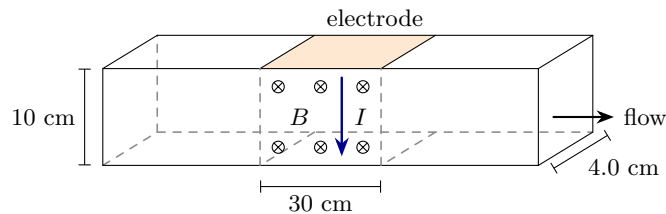


Assume that the rate at which the tube loses energy to the room depends only on the temperature of the wax, and that the energy stored in the glass and the probe is negligible. The specific heat capacity of liquid wax is $3000 \text{ J kg}^{-1} \text{ K}^{-1}$.

What are the specific latent heat of fusion of the wax, L , and the specific heat capacity of solid wax, c_s ?

- A** $L = 240 \text{ kJ kg}^{-1}$ and $c_s = 3750 \text{ J kg}^{-1} \text{ K}^{-1}$
B $L = 225 \text{ kJ kg}^{-1}$ and $c_s = 3750 \text{ J kg}^{-1} \text{ K}^{-1}$
C $L = 240 \text{ kJ kg}^{-1}$ and $c_s = 2400 \text{ J kg}^{-1} \text{ K}^{-1}$
D $L = 180 \text{ kJ kg}^{-1}$ and $c_s = 3750 \text{ J kg}^{-1} \text{ K}^{-1}$
E $L = 180 \text{ kJ kg}^{-1}$ and $c_s = 2400 \text{ J kg}^{-1} \text{ K}^{-1}$
F $L = 225 \text{ kJ kg}^{-1}$ and $c_s = 2400 \text{ J kg}^{-1} \text{ K}^{-1}$

16. Fast reactors are cooled by liquid sodium, which can be driven round the cooling circuit by an electromagnetic pump with no moving parts. In one design the sodium fills a horizontal duct of rectangular cross-section, 10 cm high and 4.0 cm wide. Along a 30 cm length of the duct, a uniform horizontal magnetic field of flux density 0.40 T acts across the duct, perpendicular to its length, and electrodes in the top and bottom walls pass a current of 1700 A vertically down through the sodium, as shown.

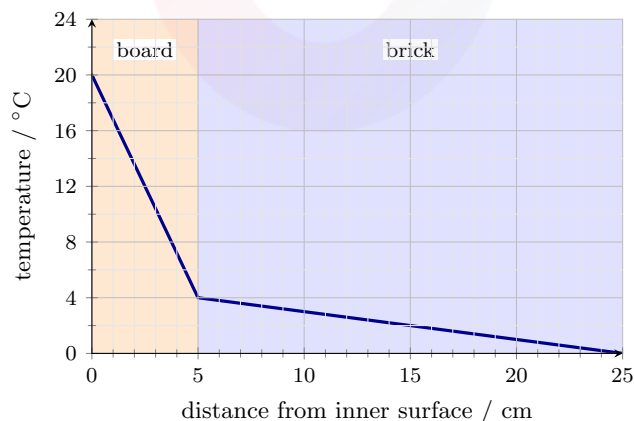


Treat the current as flowing straight down through the sodium, entirely within the field. The pressure difference produced by the pump is the total magnetic force on the sodium divided by the cross-sectional area of the duct.

The outlet of the pump is connected to a vertical pipe. With no sodium flowing, how high a column of sodium above the duct can the pump support? (The density of liquid sodium is 850 kg m^{-3} ; take $g = 10 \text{ N kg}^{-1}$.)

- | | | |
|-----------------|-----------------|-----------------|
| A 6.0 m | B 20 m | C 0.80 m |
| D 0.67 m | E 0.27 m | F 2.0 m |

17. A house wall is made of brick 20 cm thick, with a layer of insulating board 5 cm thick fixed to its inner face. On a winter day the inner surface of the wall stays at 20°C and the outer surface stays at 0°C , and the temperatures inside the wall have become steady. The graph shows how the temperature varies through the wall.



Energy passes through the wall only by conduction, at right angles to its faces. For a layer of a given material, the rate of conduction through each square metre is proportional to the temperature difference across the layer and inversely proportional to its thickness. In the steady state, energy passes through each square metre of the board and of the brick at the same rate.

The board is replaced by a board of the same material but 10 cm thick. The surfaces of the wall stay at 20°C and 0°C . Once the temperatures are steady again, the rate of energy loss through the wall is what fraction of its original value?

A $\frac{5}{6}$
D $\frac{17}{33}$

B $\frac{9}{5}$
E $\frac{4}{9}$

C $\frac{1}{2}$
F $\frac{5}{9}$

18. A sealed heater unit has three terminals, X , Y and Z . Inside are two heating elements, each of which behaves as a fixed resistor: one is connected between X and Y , and the other between Y and Z . There is nothing else inside. A technician carries out three experiments using the 230 V mains supply.

Experiment 1: the supply is connected between X and Z , and Y is left unconnected. The power of the unit is 400 W.

Experiment 2: X and Z are joined by a thick copper wire, and the supply is connected between this wire and Y . The power of the unit is 2.5 kW.

Experiment 3: the supply is connected between Y and Z , and X is left unconnected. The power of the unit is more than 1 kW.

What would the power of the unit be with the supply connected between X and Y , and Z left unconnected?

- A** 1000 W
- B** 500 W
- C** 1450 W
- D** 800 W
- E** 2000 W
- F** 2100 W
- G** 1250 W

19. A sample contains a single radioactive isotope whose decay product is stable. A detector in a fixed position near the sample registers one in every 2000 of the decays that happen in the sample. It also registers a steady background of 600 counts per hour.

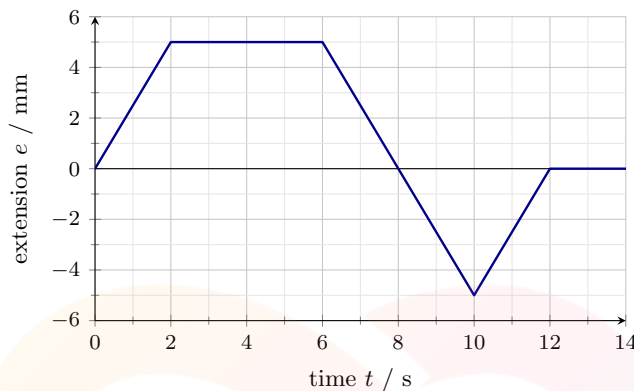
In the first hour of an experiment the detector records 6600 counts, and in the second hour it records 4600 counts.

How many undecayed nuclei of the isotope does the sample contain at the end of the second hour?

- A** 3.6×10^7
- B** 8.0×10^6
- C** 8.0×10^3
- D** 1.6×10^7
- E** 2.1×10^7
- F** 2.0×10^7
- G** 1.2×10^7

20. A simple accelerometer is fixed inside a car. A small mass can slide without friction along a straight horizontal track that points along the car's direction of travel, and it is attached to the front end of the track by a light spring that obeys Hooke's law. A sensor logs the extension e of the spring: e is positive when the spring is stretched and negative when it is compressed. To calibrate the device, it was first held with the track vertical and the mass hanging at rest below the spring, and the extension was then 25 mm.

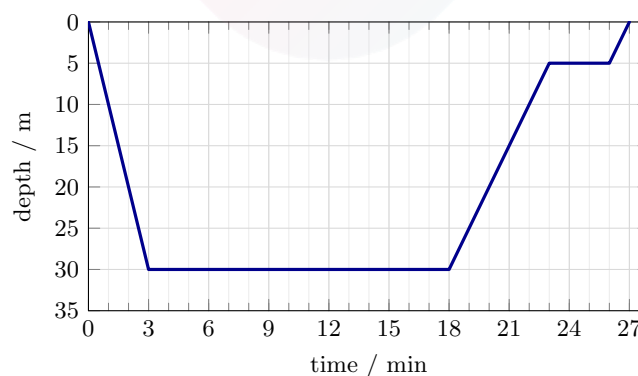
The car starts from rest at $t = 0$ and moves along a straight, level road. The graph shows the logged extension. Assume that the mass is always at rest relative to the car, and take $g = 10 \text{ m s}^{-2}$.



What is the greatest speed of the car during these 14 seconds, and at what time does it occur?

- A** 8.0 m s^{-1} at $t = 12 \text{ s}$ **B** 30 m s^{-1} at $t = 8 \text{ s}$ **C** 10 m s^{-1} at $t = 6 \text{ s}$
D 12 m s^{-1} at $t = 8 \text{ s}$ **E** 10 m s^{-1} at $t = 10 \text{ s}$ **F** 1.2 m s^{-1} at $t = 8 \text{ s}$

21. A scuba diver breathes from a tank of compressed air. Her regulator always supplies air at the pressure of the surrounding water, and at every depth she breathes in 20 litres of air per minute, measured at that surrounding pressure. The tank has an internal volume of 15 litres, and at the start of the dive its gauge shows an absolute pressure of 20 000 kPa. The graph shows her depth during the dive.

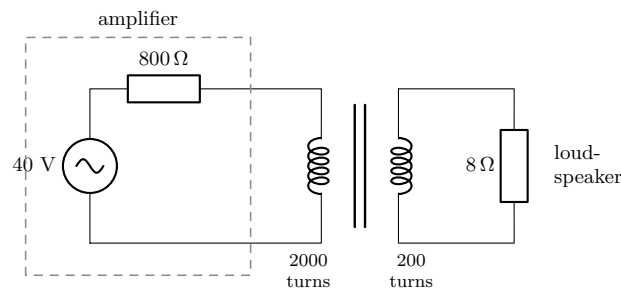


Atmospheric pressure is 100 kPa, and the pressure in the sea increases by 10 kPa for every metre of depth. Assume that the temperature of all the air stays constant.

What pressure does the tank gauge show when she reaches the surface at the end of the dive?

- A** 12 000 kPa **B** 8400 kPa **C** 11 600 kPa
D 16 400 kPa **E** 5600 kPa **F** 11 000 kPa

22. The output stage of a valve guitar amplifier behaves like a source of alternating p.d. of 40 V in series with an $800\ \Omega$ resistor, both inside the amplifier. A loudspeaker that behaves as an $8.0\ \Omega$ resistor is connected to the amplifier through an ideal transformer whose primary coil has 2000 turns and whose secondary coil has 200 turns, as shown.



All alternating p.d.s and currents in this question are effective values, which may be used in $V = IR$ and $P = IV$ exactly as for direct current. The connecting wires and the coils have negligible resistance.

A second, identical loudspeaker is then connected in parallel with the first. What is the total power delivered to the loudspeakers with one loudspeaker connected, and with two?

- A 0.17 W with one, 0.091 W with two
- B 0.50 W with one, 0.44 W with two
- C 0.50 W with one, 0.50 W with two
- D 2.0 W with one, 4.0 W with two
- E 1.0 W with one, 1.3 W with two
- F 0.50 W with one, 1.0 W with two
- G 0.50 W with one, 0.25 W with two

23. An escalator carries passengers between two floors whose levels differ by 12 m. Its steps move at a constant velocity whose vertical component is $0.50\ \text{m s}^{-1}$, and the surface of each step stays horizontal. Passenger X, of mass 60 kg, stands still on one step for the whole journey. Passenger Y, also of mass 60 kg, walks steadily up the moving steps, so that her vertical speed relative to the steps is $0.50\ \text{m s}^{-1}$.

Treat each passenger as moving with constant velocity (ignore the up-and-down motion of walking), ignore air resistance, and take $g = 10\ \text{N kg}^{-1}$.

Which of the following statements is/are correct?

- I. X and Y gain the same gravitational potential energy during the journey.
- II. The escalator does half as much work on Y as it does on X.
- III. While each passenger is on it, the escalator transfers energy to Y at a greater rate than it transfers energy to X.

- A I and II only
- B I only
- C III only
- D none of them

- E** II and III only
F I, II and III
G I and III only
H II only

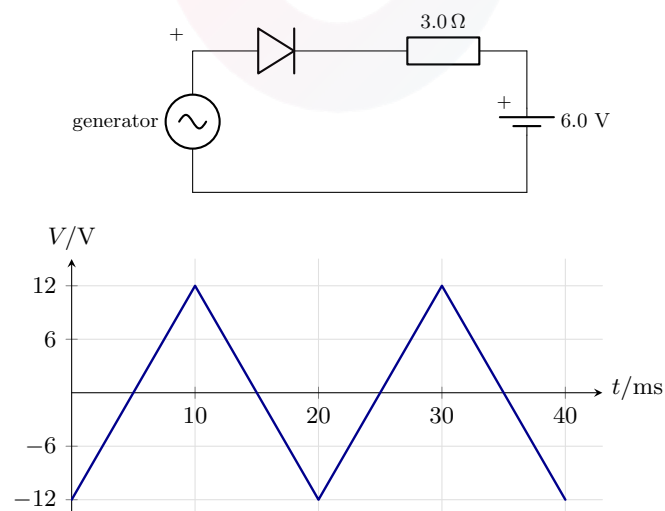
24. A bat flies at a constant speed along a straight line at right angles to two large, flat, parallel walls, away from one wall and towards the other. It emits short clicks at regular intervals of 45 ms, and it hears the echo of every click from each wall; it can tell the two sets of echoes apart.

The echoes from the wall it is flying towards reach the bat at regular intervals of 40 ms. The air is still, and the speed of sound in it is 340 m s^{-1} .

At what regular interval do the echoes from the wall behind the bat reach it?

- A** 50.0 ms
B 47.6 ms
C 50.6 ms
D 55.0 ms
E 35.6 ms
F 40.0 ms
G 45.0 ms

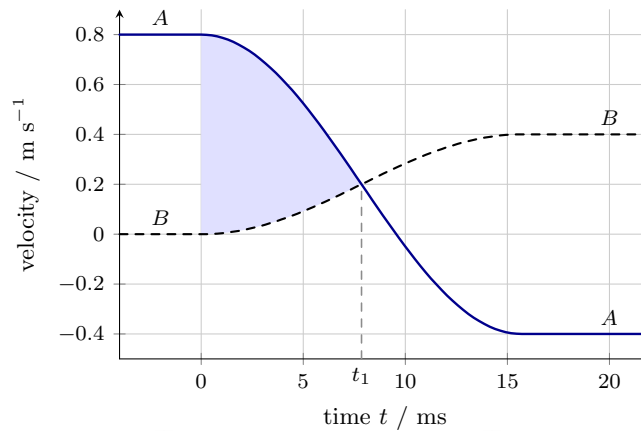
25. A rechargeable battery is charged from a signal generator through an ideal diode and a 3.0Ω resistor, connected as shown. The p.d. V of the generator's upper terminal relative to its lower terminal varies with time t as the triangular wave in the graph, which repeats indefinitely. The p.d. of the battery stays at 6.0 V throughout, and the generator, battery and wires have negligible resistance. The ideal diode has zero resistance in its forward direction and does not conduct at all in reverse.



How long does it take for 1800 C of charge to flow into the battery?

- A** 240 minutes **B** 30 minutes **C** 60 minutes
D 40 minutes **E** 120 minutes **F** 15 minutes

26. On a level air track, glider *A* of mass 0.20 kg moves at 0.80 m s^{-1} towards glider *B*, which is at rest. A light spring that obeys Hooke's law is fixed to the front of *B*, and *A* first touches it at $t = 0$. Motion sensors record the velocities of both gliders, taking the direction of *A*'s original motion as positive. In the graph the solid curve is *A* and the dashed curve is *B*; the curves cross at time t_1 .



The shaded area between the two curves, from $t = 0$ to $t = t_1$, represents a distance of 4.0 mm . Friction and air resistance are negligible, and the gliders interact only through the spring.

What is the stiffness (spring constant) of the spring?

- | | | |
|----------------------------------|----------------------------------|-----------------------------------|
| A 2000 N m^{-1} | B 6000 N m^{-1} | C 4000 N m^{-1} |
| D 8000 N m^{-1} | E 3000 N m^{-1} | F 12000 N m^{-1} |

27. A vibration generator at one end of a long horizontal rope sends transverse waves along it. The far end is attached to an absorber, so no waves are reflected. The wavelength is 0.40 m . The generator's frequency is known only to lie between 30 Hz and 70 Hz .

The room is dark apart from a stroboscope, which lights the rope with very brief flashes at a steady rate that can be adjusted. Between flashes the eye cannot follow the rope: it assumes that each crest has moved to whichever crest position in the next flash is nearest.

When the stroboscope flashes 12 times per second, the wave appears stationary. When it flashes 13 times per second, the wave appears to travel slowly back towards the generator at 1.6 m s^{-1} .

What is the speed of the waves along the rope?

- A** 19.2 m s^{-1}
- B** 5.2 m s^{-1}
- C** 1.6 m s^{-1}
- D** 0.40 m s^{-1}
- E** 14.4 m s^{-1}
- F** 24.0 m s^{-1}
- G** 20.8 m s^{-1}
- H** 4.8 m s^{-1}

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